Jerker Björkqvist, Kristina Edström,
Ronald J. Hugo, Juha Kontio,
Janne Roslöf, Rick Sellens &
Seppo Virtanen (eds.)

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APPLIED SCIENCES

The 12th International CDIO Conference

Proceedings – Full Papers

45
Research
Reports

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Editorial

The CDIO approach is an innovative educational framework for producing the next generation of engineers. The aim is an education that supports students to acquire a deeper working understanding of the technical fundamentals while simultaneously developing the competencies needed for Conceiving – Designing – Implementing – Operating (CDIO) real-world systems, products, and processes. Throughout the world, more than 125 institutions have adopted CDIO as the framework of their curriculum development.

The Annual International Conference is the main meeting of the CDIO Initiative and it includes presentations of papers as well as special seminars, workshops, events and activities. The 12th International CDIO Conference takes place in Turku, Finland, June 12–16, 2016, hosted by Turku University of Applied Sciences. The organizers together with the City of Turku welcome you to the event!

The main theme of this year is *Enhancing Innovation Competencies through Advances in Engineering Education*. It is visible in the keynote presentations, topical sessions and workshops. The rich topical program will facilitate lively discussion and contribute to further development of engineering education.

The conference includes two types of contributions, Full Papers and Projects in Progress. The Full Papers fall into three tracks: Advances in CDIO, CDIO Implementation, and Engineering Education Research. All Full Papers have undergone a full single-blind review process to meet scholarly standards. The CDIO Projects in Progress contributions describe current activities and initial developments, and were selected by the program committee co-chairs based on the submitted abstracts.

Originally, 239 abstracts were submitted to the conference. The authors of the accepted Full Paper abstracts submitted 141 Full Paper manuscripts to the peer review process. During the review, 295 review reports were filed by 74 members of the 2016 International Program Committee. Acceptance decisions were made based on these reviews. The reviewers' constructive remarks served as valuable support to the authors of the accepted full papers when they prepared the final versions of their contributions. We want to address our warmest thanks to those who participated in the rigorous review process.

This publication contains the 100 accepted full papers that will be presented at the conference, of which 14 are Advances in CDIO; 72 CDIO Implementation; and 14 Engineering Education Research. These papers have been written by 283 different authors representing 24 countries. This book is available as an electronic publication only. In addition to the Full Papers, 57 CDIO Project in Progress contributions will be presented at the conference and are not included in this publication.

We hope that you find these contributions valuable in developing your own research, curriculum development, and teaching practice, ultimately furthering the engineering profession. Seize the opportunity to discuss and network with colleagues during the conference. Global understanding and partnerships are of major importance in educating the future generations of engineers.

Wishing all of you a fruitful CDIO 2016 experience!

Turku, May 13, 2016

Jerker Björkqvist *Kristina Edström* *Ronald J. Hugo*

Juha Kontio *Janne Roslöf* *Rick Sellens*

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FLIPPING A CHEMICAL ENGINEERING MODULE USING AN EVIDENCE-BASED TEACHING APPROACH

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ABSTRACT

This paper shares the approach taken for the Diploma in Chemical Engineering (DCHE) to redesign a Year 3 core module entitled *Plant Safety and Loss Prevention*, using an evidence-based teaching approach delivered via a flipped classroom blended learning format. While the research will need further iterations and substantive evaluation, the authors are confident that the overall approach, in which the affordances of technology are utilized through the creative applications of sound pedagogic practices and process (e.g., methods that work best and validated cognitive science principles of learning), is the most fruitful path towards highly effective and creative professional practices.

In the first part of the paper, we outline the pedagogic basis and rationale for using an evidence-based teaching approach, as well as the current framing of a flip classroom blended format. We started with a theoretical perspective that effective and efficient blended learning design should follow certain broad heuristics, for example:

1. Good learning design is *always* grounded on evidence-based practice, incorporating Core Principles of Learning
2. Information-communication technologies are used *strategically* and *creatively* to enhance specific aspects of the learning process
3. The completed blended learning design *maximizes* the affordances of a range of learning modes and mediums (Sale, 2015)

This pedagogic design model guided the development of the flip classroom lessons, integrating the online components to the face-to-face sessions, seeking to maximize the affordances of both delivery modes to optimize student learning (e.g., attainment level and intrinsic interest).

Secondly, we outline our model for teaching this module, which derived from our earlier large scale implementation of the Conceive-Design-Implement-Operate (CDIO) educational framework. The module is taught through an instructional approach that focuses on students analysing and making inferences and interpretations relating to a range of chemical process hazards at different stages of a plant lifecycle. This is to facilitate their capability for diagnosing the likely causes of such hazards, and subsequently being able to select the most appropriate strategies and tools for eliminating or mitigating the impact of these hazards. Hence, through this process, they learn how to conceive, design and implement effective preventative strategies that have a high predictive capability for maximizing plant safety.

In the final part of the paper, we present our evaluation data to date, the key pedagogic learning points, challenges faced, and potential ways to further both research and practice in this exciting new educational arena.

KEYWORDS

Evidence-based Approach, Flipped Classroom, Chemical Engineering, Safety, CDIO Standards 2 and 8

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs". A "course" in the Diploma in Chemical Engineering consists of many subjects that are termed "modules"; which in the universities contexts are often called “courses”. A teaching academic is known as a "lecturer", which is often referred to a as "faculty" in the universities.

INTRODUCTION & CONTEXT

While the use of information-communication technology (ICT) in mainstream education is far from new, evidence of widespread impact in terms of significantly enhancing the practices of teaching and, most importantly, student attainment, was not quickly forthcoming. For example, Oliver et al (2007), commenting on the lack of ICT widespread application in educational settings to create engaging and effective learning experiences noted that:

> What appears to be still missing for teachers is appropriate guidance on the effective pedagogical practice needed to support such activities. (p.64)

Robinson & Schraw (2008), in reviewing the literature on e-learning research, further supported this overall perception:

> Unfortunately, empirical research informing decisions regarding “what works” ranges from sparse at best, to non-existent at worse. This is because e-learning has focused on the delivery of information rather than the learning of that information. (p.1)

However, in the present context, there are now two particularly significant factors in the educational landscape that is rapidly changing the framing and use of ICT for teaching and learning. Firstly, there is no doubt that the available technologies in recent years, as compared to a decade or so ago, are becoming increasingly more user-friendly, varied and easily accessible. As Waldrop & Bowden (2015) point out:

> …there is no denying that the evolution of classroom technology over the past two decades has transformed the options that faculty have for using and creating multimedia course materials that can be used in and out of the classroom. (p.9)

However, of equal, if not greater, importance is the emergence of a more evidence-based approach to teaching and learning (e.g., Marzano, 2007; Petty, 2009; Mayer & Alexander, 2011; Hattie & Yates, 2014). For example, Darling-Hammond & Bransford (2005), from surveying the research findings, captured the essential framing comprehensively when they concluded:

> There are systematic and principled aspects of effective teaching, and there is a base of verifiable evidence of knowledge that supports that work in the sense that it is like engineering or medicine. (p.12)

The following sections will firstly outline the flipped blended learning format and the rationale for using an evidence-based approach. Subsequent sections summarize the specific application to a chemical engineering module and the evaluation results to date.

WHAT IS THE FLIP CLASSROOM AND HOW DOES IT WORK?

The flipped classroom is essentially a blended learning format for organizing the student learning experiences utilizing the potential benefits of blended learning. While there are many definitions of blended learning, Garisson & Vaughan (2008) capture the key elements nicely when they assert it

> …is the thoughtful fusion of face-to-face and online learning experience…optimally integrated such that the strengths and weakness of each are blended into a unique learning experience congruent with the context and intended educational purpose.
> …combines the properties and possibilities of both to go beyond the capabilities of each separately. (p.6)

As recent research is beginning to support blended learning as being both more effective than both either online or face-to-face learning (Means, Toyama, Murphy, Bakia & Jones, 2010) as well as being potentially a ‘big cost saver', it’s not surprising that it is now very much a key area of research focus, with the flip format being especially popular. The basic approach is that students are given an online learning experience before coming to class, often through a recorded lecture and related reading and activities (previous done through the face-to-face class lecture), which is to help them acquire the key underpinning knowledge relating to a topic area before the face-to-face session. This approach is to free up class time to apply the content knowledge thoughtfully in more real world active learning application.

At present, research relating to the effectiveness of the flip format is more descriptive rather than empirically validated (e.g., Waldrop & Bowden, 2015). Similarly, Murray, Koziniec & McGill (2015) noted that although flipped classroom has received a lot of publicity, there has been little formal evaluation of the impacts on student satisfaction or performance.

However, there are potential benefits of the flip format (Fulton, 2012; Herreid & Schiller, 2013), which include:

- students being able to learn more at their own pace
- doing “homework” in class gives teachers better insight into student difficulties
- teachers can more easily customize and update the curriculum to meet students learning needs as they arise
- classroom time can be used more effectively and creatively
- students who miss class can watch the lectures in their own time
- students are more actively involved in the learning process
- a greater positive impact on attainment and the learning experience than the traditional mode (based on self-reporting)

EVIDENCE-BASED TEACHING

Slavin (2008) noted that throughout the history of education, the adoption of instructional programs and practices has been driven more by ideology, faddism, politics, and marketing than by evidence. Certainly for many decades, it seemed, as Sallis & Hingley (1991) commented, “Education is a creature of fashion.”

However, much is changing as far as teaching is concerned and it may, as Petty (2009) argued, be ready to:

> …embark on a revolution, and like medicine, abandon both custom and practice, and fashions and fads, to become evidence-based (cover page).

Of particular significance in this area is the work of Hattie (e.g., 2009; 2012). Mansell (2008) referred to Hattie’s seminal work on the effectiveness of different teaching methods and strategies as:

> …perhaps education's equivalent to the search for the Holy Grail - or the answer to life, the universe and everything.

There is little doubt that Hattie’s work is a definitive landmark in educational research, perhaps providing a key push in the movement away from more ideological-based paradigms towards evidence-based practice in teaching. Hattie synthesized over 800 meta-analyses of the influences on learning and most significantly, he was interested not just in what factors impacted learning, but the extent of their impact - referred to as *Effect-Size*. Effect size is a way to measure the effectiveness of a particular intervention to ascertain a measure of both the *improvement* (gain) in learner achievement for a group of learners and the *variation* of learner performances expressed on a standardised scale. By taking into account both *improvement* and *variation* it provides information to which interventions are worth having.

Hattie firstly identified the typical effect sizes of schooling without specific interventions, for example, what gains in attainment are we likely to expect over a one-year academic cycle? Typically, for students moving from one year to the next, the average effect size across all students is 0.40. Hence, for Hattie, effect sizes above 0.4 are of particular interest. As a baseline an effect size of 1.0 is massive and is typically associated with:

- Advancing the learner’s achievement by one year
- Improving the rate of learning by 50%
- A two grade leap in GCSE grades

Table 1 shows examples of effect sizes in learner attainment from Hattie’s meta-analysis which featured some high impact methods on student attainment, as demonstrated by their effect sizes. However, as Hattie notes, it is important to balance effect size with the level of difficulty of interventions. For example, providing ‘advance organizers’ (summaries in advance of the teaching) have an effect size of 0.41, which is pretty average, but they only take up a few minutes at the beginning of the lesson, and potentially offer the equivalent of moving up a year in terms of a student’s achievement. He goes on to make relative comparisons of intervention use, which enables us to go beyond identifying the effect sizes for particular innovations (deliberative intervention involving strategy/method use for a group of students), and ascertain whether the effects of a particular innovation were better for students than what they would achieve if they had received alternative innovations.

Table 1. Examples of effect sizes in learner attainment from Hattie's meta-analysis

Influence	Mean Effect Size
Feedback Students getting feedback on their work from the teacher, their peers or some other sources. Note: some feedback has more effect size than others. For example, peer assessment is 0.63 and self-assessment is 0.54	0.73
Meta-cognitive strategies Students can systematically think about (plan, monitor and evaluate) their own thinking and affective processes (e.g. beliefs, emotions, dispositions) to develop effective learning to learn capability and self-regulation	0.69
Challenging goals Students having a clear frame on, and see purpose in, what they are learning, as well as experience realistic challenge in meeting goal expectations	0.56
Advanced organizers Giving students an overview (in an appropriate format and level of understanding) of what is to be learned in advance of the lesson, to help make meaningful connections between their prior knowledge and the new material to be presented	0.41

Of particular significance is the fact that it is not just the effect size of one intervention that is important, but how a number of effective methods can be strategically and creatively combined to produce powerful instructional strategies that significantly impact student attainment. As Hattie (2009) pointed out:

> …some effect sizes are 'Russian dolls' containing more than one strategy. For example, 'Feedback' requires that the student has been given a goal, and completed an activity for which the feedback is to be given; 'whole-class interactive teaching' is a strategy that includes 'advance organisers' and feedback and reviews. (p.62)

From an evidence-based perspective, it is not just the methods that work best, but also the underlying core principles of learning that facilitate the learning process (e.g., Sale, 2015; Ambrose, Bridges, DiPietro, Lovett and Norman, 2010; Willingham, 2009). For example, Sale (2015) offers the following 10 Core Principles of Learning as key guiding heuristics from which teaching professionals can plan learning experiences and teach more effectively:

1. Motivational strategies are incorporated into the design of learning experiences
2. Learning goals, objectives and proficiency expectations are clearly visible to learners
3. Learners prior knowledge is activated and connected to new learning
4. Content is organized around key concepts and principles that are fundamental to understanding the structure of a subject
5. Good thinking promotes the building of understanding
6. Instructional methods and presentation mediums engage the range of human of senses
7. Learning design takes into account the working of memory systems
8. The development of expertise requires deliberate practice
9. A psychological climate is created which is both success-orientated and fun
10. Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback

The 10 Core Principles of Learning are not exhaustive or summative as new knowledge and insights will continually enhance our understanding of human learning and the implications for how we teach. However, as Willingham (2009) rightly noted:

> Principles of physics do not prescribe for a civil engineer exactly how to build a bridge, but they do let him predict how it is likely to perform if he builds it. Similarly, cognitive scientific principles do not prescribe how to teach, but they can help you predict how much your students are likely to learn. If you follow these principles, you maximize the chances that your students will flourish. (p.165)

Furthermore, just as combining high effect methods can have a powerful overall impact on learner attainment, as captured in Hattie (2009) and Petty's (2009) analogy of 'Russian Dolls', the same applies to the thoughtful and creative application of core principles of learning. As Stigler & Hiebert (1999) highlighted:

> Teaching is a *system*. It is not a loose mixture of individual features thrown together by the teacher. It works more like a machine, with the parts operating together and reinforcing one another, driving the vehicle forward. (p.75)

The following sections document the use of a flip classroom format to the teaching of a chemical engineering module, using the evidence-based approach outlined above.

REDESIGNING PEDAGOGY FOR AN EVIDENCE-BASED FLIP APPROACH

The module *Plant Safety and Loss Prevention* is a core module for the Diploma in Chemical Engineering (DCHE), taught to all Year 3 students (numbering approximately 120), in 6 classes of 18-22 students each. It is a 60-hour module with no semester examination, i.e. all assessments are based on course-work, with students working both individually and in group. To prepare for flipped classroom, the module was extensively reviewed using the 12 CDIO Standards adopted for use at module-level (Cheah and Lee, 2015). A key outcome of the module review and redesign process is the introduction of a new approach for teaching it, modelled after the lifecycle of a typical chemical process plant, as shown in Figure 1.

This insight came about from a parallel seen between the plant lifecycle and the CDIO process of conceiving, designing, implementing and operating a product or system. Also shown in Figure 1, above the 5 stages of the plant lifecycle, are the hazards associated in a typical chemical plant. Below the plant lifecycle is shown a tool box of techniques and methods and a range of risk management strategies that can be used to identify hazards that may arise at various stages of the plant lifecycle, and the approaches that can be taken to mitigate against these hazards. Figure 1 is communicated to students during the first lesson, and is used as an "advanced organizer" throughout the entire semester as this provides a key anchor point for two-way feedback in checking the development of key understanding.

A 15-week lesson master plan is then prepared to guide the detailed weekly lesson preparation. We felt this is necessary as this is the first time we embarked on designing a flipped classroom for the entire semester (i.e. 15 weeks). For each week, a set of guidance notes were also prepared, which spelt out in greater details the topics to be covered for the week, as well as the resources made available. The set of guidance notes are given to students ahead of their weekly lessons so that they can better prepare for flipped classroom. The key concepts are made explicit and reinforced via classroom activities.

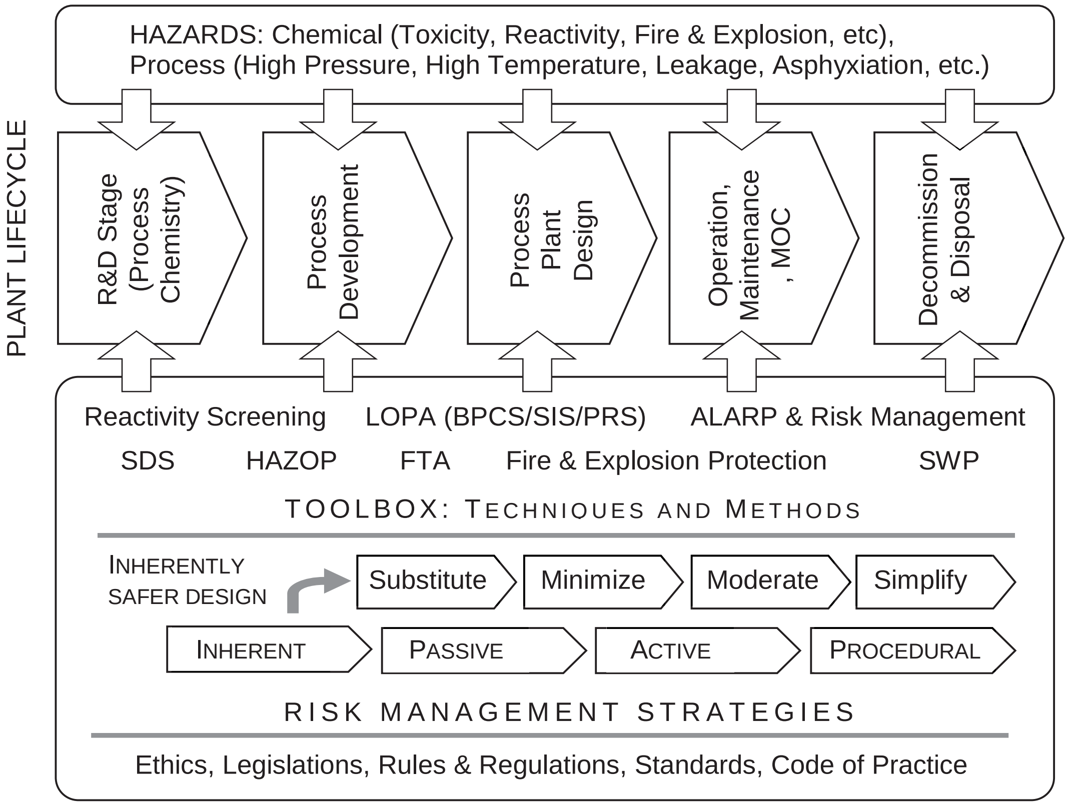


Figure 1. Lifecycle Approach to Teaching *Plant Safety and Loss Prevention*

The type of assessment evidence we seek to obtain are focused on students thinking and key understanding relating to key outcomes, such as:

1. Ability of identify from the assigned cases the correct safety issues at the proper stage of the chemical plant lifecycle
2. Ability to identify probable causes that can lead to deviation from safe operating conditions and predict likely consequences or damages
3. Ability to apply the correct preventive or mitigation strategies to prevent the occurrence or minimize the impact of any occurrence of a chemical process hazard
4. Ability to transfer lessons learnt from analysis of earlier cases to fresh cases presented at a later part of the semester

In addition, we collect data, in terms of direct feedback from students relating to our teaching effectiveness and the design of the learning tasks set. This is an important tenet of an evidence-based approach as it is necessary to ascertain how we can best teach in ways to maximize student learning opportunities.

DISCUSSION OF WORK DONE

While case study is the main teaching method employed, this is fully supported by appropriate use of ICT tools (e.g., those that enhance aspects of the leanring process and are efficient in context such as dynamic simulation), videos from various sources including U.K. IChemE (Institution of Chemical Engineers) and U.S. CSB (Chemical Safety Board) and other supporting textual and graphic resources. This utilizes different modes of presentation and methods to add variation and novelty to the learning experience.

Two key cases - namely Bhopal Gas Disaster and Piper Alpha Accident were used as "anchors" to scaffold student learning, in particular to strengthen long-term retention and transfer the application to other case scenarios, which is briefly described below.

In the flip classroom format, students first learn the key safety concepts on their own prior to coming to class, which is intented to activate their prior knowledge and go through a self-directed learning epxerience with the new material. They use the quizzes as self-assessment tools for checking understanding, and are encouraged to note areas of difficulties, which can then be addressed in the face-to-face sessions. This is usually in the form of watching PowerPoint files with narratives created using Camtasia Studio, and (where needed) videos available from YouTube or CSB web site (www.csb.gov), plus reading of journal articles or technical notes curated by the teaching team. Actual classroom contact time is 4 hours per week, in 2-hour blocks. When in class, for the first 2-hour block we firstly spend about 10-15 minutes in ascertaining students' understanding of the key concepts using a quiz comprising 3-4 multiple choice and/or true-false questions administered in real time using Socrative (www.socrative.com). This is then followed by a quick re-cap (5-10 minutes) of the important topic components and key concepts. A mini-lecture is given if results from Socrative show a significant number of students did not fully grasp the concepts covered in the self-study part of the flipped programme. This ongoing formative assessment, which fosters effective two-way feedback, is crucial to the learning process as documented by Hattie’s research (2009), which reported an overall effect size of 0.73. Furthermore, the very process of engaging students more in two-way feedback activty seems to enhance the building of rapport with them, as students may be perceiving this as showing greater interest in their learning. For the rest of the class time, we then use the "anchor" cases to demonstrate how safety principles were violated in these accidents. We place particular emphasis on how these accidents could have been avoided had systematic analysis been given at different stages of the plant lifecycle; and appropriate safety protective measures (both preventive and mitigative) measures were put in place. Then, during the next 2-hour block, students are now required to apply the understanding learnt from the Bhopal or Piper Alpha case to display transfer of leanring to different scenarios. Here we use another "anchor" case study, based on the EnVision Dynamic Simulation System's Amine Treating Unit (ATU), which is supplemented with other case studies as appropriate to further strengthen the transfer outcome.

All the learning tasks for engaging students in the classroom are decided by what strategy and method combination is most likely to work, and applied thoughtfully in terms of core principles of learning. Key strategies used include: activation of prior knowledge, direct instruction, peer tutoring, feedback, advanced organizer, etc. Some of our approaches took on the characteristics of "Russian Dolls”, in terms of the analogy mentioned earlier. In addition, we also based the design of our learning tasks based on recent research that highlighted the effectiveness of repeated testing in promoting the transfer of learning to new contexts (Rohrer, Taylor and Sholar, 2010; Carpenter, 2012), by repeatedly revisiting earlier concepts in later weeks of the lessons.

Classroom discussions utilize Google Doc, whereby a class of 18-22 students is divided into 4-5 groups of 4-5 students each. Students discuss and present a group answer to the questions posed by typing in real time into the response box created in Google Doc. In some situations, students are asked questions that have more than one answer, so each group is required to provide a different answer. In other situations, different questions are asked to each group, so that they need to collaboratively come up with part of the answer. We also encouraged academically stronger students to help their weaker counterparts, to co-create the response together, hence fostering a sense of cameraderie. Indeed, as noted by Boettcher (2006), the key benefit of learner-generated content lies in the processes of creation, knowledge construction, and sharing as opposed to the end product itself.

Important concepts such as inherently safer design, layer of protection analysis, etc. are repeatedly revisited at later topics in subsequent weeks. Hence, review was systematically employed to ensure consolidation of key knowledge in long-term memory. Appendix 1 provide 2 examples of learning tasks prepared for Week 13 in which we covered chemical hazards. For this week, we used a new case study involving an incident at Formosa Plastics Corp available from YouTube, and require that students revisit how the loss prevention strategies can be used at different stages of the plant lifecycle. In a similar vein, students are required to apply the concepts of inherently safer design learnt in Week 1 to a new case of “Fatal Exposure – Tragedy at Du Pont”.

Conceptual understanding is particularly important for long term retention and transfer. To facilitate this, evidence obtained from Socrative is used to ascertain students understanding of a given concept, as explained earlier. Difficult concepts are reinforced in subsequent activities. Appendix 2 showed two examples of how we make use of Socrative in real time to better understand students' grasp of the concepts presented. For the first example (top), the majority of students selected the wrong answer 'A', which means that they still had difficulty applying the concept of SIS (safety instrumented system) to certain aspects of chemical plant operation. The second example (bottom) showed a typical Excel output from Socrative, which summarized individual student's performance during a particular quiz session.

Evaluation of student’s ability to apply the concepts is done in-class using students' work in Google Docs. The lecturer provides feedback, also in Google Doc, to students on their entries during class time where possible, for example as shown in Appendix 3. In this case, from the responses given, the lecturer can immediately ascertain that students had difficulty with the application of inherently safer design in terms of process chemistry, when he noted that none of the groups provide an entry under this category.

EVALUATION

At the end of the semester, a survey is conducted to ascertain the student’s learning experience using the flipped classroom approach. A total of 40 students responded to the survey, representing approximately 33% of the total Year 3 cohort. Figures 2-7 represent the survey findings.

Overall, majority of students reported that they are able to understand the information (mostly concepts and strategies related chemical plant safety, and factual information such as definitions of technical terms, safety procedures, properties of chemical substances, standards and codes of conduct, etc.) in the pre-recorded videos to be useful (Figure 2). All the students are new to flipped classroom, and thus it is not entirely surprising that many of they took significantly longer time to get used to this method of learning. As can be seen in Figure 7, up to 20% of students reportedly required over 8 weeks (i.e. more than half a semester) to get accustomed to flipped classroom. A large majority of students also either "Agree" (52.5%) or "Strongly Agree" (7.5%) that they found the lifecycle model of chemical process plant (as depicted in Figure 1) served as a useful "sign post" to help them stay on course in the lessons

(Figure 6). Students also agreed that the use of case studies is useful in helping them understand the module better (Figure 3), and that they felt more engaged in the classroom via activities such as answering questions in Socrative or collaborate with one another in Google Doc (Figure 4).

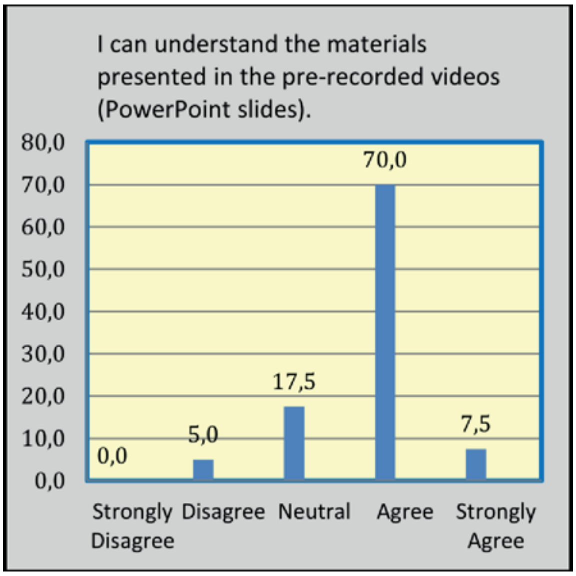


Figure 2. Understanding of pre-recorded lectures

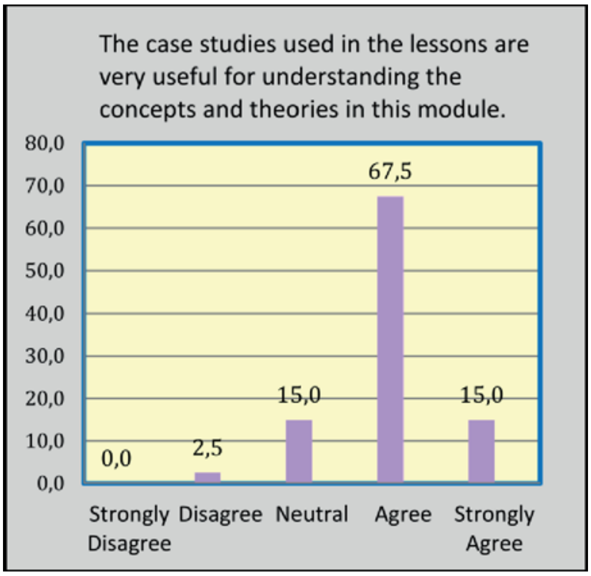


Figure 3. Usefulness of case studies

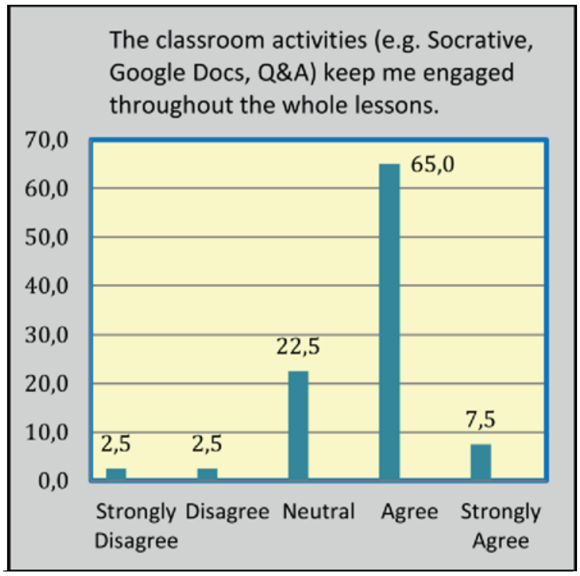


Figure 4. Classroom engagement

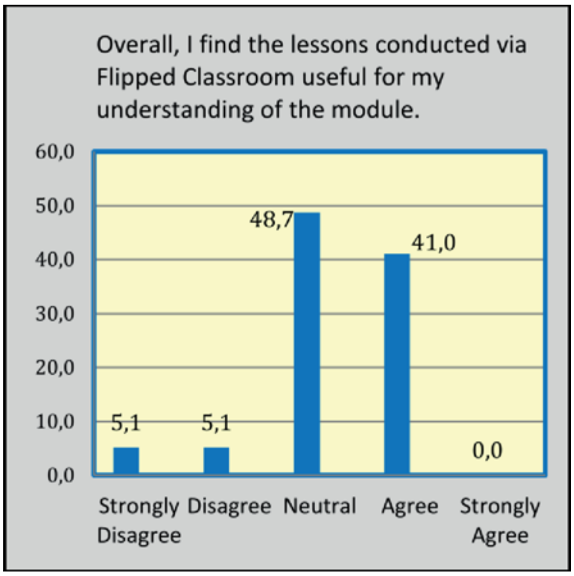
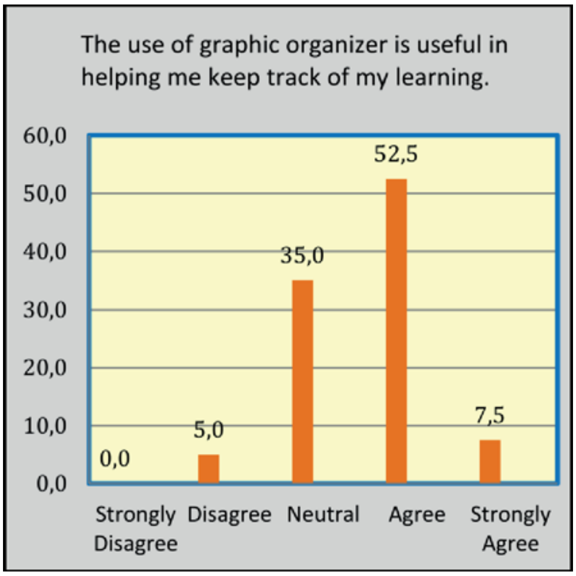


Figure 5. Overall experience on flipped classroom

Despite these positive outcomes, as shown in Figure 5, many students are still ambivalent about flipped classroom: whereby only 41.0% agreed that lessons conducted via flipped classroom are useful to their learning. Almost half (48.7%) of the students would rather chose a "Neutral" position on this question.



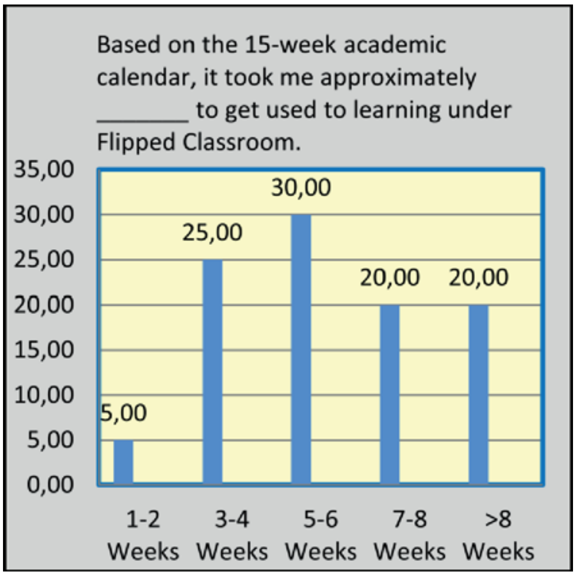


Figure 6. Usefulness of graphic organizer

Figure 7. Adjustment period for flipped classroom

One limitation of the present research is that the evaluation lacked a control group for comparison. Having a randomised control group has been touted as the "gold standard" for evidence-based practice (Buckley, 2009). However, in our present Singapore context, this is not ethically feasible as student sensitivities, especially being perceived as being “left out” from potentially beneficial teaching and learning approaches, and allegation of being placed in “disadvantaged positions” affecting their Grade Point Average is always a serious concern. This is especially true in today’s world, whereby students can take issues by voicing their dissatisfaction via social media.

Comparison of students’ attainment between this cohort and a previous cohort, which was not subjected to flipped classroom is also not feasible, as the assessment schemes used for the two cohorts are not the same. In fact, if we were to compare the module average mark for the two cohorts, we found that the previous cohort of students appeared to have fared 'better' than current cohort of students, as shown in Table 2.

Table 2. Comparison of Performance of Two Cohorts of Students

Cohort of Students	No. of Students	Module Average Mark
Previous (no flipped classroom)	62 (Sem 1) + 52 (Sem 2)	78.10
Current (with flipped classroom)	124 (Sem 1 only)	75.59

Such a result should not be negatively interpreted re use of a flipped blended learning format. As noted earlier, the assessment schemes for the two cohorts are not the same. For the current cohort of students we set more challenging questions, focusing on transfer of knowledge, with more in-depth applications of key concepts rather than largely assessing factual knowledge with limited real-world application. A further comparison of the two cohorts is shown in Figure 8, in terms of grades attained (where AD = Distinction, P/F = Pass Fail). No doubt the number of students who scored ‘A’ has dropped somewhat, we felt this is acceptable given the rationale given earlier. This is more or less ‘compensated’ by the increased in number of students getting

‘B’ grades. We also have 10 students more in the present cohort. We ignore the 3 students who were given a Pass/Fail grade as this is the result of them not fulfilling a new attendance requirement introduced in SP, rather than poor performance per se. At the time of writing this paper, the module team has already carried out certain pedagogic interventions to improve students’ learning under the flipped classroom approach. These include enhanced feedback opportunities, especially the use of peer marking.

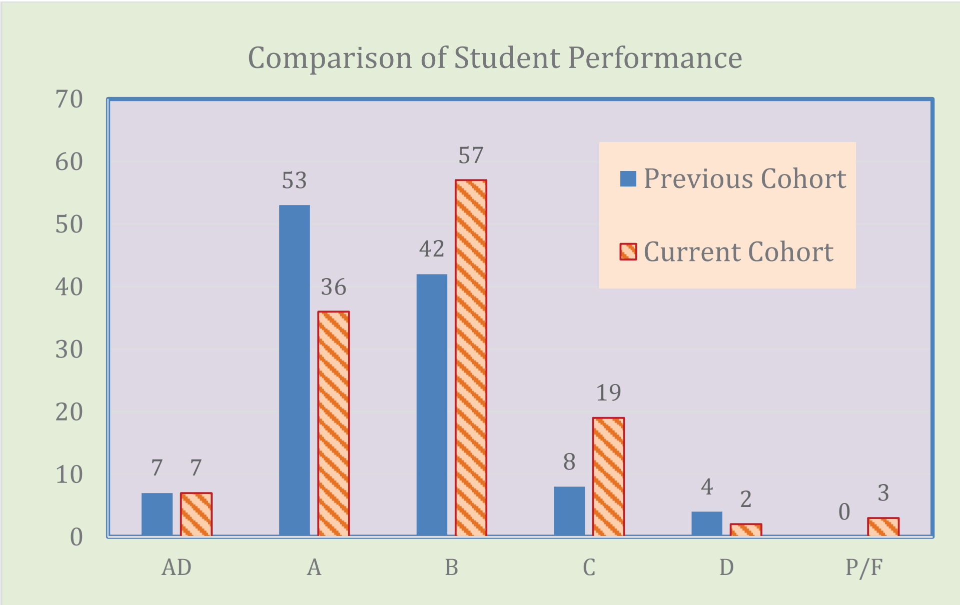


Figure 8. Comparison of Grades between two Cohorts

A second limitation of the research concerns the scope and depth of the evaluation. While focused on certain key areas relating to the impact of the flip classroom and some specific pedagogic practices, a more comprehensive and deeper evaluation approach is needed in future. This has been identified as a main focal area to address for subsequent research.

KEY CHALLENGES FACED

Invariably, any significant change in teaching practice throws up a wide range of challenges. For example, as this current cohort of students are new to the flipped classroom approach, a significant number of them had a difficult time adjusting to this way of learning. Although there was some initial resistance, the students gradually adjusted to the format, especially when they realized that the lecturers are serious in using this new approach. Therefore, it is important for the instructor to establish expectations early in class. Overall, we feel that the decision to implement a flipped classroom for the entire semester, as compared to a more partial approach, was vindicated. The flipped classroom, like any new learning format, takes time for students to adjust to, and so short-time use may not be realising the full benefit of a flipped classroom (Mason, Shuman and Cook, 2013).

Furthermore, as the entire original module materials had been shifted to out-of-class activities, the flipped approach afforded the team opportunities to cover more material than that in a traditional classroom. However, this also meant that we had quite a bit of developmental work to do, starting more or less from scratch. We estimated that approximately 80% of the content for the 60-hour module is new. With the module slated for its first appearance on April 2015, the team had started the preparation work back in September 2014. Even with this lead time (or so we thought), when the module was actually rolled out the team had to cope with minor modifications to some of the learning tasks at various points throughout the entire semester.

A key learning point for us was the realization in practice that a successful flipped classroom must provide students with adequate structure (Mason, Shuman and Cook, 2013). One challenge we faced was that some students did not come to the class prepared. This may be because no marks were allocated for the pre-class test mentioned earlier. However, we resist the temptation to reward students with marks for this purpose, and instead reinforce in them that they need to take responsibility for their own learning. We had to make a conscious decision not to cover the lectures in any great details in class, and eventually all students will "get the message". For difficult concepts such as HAZOP and Fault Free Analysis, which is rather procedural in nature, we take the students through worked examples in class, although they are still required to understand the methods on their own study time.

Another important issue that challenged us concerned the varied student prior experience in chemical plant operation. Not surprisingly, most of our students had limited knowledge of real-world operation of a chemical plant. To ensure that they had an acceptable level of understanding, we created a self-learning package based on the Amine Treating Unit from EnVision. This is the same dynamic simulation model that was mentioned earlier as the key mechanism that we use to ascertain our students' ability to transfer the learning gained from the Bhopal and Piper Alpha anchor cases. The package consists of detailed description of the amine treating process, piping and instrumentation diagrams, control and safety systems, etc, plus a suite of self-paced simulation exercises so that students can familiarise themselves with the amine plant operation. Through this, we hoped to impart the requisite experience (albeit a virtual one) to the students. On hindsight, we should have surveyed the students on their learning experience practicing on a virtual model, to ascertain the usefulness of the material that we prepared.

CONCLUSIONS

The challenge of designing and facilitating the student learning experience from an evidence-based teaching approach using the flipped classroom format was an exciting one. We feel the results are encouraging, particularly as this is a new innovation, and the real benefits may not be manifested until sufficient expertise is honed in the design and facilitating process. Hence, this will continue as an ongoing professional development activity. As Dziuban, Hartman & Moskal (2004) point out:

> Maximizing success in a blended learning initiative requires a planned and well supported approach that includes a theory-based instructional model, high quality faculty development, course development assistance, [and] learner support. (p.3)

Certainly we feel that an evidence-based approach is the most logical theory-based instructional model to underpin our teaching using the flip classroom format. Our future goal is to improve the capability of maximizing the blend of high effect size teaching methods and the affordances of the flip format to create highly effective, efficient and creative learning experiences for the students we teach. This we feel is a real merging of the science and art of teaching.

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BIOGRAPHICAL INFORMATION

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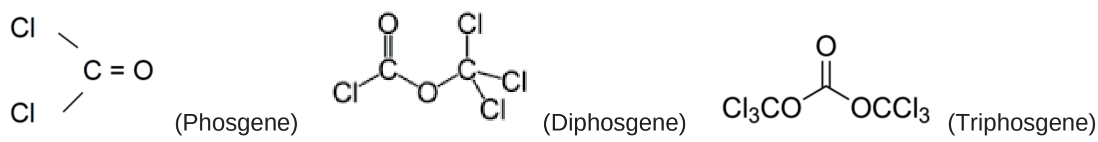
Appendix 1 Selected Examples for Week 13

<u>Activity 3</u>: **LEARNING FROM ACCIDENT - Inherently Safer Design Revisited**

Despite its toxicity, phosgene is still widely used in industry as a chemical intermediate for isocyanate-based insecticides, polymers, and pharmaceuticals. It is manufactured through the reaction of carbon monoxide and chlorine. It is reacted with primary amines to form isocyanates (R-N=C=O). Isocyanates are a family of highly reactive, low molecular weight chemicals. They are widely used in the manufacture of flexible and rigid foams, fibers, coatings such as paints and varnishes, and elastomers, and are increasingly used in the automobile industry, autobody repair, and building insulation materials. Alternatives to phosgene such as diphosgene and triphosgene had been proposed:



Explain how the 4 Chemical Process Safety Strategies of *Inherent, Passive, Active, Procedural*, can be used to improve safety in the company's phosgene unit.

Share your answers in Google Doc using the link given.

<u>Activity 6</u>: **LEARNING FROM ACCIDENT - Application of Loss Prevention Principles at Different Stages of Plant Lifecycle**

<u>Instruction to Students</u>

Watch the CSB Video “Fire and Explosions at Formosa Plastics Corp” (8:23 mins) available at the CSB web site or YouTube at https://www.youtube.com/watch?v=gDTqrRpa_ac
Obtain the sample MDSD for propylene from Praxair available at the module Blackboard site.
Identify issues highlighted in this video and organize them under the following categories related to principles of loss prevention learnt earlier:

- Process Description – present the relevant information obtained from the given SDS
- Plant Design
- Plant Layout
- Plant Operation

Using suitable search engine, find out more about “fireproofing” mentioned in the video.

Apply Loss Prevention Principles in...	DCHE/3A/03	DCHE/3A/04
Process Description	A	A
Plant Design	B	B
Plant Layout	C	C
Plant Operation	D	D
Finding out about "Fireproofing"	E	Any Group

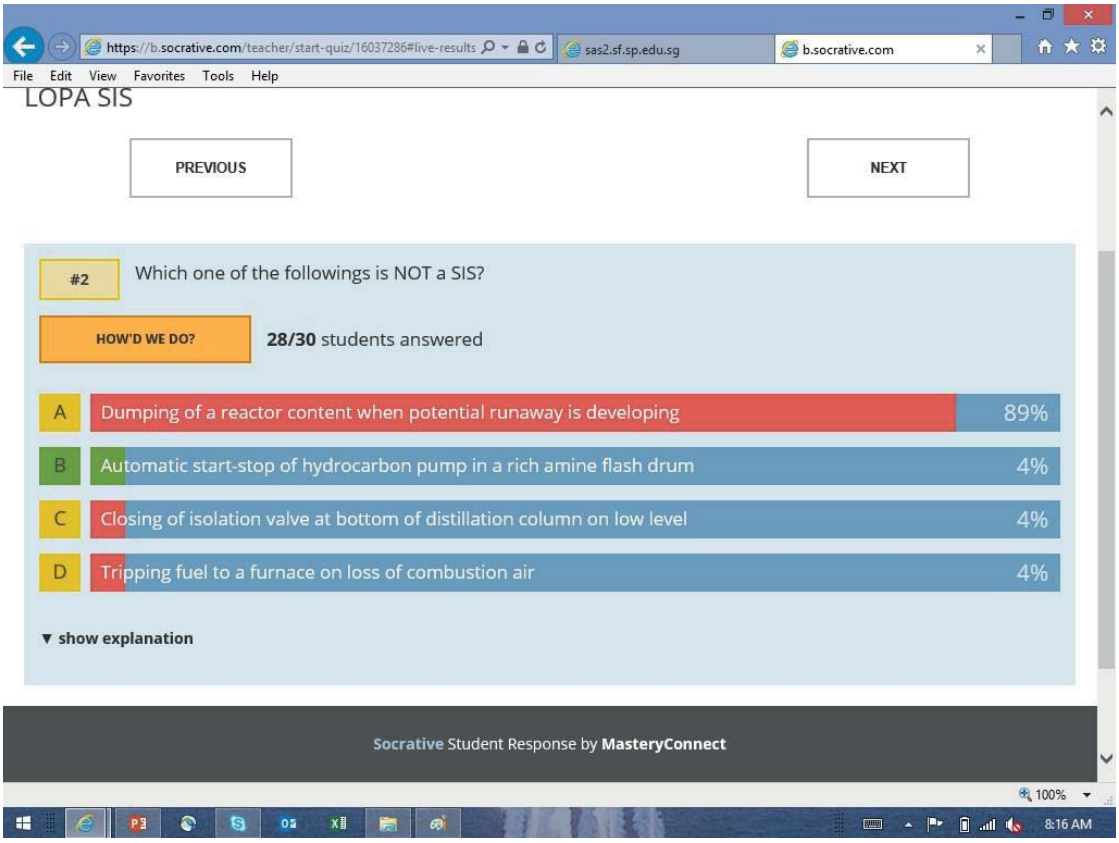
Submit your entries using the Web 2.0 Tools Padlet available from the link below:

DCHE/3A/03: http://padlet.com/smcheah/CP5033HBL-T-DCHE03

DCHE/3A/04: http://padlet.com/smcheah/CP5033HBL-T-DCHE04

Please refer to earlier instructions on using Padlet.

Appendix 2 Sample outcomes from "Concept Checkpoint" session using Socrative



This example shows that majority of students are quite clear about answers C and D, which are correct examples of Safety Instrumented System (SIS), but not so certain between answers A and B.

Strategies for Loss Prevention
Tuesday, April 28 2015 08:21 AM
Room: CP5033

Student Names	Total Score (0 - 100)	Number of correct answers	The four chemical process safety strategies in order of robustness and reliability are:	It is stated that "Hazards are intrinsic to a material, or its condition of use" .Which one of the following is WRONG in trying to eliminate/reduce the hazards?	Which one of the followings is NOT an "active" chemical process safety strategy?	Dilution and refrigeration are examples of the inherently safer design of ______.
1	80	4	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
2	80	4	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
3	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Minimize
4	40	2	Inherent, Passive, Active, Procedural	Change the person using the material	Emergency vent valve triggered by high pressure in vessel	Minimize
5	40	2	Inherent, Passive, Active, Procedural	Change to a different, non-hazardous material	Containment dike around a hazardous liquid storage tank	Minimize
6	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Minimize
7	20	1	Active, Inherent, Procedural, Passive	Adopt a different way of using the material	Containment dike around a hazardous liquid storage tank	Minimize
8	80	4	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
9	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Minimize
10	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Simplify
11	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	
12	40	2	Inherent, Passive, Active, Procedural	Eliminate the use of the material	Containment dike around a hazardous liquid storage tank	Minimize
13	60	3		Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
14	80	4	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
15	80	4	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Moderate
16	60	3	Inherent, Passive, Active, Procedural	Adopt a different way of using the material	Containment dike around a hazardous liquid storage tank	Moderate
17	40	2		Change the person using the material	Containment dike around a hazardous liquid storage tank	Minimize
18	60	3	Inherent, Passive, Active, Procedural	Change the person using the material	Containment dike around a hazardous liquid storage tank	Minimize
19	40	2	Inherent, Passive, Active, Procedural	Change the person using the material	High level alarm to trip a reactor feed	Minimize

This is the original raw data (boxes coloured by author) from Socrative's export into Excel format. This is a summary of a "concept checkpoint" session comprising 4 multiple choice questions. Such data can easily be converted to graphical display e.g. pie chart for better clarity.

Appendix 3 Sample Entry in Google Doc for Student In-class Work on Application of Strategies of Inherently Safer Design to Case of Bhopal Gas Disaster

(Text in Comics San MS are author's feedback to students)

Area of Application of Loss Prevention Principles	Case of Bhopal (explain why it is not desirable)	How application of Inherently Safer Design can reduce the hazard(s).
Plant operation	Refrigeration system decommissioned for a long time. Safety interlocks bypassed. Vent scrubber decommissioned. SOP not followed, blind not inserted. Flare tower under maintenance since long time ago, not enough manpower. Control instruments such as T and P gauges not working properly	(Design) Moderate - The refrigeration system should never be decommissioned to ensure safer storage of MIC. YES! That is correct. Minimise - Storage of MIC should be done in smaller tanks. 10 small tanks are safer than 3 large tanks. Better still and to adhere strictly to the principles of ISD: have 3 smaller tanks. Otherwise the tendency is to fill all 10 small tanks! Substitute - Since water reacts with MIC in a exothermic reaction, alternative material such as nitrogen or plant air can be used to purge or wash the pipes during maintenance Good thinking. You got that right!
Plant layout and design	There was supposed to be four vent gas scrubbers for stand-by. Since in Bhopal there was only one vent gas scrubber. There was no standby vent for maintenance. The capacity of the flare is incapable in managing the volume of waste gas produced.	Vent, flares etc are not part of inherently safer design. They are 'add-ons' installed to mitigate any consequence of MIC leak. They fall under the active (as opposed to passive) protection strategies. Since this group identify the area of loss prevention as "Plant layout and design", for the layout part you could consider the location of the plant - it is close to slum areas where a large population existed. One can SUBSTITUTE this location with one which is safer, and not have the wind blowing MIC in its direction.
Plant design	Using carbon steel instead of stainless steel for plant design. after a long time, rust will form which is the catalyst that triggers the reaction between MIC and water.	Substitute - Use stainless steel instead to reduce the chance of formation of rust hence reducing the amount of catalyst produced, thus leading to a slower reaction between MIC and water even when there is water flow into tanks. GOOD - you got this right!
OVERALL COMMENTS: Most of the answers above centred about Plant Design or Operations. Remember that more can be achieved by considering Process Development at the earliest opportunity, at the R&D stage. One can consider not using this reaction chemistry between phosgene (itself a toxic substance) and MMA altogether, and use something much less hazardous. This will achieve the aim of SUBSTITUTE of ISD. If really the MIC route must be used, then the next best thing to do, is to MINIMISE the quantity of MIC stored on-site.		

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EXPERIENCES ON COLLABORATIVE QUALITY ENHANCEMENT USING CROSS-SPARRING BETWEEN TWO UNIVERSITIES

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ABSTRACT

Aston University and Turku University of Applied Sciences (TUAS), together with six other partners, participated in an Erasmus+ funded project aimed at developing a collaborative, comprehensive and accessible evaluation process model for HEIs to use in their Quality Assurance and Enhancement. As a part of the project, the developed model has been piloted by the participating universities. The starting point for these pilots was a self-evaluation exercise inspired by the CDIO self-evaluation model. Whilst completing the self-evaluation, the participants also defined a set of criteria particularly relevant and of interest for the further development of their activities. After the self-evaluation phase, each institution was paired with another institution that provided a best fit concerning the strengths and development areas of the other based on the respective self-evaluation results,. Thereafter, the so called cross-sparring visits took place. In this paper, the experiences of the self-evaluation process as well as of the cross-sparring visits between Aston University and Turku University of Applied Sciences are reported. The process and practical arrangements of the visits are described, and the key findings based on the cross-sparring results are discussed.

KEYWORDS

Quality Assurance, International Collaboration, Faculty Development, Standards: 1, 10, 12

INTRODUCTION

Higher Education Institutions (HEIs) need to continuously improve the quality and efficiency of their operations. This is important not only in order to ensure the best possible education to future generations of professionals but also to be able to use the scarce resources in an optimal way. Topics connected to quality assurance have been widely discussed in the literature (see, eg., Van Der Wende and Westerheijden (2001) and Amaral & Rosa (2010)), while the CDIO initiative also underlines the importance of continuous development. Under CDIO, each HEI should have proper processes for evaluating its programs to determine their effectiveness and efficiency in reaching the intended goals and, thus, serve as the basis of continuous program improvement (CDIO, 2015).

Aston University and Turku University of Applied Sciences, together with six other partners (all CDIO member institutions), have participated in an Erasmus+ funded project called QAEMarketPlace4HEI (http://projects.au.dk/cross-sparring/) aimed at developing a collaborative, comprehensive and accessible evaluation process model for HEIs to use in their Quality Assurance and Quality Enhancement work. The project has promoted cooperation in quality assurance through the design and piloting of a new kind of continuous, accessible, cooperation based model supporting so called cross-sparring between the institutions. The project and its goals have been previously reported by Bennedsen, Clark, Rouvrais & Schrey-Niemenmaa (2015) and Clark et al. (2015).

As a part of the project, the developed model has been piloted by the participating partner universities. The starting point for these pilots was a self-evaluation exercise inspired by the CDIO model with participants ranking their current level of maturity over a range of 28 criteria covering a range of learning and teaching themes such as the use of technology in programmes, links to employability and the development of faculty competence. Whilst completing the self-evaluation, the participants also identified which criteria were particularly relevant and of interest for the further development of their activities. After the self-evaluation phase, each institution was paired with another based on the self-evaluation results, to provide a best fit concerning the strengths and development areas of the other. Thereafter, the so called cross-sparring visits took place. Cross-sparring is a process that makes feedback collaborative, concrete and objective. The sparring partners focus on the objectives, learn from the experiences of others and engage in reflection. The aim of the approach is to benefit both the institution evaluated, which will get a more objective view on its strengths and potential improvement areas, and for the sparring partner which may identify best practices that can be useful for their own institution.

This paper will explore the experiences of the self-evaluation process as well as of the cross-sparring visits between Aston University and Turku University of Applied Sciences. The process and practical arrangements of the visits are described, and the key findings based on the cross-sparring results are discussed. The structure of the paper is as follows: After this section the developed self-evaluation and cross-sparring methods are described in more detail. The next two sections include descriptions of the cross-sparring visits, experiences on the pilot, and the main findings by TUAS and Aston University participants respectively. Finally, the joint conclusions are reported and results discussed.

ON THE SELF-EVALUATION AND CROSS-SPARRING PROCESSES

In Higher Education today, institutions are constantly trying to balance the time spent and resource allocated to the areas of Quality Assurance (QA) and Quality Enhancement (QE). Often the quality assurance element dominates as this is what is most closely linked to the measures identified by institutions to ensure a high level and consistency in tertiary learning provision. Quality enhancement is often identified in bespoke projects or left to the enthusiasm and energy of programme teams and individual teachers.

The QAEMarketPlace4HEI project has been designed to bring the QA and QE elements of Higher Education activity together into one process. The objective behind the project is to develop an approach that when applied ensures the satisfaction of the QA requirements but at the same time actively promotes a culture that identifies enhancement opportunities for modules and programmes. The specific focus has been on programmes that use or aspire to use active learning as a key pedagogical element of their Higher Education provision (Kontio et al, 2015).

The starting point for the process, as already identified, is the Self-Evaluation exercise. Across the globe, Higher Education quality assurance systems invariably start with some form of reflective exercise where programme teams are invited to consider the features of programmes and to record this reflective thinking in some form. In some systems this is in the form of a narrative often referred to as a Self-Assessment Document. This can be an onerous exercise as the open ended nature of the document guidelines can lead to lengthy documents in which teams try to include as much about the programme as possible. This potential lack of focus was acknowledged by the CDIO community at its inception and addressed through the development of a self-evaluation tool that is based on identifying the most appropriate statement relating to the evaluation of a particular criterion. This approach is based on levels of maturity, higher numbers indicating more mature thinking and action in addressing the criterion.

The CDIO approach to self-evaluation was taken as the basis for the process. The criteria list had to be expanded in order to consider the wider considerations of a full QA exercise, hence the 12 CDIO criteria was expanded to 28 criteria following an iterative exercise that took into account several different QA systems from across the globe. The detail of this process has been reported by Bennedsen, Clark, Rouvrais & Schrey-Niemenmaa (2015) and Clark et al. (2015). Despite the iterative nature of the exercise adopted at the self-evaluation generation stage of the project, the project team always anticipated that the criteria and the wording used to describe the different levels of maturity would need to be revisited at the conclusion of the cross-sparring process. The self-evaluation process also requires participants to identify examples of activity that can be used to justify the maturity level value attributed to a programme. This was a conscious decision to request this, even though it added a little to the requirements of the self-evaluation process, as then the MarketPlace, into which the self-evaluation data is fed, could then become a repository of ideas and examples to both ensure consistency in the level identification, but to also stimulate ideas.

Once a self-evaluation has been conducted it can be entered into the MarketPlace software platform and used as the basis for a pairing with a partner institution. Each institution is able to identify the criteria it wants to be paired against. For the pilot phase of the project it was decided to pair institutions based on 4 selected criteria. Generally the pairing related to criteria where institutions wanted to develop ideas for improvement. This meant that the criteria would pair institutions where there was some form of gap between their performance as identified by the self-evaluation scores. The output of this phase of the project is the identification of the cross-sparring pairs.

The next stage requires the paired institutions to prepare for a two day visit from their partner institution. For the pairing being discussed in this paper, 3 representatives of TUAS visited Aston first and then around 3 weeks later, 2 representatives of Aston visited TUAS. The preparation required the identification of an agenda with each institution using the chosen key criteria as the basis for discussions, presentations, demonstrations and any other activity deemed relevant. After each visit the participants completed a ‘visit report’ identifying the key features and learning from the experience. From a methodological viewpoint, each pairing (4 in all) can be considered as a discrete case study. Each has the opportunity to offer ideas and findings related to that particular partnership. In addition, looking across all of the case studies offers the project team an opportunity to explore common themes around QA and QE in Higher Education as well as to offer insight into the value and efficiency of the process.

This is important for the project as the team work towards the development of a tool and process that can see wider use across the sector.

TUAS EXPERIENCES – AND VISIT TO ASTON

The TUAS participant was the ICT Unit that is one of the departments of the Faculty of Business, ICT and Chemical Engineering. The cross-sparring activity was started according to the defined process by filling the introductory documents and completing the self-evaluation. The self-evaluation activity was performed by the unit management team during a dedicated workshop in spring 2015. The team members (leaders of the education teams and research groups) had studied the evaluation matrix and instructions prior to the meeting and, thereafter each evaluation item was jointly discussed and rated. All the unit's teams had also completed a standard CDIO self-evaluation before this workshop as a part of the unit's annual planning process. Therefore the results and findings of the CDIO self-evaluation were available when this extended evaluation phase was conducted.

In general, the self-evaluation was found straightforward and easy to complete. One reason for this could be the fact that the faculty has used the CDIO self-evaluation as a tool to support the continuous development process for several years. Moreover, the unit had just completed an extensive self-evaluation activity connected to the Finnish national quality audit process. Most of the evaluation items were clear and it was easy to position the unit's maturity level but some of the items were found overlapping and certain rubrics partly unclear. This feedback was reported back to the project and will be addressed.

The self-evaluation included a task to determine a set of so called priority criteria that were found especially important to the development of the unit. These criteria were the following:

- Faculty development
- Technology to engage students in learning
- Equality, diversity and equal opportunity considerations
- Different learning styles are taken account of

Although the self-evaluation was completed on the ICT Unit level, the specific programme participating in the evaluation and cross-sparring process was the BEng degree programme in Information and Communications Technology. This program has an annual intake of 200 students (including an international programme taught completely in English). The extent of the program is four years (240 ECTS credits), and the current competence tracks (or major subjects) are Electronics and Telecommunications, Data Networks and Information Security, Embedded Software, Game Development, and Health Informatics. The program was inspired by the CDIO initiative and has been active for almost ten years.

Cross-sparring visit to Aston University

The TUAS programme was paired with Aston University based on both institutions' self-evaluation results and documentation. More specifically, the cross-sparring partner was defined to be the Mechanical Engineering and Design programme at Aston University. Also this program has utilised the CDIO model in its development for a significant time already which provided a nice platform for mutual discussions.

The cross-sparring activity was initiated by filling out the institution descriptions and exchanging other materials that guided both partners in preparing for the visit. The agenda of the visit was planned jointly based on the defined priority criteria of both partners. TUAS's visit to Aston University was scheduled for December 1-2, 2015. The TUAS visit team consisted of three members of the ICT Unit's management team: Elina Kontio (Research Group Leader, eHealth Technologies), Paula Steinby (Programme Leader, ICT BEng Basic Studies), and Janne Roslöf (Head of the Unit). The hosts of the visit were Robin Clark (Associate Dean for Learning and Teaching) and Gareth Thomson (Head of Mechanical Engineering and Design).

The visit agenda included general presentations on the UK educational system, Aston University in general, and the Mechanical Engineering program in particular. The curricula and different project-based learning opportunities were widely discussed. The recently updated active learning workshop facilities were visited (see Figure 1). Certain parts of the agenda were tailored based on the TUAS priority criteria. The TUAS team had the opportunity to discuss, for example, with Aston's specialists in student experience creation, and got familiar with different technologies utilized to support the learning process.

Lots of time was reserved for mutual discussions on topics arising during the presentations and visits. This was found to be very fruitful and helped to create a productive atmosphere – not to forget the continued discussions during a joint dinner. The visit was concluded by filling the first versions of the memos using the predefined templates. The templates were found unnecessarily complex, and they could be made simpler and more usable, another piece of feedback to the project team for action.

Figure 1. Visiting Aston's CDIO learning environment (from the left: Robin Clark, Gareth Thomson, Paula Steinby and Elina Kontio) and getting familiar with the students' projects.

Experiences and findings

The presentations and discussions during the visit were found very fruitful and useful for the future development of TUAS and the participating degree program. The program of the visit was well prepared and provided information from several different perspectives. Also the connection to the selected priority criteria was considered. Furthermore, the fact that the cross-sparring partner represented another field of engineering was found positive even though the TUAS team was hesitant at first as it helped ensure the focus remained on the processes and the priority criteria relating to learning and teaching rather than on the disciplinary content.

The main findings connected to the improvement of the programme were as follows:

- Different technologies to enhance learning and teaching could be utilized more at TUAS. Aston's platforms are more developed concerning, for example, the possibilities to record and share learning sessions. Also the AstonApp concept was found interesting.

- Aston's tradition and processes to consider equality and diversity issues are more mature than at TUAS. It seems that we are just starting to learn about these topics which have been present at Aston for a long time already.

- Faculty development was selected as one of the priority criteria by the both partners. The challenges connected to it were widely discussed during the visit. There are certain practices and faculty training opportunities in both institutions but still there seems to be a need for development. For example, there could be room for a common development project initiative.

The final phase of the cross-sparring activity was to identify potential best practices to be published on the open QA MarketPlace developed by the project. Based on the cross-sparring visit, the TUAS team proposed the inclusion of the following Aston practices:

- The newly updated "CDIO workspace" and the courses and practices connected to it can clearly be considered as a best practice in both learning environment design and active learning development. The concept could serve as a reference model to institutions planning to improve their activities in this area.
- Connected to the courses utilising the CDIO workspace, also some practical innovations valuable to TUAS were identified. For example, the usage of videos as a project reporting tool as well as the "GANTT-chart-like" project progress visualisation method which will be adopted.
- Aston's Learning Development Centre that focuses on helping the students with all aspects of academic skills could be a best practice. If its operations were understood correctly, it could be a very interesting practice to benchmark to TUAS and for many other institutions as well. Unfortunately, there was not enough time to focus more on this centre during the visit.
- The practices connected to student experience creation and consideration of diversity and multicultural aspects could be defined as a best practice as well. However, it is difficult to describe and conceptualise these activities in this context. Maybe it is partly a cultural topic to, and not only a practice that can be described and adopted in the traditional way. Also, it may be difficult for the TUAS team to determine whether Aston's way of handling these topics is a best practice on a wider arena – or does our experience more reflect the immaturity of TUAS in this field?

ASTON'S EXPERIENCES – AND VISIT TO TUAS

The Aston participant in the cross-sparring project was the Mechanical Engineering & Design (MED) subject group, which sits within the School of Engineering & Applied Science at the University. This group runs three year long, Bachelor and four year long, Masters undergraduate degrees in disciplines allied to Mechanical Engineering and Product Design. While the Product Design and Mechanical Engineering degrees have around 50% commonality, for the purposes of the cross-sparring, the Mechanical Engineering family of degrees were chosen as the focus of the work. Around 110 students embark on these Mechanical Engineering programs each year with joint classes of up to 140 when taught together with the Product Design students.

The subject group has been an active member of the CDIO initiative since 2010 and its standards have very much shaped the nature of the degrees run by MED. A further key driver for the engineering degrees run by the group is the necessity for these to be accredited by the UK's Institution of Mechanical Engineers, allowing graduates to progress to professional registration once in employment.

The self-evaluation was carried out as a discussion between the School's Associate Dean for Learning & Teaching and the Head of Group of Mechanical Engineering & Design, both having first made themselves familiar with the evaluation matrix and formulated draft evaluations. In general the process was relatively straightforward however for some criteria there was some difficulty in relation to determining the appropriate rating. Typically for each sparring criteria a rating of 3 indicated the criteria was being considered and activities were in place to address this, 4 related to evidence of impact and 5 had the programme team reflecting on their actions with an aim of continuous improvement. For many of the criteria, while there was continuous reflection and improvement, having hard "evidence" – as opposed to anecdotal or experiential information, was seen as problematic. This is perhaps a reflection of the need within the MED group to be more systematic with its evaluation of the activities, however it also highlights the difficulty in determining a pragmatic definition of evidence with regard to the self-evaluation.

Of the 28 criteria set, those considered by the Aston team to be where there was both a low ranked self-evaluation and where it was felt improvement would have significant strategic benefits were identified. These criteria were as follows:

- Faculty development (knowledge and teaching)
- Links to employability are made throughout
- Feedback is timely, appropriate and formative
- Student participation in program review and development

Cross-sparring visit to TUAS

As discussed previously Aston's Mechanical Engineering programs had been paired with the ICT programme at TUAS. In addition to the cross-sparring criteria there was both commonality in terms of involvement in CDIO and similar intake cohort sizes but also contrasts in terms of subject discipline and national contexts. Attending from Aston were Robin Clark and Gareth Thomson, with Janne Roslöf and Paula Steinby acting as hosts at TUAS. This mirrored the roles from the visit to Aston two weeks earlier.

The agenda for the visit had been loosely defined prior to the visit of TUAS to Aston however was such that adjustments could readily be made based on the experiences of both parties following the UK visit. The programme began with a general presentation of the Finnish Higher education system to help set context and highlight any local constraints before the agenda moved quickly to the cross-sparring criteria.

Specific target criteria included student participation in program review and development. To support this, the panel were joined by two student representatives from the TUAS ICT program who took part in an interesting and open discussion on how they saw their role in the management process within the department. The Aston team were also shown TUAS's approach to employability, particularly with regard to entrepreneurship. This included a visit to the internal student run consultancy company allowing students to gain access to and experience on small scale commercial ICT projects. This was followed by a visit to the adjacent SparkUp incubator unit run by the local science park to encourage start-up businesses, which commonly had ICT graduates at their heart.

Experiences and findings

The visits, both of the TUAS team to Aston and the UK team's trip to Finland were found to be extremely productive and while there are no immediate answers to fully address the criteria marked for development, a pathway has begun to be forged. There were a range of findings based on TUAS ICT experiences which could form the basis of improvements to the Mechanical Engineering programs at Aston.

- TUAS, while having similar cohort sizes to Aston, had a novel method of structuring these with cohorts typically broken down into a number of parallel classes of around 30 students. Each class would have at least one class rep and the small class sizes appeared to create a more collegiate relationship between students and staff.
- TUAS has a more developed approach to employability, industrial involvement and entrepreneurship than MED at Aston. The development of a student consultancy, something which also exists in Aston's own ICT group, while perhaps not directly replicable can act as inspiration for the development of entrepreneurship activity.
- Final year projects were all industrially linked and this was seen to be a key cornerstone of the TUAS ICT degree philosophy.
- Faculty development was seen as an area which both groups were keen to explore further and it was felt that this could offer opportunities for future collaboration.

A number of best practices at TUAS were identified which might be transferrable: elsewhere and not just to Aston:

- While independent from the ICT group at Turku, the adjacent location of the SparkUp facility together with a pipe stream of graduates and undergraduates entering this must be seen as best practice. Key however to this is the internal ICT company "the FIRM" which gives students early experience of, and confidence in, undertaking commercial work. In so doing this acts as a primer and breaker of barriers for students developing both entrepreneurial and more conventional industrial careers.
- The informal and close relationship with students was seen as very good practice, with opportunities to discuss issues on an informal basis with both the class teachers and the Dean seen as highly positive.

- The TUAS group also encouraged multi-disciplinary co-operation in projects and this must also be seen as best and industry reflecting practice.

CONLUSIONS

In this paper, the experiences of the self-evaluation process as well as of the cross-sparring visits between Aston University and Turku University of Applied Sciences have been presented and discussed. In general, the process was found positive by the both partners, and fruitful discussions took place during the different phases of the pilot. The cross-sparring helped to identify development areas and to find improvement ideas connected to topics in diversity, student employability and project-based learning methods, for example.

The piloted self-evaluation and cross-sparring processes were found rather well-functioning. Also the practical arrangements were successful, and the visit programs supported the defined priority criteria of the both partners. Yet, it would have been beneficial to include even more people to the process especially during the visits. The fact that the participating programs represented different fields of engineering was found to be an important element in keeping the desired focus during the visits. On the other hand, the instructions and templates used in the evaluation and review could still be improved in terms of simplicity and usability.

This type of activity can be recommended to any programs interested in developing their operations. However, it is important to invest enough effort in the process from the very beginning. Also the pairing of the partners has a great significance. In this case, there was a nice combination of strengths and development areas present. In the optimal case, the cross-sparring should not just be a “one hit” but lead to an ongoing cooperation in the future.

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BIOGRAPHICAL INFORMATION

Robin Clark is currently Professor of Engineering Education and Associate Dean for Learning and Teaching in the School of Engineering and Applied Science at Aston University. A Chartered Engineer, Robin spent 14 years in industry before joining Aston in 2003. Robin is a National Teaching Fellow and heads Aston´s newly established STEM Education Centre. He leads the UK and Ireland Engineering Education Network and is on the Board of Directors of SEFI (the European Engineering Education Society).

Elina Kontio is a Doctor of Sciences in Health Sciences. She received the M.Sc in Nursing Science (2003) from University of Turku, Finland and is a registered Nurse. At the moment she is a Research Group Leader of eHealth Technologies and a Principal Lecturer in the Faculty of Business, ICT, and Chemical Engineering at the Turku University of Applied Sciences. Her primary areas of interest includes eHealth, Health Informatics and decision-making in hospitals.

Janne Roslöf is a Head of Education and Research (ICT) at Turku University of Applied Sciences. He holds a D.Sc. in Process Systems Engineering and a M.Sc. in Chemical Engineering from Åbo Akademi University (Finland), and a M.A. in Education Science from University of Turku (Finland). He has participated in several national and international educational development assignments. Currently, he is a member of the national engineering education working group of the Rectors' Conference of Finnish Universities of Applied Sciences, as well as the coordinator of its ICT Engineering core group.

Paula Steinby is a Programme Leader (ICT) and a senior lecturer at Turku University of Applied Sciences (TUAS). She has a Licentiate's degree in Mathematics for IT (2003) and a Subject Teacher qualification in Mathematics and Computer Science (2007). She has experience in teaching both higher and upper secondary level students. Her interests include various aspects of facilitated learning and the impact of ICT and communication in learning processes.

Gareth Thomson is the Head of Group of Mechanical Engineering & Design at Aston University and also acts as programme director for the University's suite of undergraduate Mechanical Engineering degrees. He is a Senior Fellow of the Higher Education Academy and holds a PhD in Laser based Materials Processing from the University of Dundee.

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ASSESSMENT AND ANALYSIS OF ENGINEERING PRACTICAL ABILITIES LEARNING OUTCOMES OF UNDERGRADUATES THROUGH UNIVERSITY-ENTERPRISE COOPERATION

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ABSTRACT

Through CDIO syllabus, CDIO initiative emphasizes the training of students' abilities. In 2010, the Chinese Ministry of Education started the Excellent Engineer Education Plan which also emphasized the abilities training, especially the engineering practical ability. The Plan proposes the "Three+One" training mode for its implementation in both colleges and enterprises. The "Three+One" stands for three-year theory-majored study in colleges and one-year practice in enterprises. However, both CDIO and the Plan are facing a critical issue: how to evaluate students' learning outcomes, especially engineering practical ability training outcomes. After more than one year's joint implementation on the undergraduate education in engineering practice, Shantou University and Esquel Group went into a new phase of cooperation to address this issue. Combined with the technology and management positions assessment in enterprise, two units jointly built the engineering practice competency model for undergraduates and designed an assessment method with a process and its operating instruction for engineering undergraduates, which is based on on-site team projects and face to face communication. The method was applied on 13 Mechatronic engineering undergraduate students of Shantou University for the first time. These students joined the Plan and studied in two enterprises by following the Plan. The undergraduates' assessment result was also applied on the appointment of engineering technical positions in enterprises.

KEYWORDS

Engineering Student Competency Model, Engineering Practice, Abilities Assessment, Undergraduate student, Intended Learning Outcomes, University-Enterprise Cooperation

INTRODUCTION

Higher engineering education should be based on comprehensive development, social needs and international background, which develops the graduates with all-round competencies explicit and implicit in developing a successful career (Chinese Academy of Engineering Education Committee, 2007). It means that graduates not only acquire the working skills, but also learn to live and survive. Therefore, one priority to higher engineering education is to explore different approaches to improve education quality, student competency model and investigation of problems at home and abroad, which also intends to improve students to exercise self-management, self-service and core competencies in interpersonal communication.

How to design and implement an effective approach for developing capabilities become a critical part of higher education. Decades of experience on engineering education in China has shown that University-Enterprise Cooperation can be one effective approach for developing …. capabilities. In June 2010, the Chinese Ministry of Education comes up the Excellent Engineer Education Plan which encourage the"*Three+One*" training mode joint with both colleges and enterprises. "*Three+One*" stands for *Three* years' knowledge-majored study in colleges and *One* year's product design-oriented practice in enterprises. College of Engineering, Shantou University, is a part of the Plan.

Shantou University (STU), founded in 1981, is a comprehensive university jointly supported by the Ministry of Education, the Guangdong Provincial Government and the Li Ka Shing Foundation. It is the only public university in the world that receives long-term funding from the Li Ka Shing Foundation. The University campus is located in the northwestern part of Shantou, a seaside city, Guangdong Province, China. The University consists of 8 colleges and schools, namely, College of Liberal Arts, College of Sciences, College of Engineering, Medical College, Law School, Business School, Cheung Kong School of Art and Design, and Cheung Kong School of Journalism and Communication. It enrolls qualified students from all over the country. The Mechanical Engineering Program in STU took part in the Excellent Engineer Education Plan in 2010 and has started the university-enterprise education, cooperated with many international companies since then. The cooperation was implemented especially on that, the undergraduates spent the whole fourth year in enterprises on receiving engineering practice training, and carrying out and completing the graduation design of practical subjects based on engineering requirements of the enterprise.

Founded in 1978 and Headquartered in Hong Kong, Esquel Group is one of the world's leading producers of premium cotton shirts. With production facilities in China, Malaysia, Mauritius, Sri Lanka and Vietnama, and a network of branch offices servicing key markets worldwide, the Group is one of the most dynamic and progressive global-scale textile and apparel manufacturers with a vertically-integrated supply chain that straddles from cotton to retailing. Esquel employs a 58,000 multinational workforce. Esquel manufactures over 100 million pieces of garments annually for leading brands including Ralph Lauren, Tommy Hilfiger and Nike. Long an advocate in innovation, environmental protection and corporate social responsibility, Esquel aspires to make a difference in the textile and apparel industry and contribute to the well-being of a wider community.

The Mechanical Engineering Program in STU focuses on educating technical and management talents with good thinking and practical ability, teamwork and communication skills, and developing their interest in intelligent equipment, production manufacturing lines, industrial automation and other fields of mechanical design and electrical design automation.
The Esquel Group, which was pursuing the automation and intelligence of clothing manufacturing, started cooperation with Shantou University in 2013. The joint education of STU-Esquel on the undergraduate students in Mechanical Engineering has been developed since then.

Firstly, by a survey of stakeholders of teachers, students and employers through interview, questionnaire and statistical analysis, STU and Esquel Group jointly built the engineering practice competency model for undergraduate students. And then based on the model, comprehensive assessment methods are given with examples (e.g., some questions and special observation points from undergraduate students). Accordingly, an evaluation process and model are developed and expected to make an effective assessment on students' ability during their enterprise education. A special instance of undergraduate assessment results from Esquel Group and STU are shown at the end of this paper.

COMPETENCY MODEL OF ENGINEERING UNDERGRADUATE STUDENTS

Competency model defines the underlying sets of skills, knowledge, personal characteristics and abilities that needed to perform in a role and helps achieve the organization's goals(Anne F. Marrelli, 2005)(Mark A Albanese, 2008). The competencies and corresponding level assessment are defined and described in a model (Bradley, 2008). Competency model enables the identification, evaluation and development of the behaviors in individual employees. It helps build a strategic HR foundation for subsequent staffing, development, succession planning, and performance management. It has many types like position competency models for technical, managerial and marketing positions (Glenn M, 2005).

Dimensional Representation of Competency Model

Based on the above competency model and construction method, College of Engineering of STU and cooperative enterprises, construct undergraduate competency model suitable for our college orientation and professional cultivation objectives. The model is composed of two parts:

The core competency model of operational excellence department, are described in detail as shown in Table 1, including *Four Dimensional Representations*, such as, mental health and behavior, teamwork, leadership, execution.

The competency model related to the working position, are described in detail as shown in Table 2, including *Four Dimensional Representations*, including leadership, critical thinking, effective problem solving, innovation and application, communication and interpersonal communication, active learning and independent thinking.

Table 1.The dimensional representation description of core competency model for operational excellence department

Representations	**Descriptions**
Features	Low cost, high quality products and service to provide value for customers
Core abilities	Team Cooperation
Quality of staff	•Mental health and behavior •Teamwork •Leadership •Execution
1. Mental health and behavior	
Definition	Health status; Oneself and interpersonal relationship; Life adaptation and psychological adjustment; Ethical behavior and individual morality
Key concepts	Pleasant personality, emotional stability, Optimistic, interpersonal harmony, good conduct

Main behaviors	•Good health and physical strength; •Pleasant personality, emotional stability, optimistic, interpersonal harmony ; •Own a strong ability to adapt to life and psychological adjustment ability, be able to correctly deal with difficulties and setbacks •Keep the faith, resolute in the idea and ability; • Be able to handle interpersonal relationships and moral behavior in the interpersonal communication, and personal moral cultivation
2. Teamwork	
Definition	Clear team goals, lead the team, pay attention to internal team and team's relationship with other institutions or organizations, to achieve common goals
Key concepts	Fully inclusive and equitable, act with united strength, external cooperation, to establish cooperative network, respect for others
Main behaviors	•Clarify the roles and tasks of team members, take personal responsibility in the team; •Play fair, concerned about team members and coordinate relationships, provide timely support and assistance, encourage team towards common goals; •Coordinate the relationship between the team and the other team, clarify the cooperation mechanism among teams;
3. Execution force	
Definition	In strict accordance with the definition of business process, driving the operation of a business process instance
Key concepts	Specification, process control, pay attention to the process
Main behaviors	•Pay attention to the regulations, to do things organized •implement and follow up tasks according to regulations •Consider repeatability and sustainability, focus on every step in the process •Take the initiative to find and willing to accept new ideas, experience and ways of doing things, improve the current process and system, etc
4. Leadership	
Definition	Drive oneself and team members to achieve stated goals energetically in as short a time period as possible, .
Key concepts	Set goals, focus on the target deadline, overcome obstacles, reach the goal
Main behaviors	• Attention to the deadline of reaching the goal, driving the team put in more effort, to accomplish the goal in the shortest possible time; • To put the time and effort required for the work, have the courage to try, try to overcome obstacles to complete the task; • Maintain focus, tough, dedication; mobilize the required resources, to ensure to reach the objective. •The final results for action guiding, attach importance to practical action •Not satisfied with the status quo, refine on request

Table 2.The dimensional representation description of core competency model related to the working position

Representations	Descriptions
Features	Low cost, high quality products and service to provide value for customers
Core abilities	Critical thinking
Quality of staff	•Critical thinking and effective problem solving •Innovation and Application •Active learning and independent thinking •Communication and interpersonal communication •Active learning and independent thinking
5. Critical thinking and effective problem solving	
Definition	Doubt routine, the innovation idea, change; Timely and effectively solve the difficult problem; Follow up until the obstacle is ruled out.
Key concepts	Recognize problems, feasibility analysis, determine the solution plan, carry out and follow up project
Main behaviors	•To grasp the essentials, have genius for discrimination, based on rigorous inference, witty aura, daily clear thinking agility. •In the face of difficulties, timely put forward or to perform a feasible solution; •Provide the resources to solve the problem, or offered to resource requirements and follow up to ensure that resources are in place; •Implement and track solution, ensure the effective solution to the problem
6. Innovation and Application	
Definition	Have the ability to think from multiple angles, facing the challenge to come up with a new and effective solution.
Key concepts	Overall innovation, good at invention and creation, continuous improvement, good at learning
Main behaviors	• Not satisfied with the commonly accepted views, look for new opportunities for improvement • Create a better solution to meet customers' needs and expectations •Looking for internal and external resources, using the views and ideas that have been confirmed, create new solutions
7. Communication and interpersonal communication	
Definition	Enthusiasm, clearly, correctly listening and communication, to create an atmosphere of open communication
Key concepts	Listening, expression, conflict processing
Main behaviors	• Clearly, clarify, logically express personal thoughts and opinions; emphasis; • Using the appropriate speed, volume, language, body language, etc, performing proper enthusiasm ; • Pay attention to others' message; correctly interpret the information and respond appropriately
8. Active learning and independent thinking	

Definition	Find out their own strengths and weaknesses, maintain their own advantages, improve the shortcomings; to determine their own development needs, and change the environment to improve individual and organizational performance
Key concepts	Predict the gap, continuous learning, and apply it in the work
Main behaviors	• According to the needs of the work, actively participate in learning new knowledge and skills； •Actively learning relevant knowledge of different disciplines under different cultural backgrounds and new ideas and new knowledge generated from the intersection of knowledge. • Through formal and informal learning activities, integrate and absorb new information and knowledge； • Actively participate in learning activities, in order to achieve the best learning effect； • To put the new knowledge or skills in practical application in the work, through repeated practice to increase proficiency. • Without outside help, ability to solve problems by exploring and thinking though one's own

Detail Behavior Level Description of Dimensional Representation

The developed competency model can provide the overall expectation of the employers. However, the desired degree or degree of the assessment which is critical important do not considered by the competency model. This section will be based on the above undergraduate competency model made by University-Enterprise Cooperation. According to the intended development outcomes of students, the enterprise development needs and all kinds of enterprises and all types of professional post requirements, formulate the behavior level defining the performance merits of all kinds of posts. Behavior level is mainly used for standard criteria for the assessment of the undergraduate competencies, and usually can be divided into 1-5 grades(Rubin Nancy, 2007).

Level 1 is the general competency requirements. It generally refers to the students can know and master basic concepts and terms, organization process or relevant tool use, also can carry on the simple analysis; Level 2 is for intermediate demand of ability quality, generally require students to fluently, independently carry out tool operation or to use knowledge of all aspects, and at the same time to carry on the simple education and management for other students or group members; Level 3 are sub-high level requirements for the ability quality. It generally requires students to master certain knowledge, processes or a particular aspect of tool use. It also can travel more complicated management functions; Level 4 are senior requirements for ability quality. It generally asks students to put forward strategic suggestions or make adjustments to the knowledge, processes or tools they grasped; Level 5 are the most senior requirements for the ability quality. It generally requires students to have enough foresight and insight to the development trend of things and the connotative problem.

Due to the limited length of the paper, table 3 only presents detail behavior level descriptions of cooperative ability in the TEAMWORK dimensional representation from the core competency model of operational excellence department. The detail behavior level descriptions of CRITICAL THINKING AND EFFECTIVE PROBLEM SOLVING dimensional representation from core competency model related to the working position are shown in table 4.

Table 3. Detail behavior level description of the TEAMWORK dimensional representation

2. Teamwork	
Grade	Descriptions
5	• Themselves have the courage to bear and help team members to assume their respective responsibilities, to work together • Adjust the priority of the task to achieve the team goal, self initiatively innovate style, timely adopt new methods • Suggestions or development of new methods, to maximize the participation and pay of team members • To promote cooperation within the organization and between different groups, to achieve common goals • Remove the barriers between teams (such as the organizational structure / function / culture etc.), promote the professional skills and resources sharing • Lead the related team to establish mutually beneficial win-win long-term relations of cooperation, through regular exchanges, strengthen and ascend partnership
4	• Able to undertake and help the team members to assume their respective responsibilities, and to establish effective cooperative relationship • To change the style and method with the help of the external force, can effectively drive team members to participate in and pay • Can help cooperation within the organization and between different groups, to achieve common goals • Help related teams to establish mutually beneficial win-win long-term cooperative relationship
3	• Take personal responsibility in a team, have a clear understanding of the team's goals and the roles and tasks of each member • Cooperate with others sincerely, justice, caring, respect • Take the initiative to provide support for colleagues, actively cooperate with colleagues rather than distorting competition • make good use of colleague's participation and pay, can listen to their views on the basis of independent analysis • Communicate with the various aspects, balance interests, persuade the parties to reach a consensus, work towards the common goal specified
2	• Can only assume personal responsibility in the team • Can cooperate with people, treat each other sincerely, balance interests • Able to provide support for colleagues, active cooperation between each other • Respect participation and dedication of colleagues, can listen to and adopt their point of view
1	• Prefer to work alone • Cooperate with people not humbly, not easy to establish and maintain relationships with others • Do not understand the important value of the differences between team members in the process of constructing the team • Be Insensitive to the needs and feelings of others

Table 4. Detail behavior level descriptions of CRITICAL THINKING AND EFFECTIVE PROBLEM SOLVING dimensional representation

5 Critical thinking and effective problem solving	
Grade	Descriptions
5	• Propose feasible solutions and contingency plans facing with problems • Propose solutions to problems with specific action plans and resource requirements, reach a consensus with stakeholders, promote the implementation of the plan; • Follow up the working schedule and its implementation to ensure problem solved; afterwards sum up experiences and share with others to firm proper operation and avoid the same problem. • Be not content with the current status, strive for excellence • Set higher standard and goal, persist in doing things better and better • Play a role of important driver of change • Seek for resources integration to improve organization functioning
4	• Able to undertake and help the team members to assume their respective responsibilities, and to establish effective cooperative relationship • To change the style and method with the help of the external force, can effectively drive team members to participate in and pay • Can help cooperation within the organization and between different groups, to achieve common goals • Help related teams to establish mutually beneficial win-win long-term cooperative relationship
3	• Timely propose or carry out possible solutions facing with problems • Offer needed resources to solve problems or make resource demands and follow up to ensure resources are in place • Implement and follow up the solution plan, ensure problems to be solved • Keep positive with the unsatisfied status quo • Actively seek and be willing to accept new ideas and ways of doing things to improve current processing systems
2	• Can only assume personal responsibility in the team • Can cooperate with people, treat each other sincerely, balance interests • Able to provide support for colleagues, active cooperation between each other • Respect participation and dedication of colleagues, can listen to and adopt their point of view
1	• Can not make decisions or propose a solution within a reasonable period of time; • Fail to offer the necessary resources or make resource requirements to solve problems • Just propose solution plan without following up or implementation • Be unawareness of improvement and be content with current situation • Act with anxiety and resistance to new changes and situations • Expect other colleagues initiate change • Accept new things slowly

ASSESSMENT PROCESS AND METHODS OF ENGINEERING PRACTICAL ABILITIES

After establishing the undergraduate student's competency model and its behavior grade, it is important to apply this model to the undergraduate students' comprehensive ability quality assessment process. In order to show the effectiveness of the new model, it is necessary to combined the new model with relatively complete evaluation system.. In addition, the most fundamental way to detect the competency model is performance management, and thus a set of objective, impartial, fair performance management system is critical to the establishment and perfection of the competency model.

Assessment Process

In order to apply this competency model for assessment of the graduates' engineering practice ability, a complete assessment process need to be further designed. The main purpose of this process is to ensure that the evaluation of the graduates' engineering practical ability is more scientific, normative and accurate under certain conditions, and thus for the corporate HR to choose the right undergraduates adapted to corporate development and culture, for the university to improve its education quality and further revise its training objectives and curricula.

The following questions need to be answered in each step of the design of assessment process:

(1) What's the criterion of the assessment?
The undergraduate's competency model established above.

(2) Who are the raters?
The rater group incorporates 6 persons from both party of corporate HR department and the university, that is, three staff of HR chief director, director, and one technician from the enterprise and three of the department head, 2 professional teachers(professors) from STU. The enterprise plays a leading role in the process while the university assists.

(3) What methods would be more scientific for assessment?
Considering both characteristics of students and the enterprise, the assessment takes a method of two stages, which is detailed described in next section.

(4) What's the conclusion?
The conclusion is whether the assessed meet the enterprise's entry requirements of middle-level management/technical positions.

Assessment Methods

The two-stage assessment method was led by the enterprise and designed by the university-enterprise assessing group. It relatively ensures the method to be scientific, normative and accurate.

Stage I : Stack up the plates

This stage was conducted in groups. 14 students were divided into 2 groups and performed 5-10 rounds of stacking up plates simultaneously as groups. The given time would be shortened as each round went on. The whole process might take 2 hours or so. After group discussion, the members are asked to sort a certain number of plates with numbers by ascending counts one by one and pass through a transit space to stack them up on another pile in a given time. Interpersonal communication is not allowed in this process. The purpose of this stage is to evaluate the students' performance of the 8 dimensional presentations in the competency model in a teamwork situation.

Stage II: Personal Interview

After teamwork project, both party designated one staff to form an interview group of 2. They will interview each student and ask the questions advised in table 5. The interview should be limited in less than 15 minutes.

Table 5 is based on the research conclusion of the previous sections, presenting a reference to student's interview assessment content and asking questions, which is very conducive to the application in the concrete operation of student assessment.

Table 5. Reference to undergraduates' interview assessment content and asking questions

Assessment content	**Problems of reference (Details please ask)**
1. Core Competency	
①Mental and behaviours	• Your mood is bad? For example, often pessimistic, depression, anxiety, irritability or irritable, like attacking etc. • Whether your work, study and attention are significantly decreased? • Whether there is abnormal and behavior you yourself can't control? For example, repeated washing, closing the door, making a face, etc. • See the elderly, children, beggars and other vulnerable groups, what would you do? Think what? • What do you think of the beautiful countryside teachers program?
②Teamwork	• Take a collective activity you have participated in for example, what is each team member's responsibility? And what kind of role did you play? • In this activity, whether there is any crew you don't like (him / way)? How did you handle it? And what's the result? • In the activities you experience, which one has the most intense time / task quantity, and how to collaboratively finish on time with team members?
③Executive force	• The most accomplished/the most proud of/ the most successful thing. • In the activities, if there is a situation where anyone has different opinions? • Tell a matter which cost less than expected, and the results were better than expected? • How did you prepare for the final exam? CET Four / CET Six?

④Leadership	• As a project leader, if you have any experience that do not reach the expected target? Then how did you deal with it? • Please tell about a project you have recently led to complete? What procedures are you in to ensure the completion of the project on time and accurately? • In the activities you have experienced, which has the most limited resources? How did you work? ?
2. Competency model related to the composition	
⑤Critical thinking & solve problem effectively	• Will you often use subversive ideas to think about a problem? • What is the most challenging / the most complex / the most difficult thing you encountered? • What solutions have you proposed? Choose which program? The result? • If you have such experience that your behavior or ideas avoid a potential problem?
⑥Innovation and Application	• If you have such experience that you put forward a new viewpoint or ideas or methods in an activity making the activity very successful? • What aspects do you think the novelty of the idea is reflected? • When you told the new idea to the players, whether you ever encountered opposition and how did you deal with it?
⑦ Communication & interpersonal communication	Through the process of asking questions, at the same time, inspect the candidates' communication ability.
⑧ Learning and independent thinking	• In your recent study, are there no any special achievements? • If you have any experience that you were not satisfied with your grades? How did you change? • If ever found a classmate do hard on something, you helped him to complete? What was the situation? What did you say? Do?

Assessment Results

After the two-stage assessment, the interview group gave the assessment of each student, as well as a detailed description of the result, as is shown in ANNEX 1.

CONCLUSION

Based on the work of CDIO engineering education reform, a undergraduate competency model, a standardized process to apply this competency model, and a method for the application of competency assessment were developed by Shantou University and Esquel Group..

Practice at Shantou University has shown that the newly developed method can be used to evaluating learning outcomes of the undergraduate students in different programs at STU. The assessment results can also bring benefit to the Mechanical Engineering Program for readjusting its training objectives, standards, curricula, and practice section.

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ANNEX 1：Student Ability Assessment Sheet

Assessment Panel: Song Qian & Chen Yueyun, Human Resources Department, Esquel Group
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Remarks :1) Please record the key behavior and performance of the participants' abilities in the typical behavior Column and grade them (one to five points).
2) Please record the comprehensive evaluation of participants.

NO. Student	Team work	Leadership	Innovation & Application	Communication & interpersonal communication	Learning and independent thinking	Critical thinking & solve problem effectively	Executive force	Comprehensive evaluation/Record
1	4	4	4	4	3	3	3	Be able to clarify the rules, put forward to the important points of view
2	3	3	2	4	3	2	3	The ability to solve problems is relatively weak. In the activities, he proposed the law of the maximum.
3	5	4	3	4	3	3	4	Record the rules in the activities; record the transfer process; strong sense of responsibility
4	2	2	3	2	3	3	2	Less participation in team activities; think alone; less put forward his own ideas; don't make decisions
5	3	2	4	3	4	3	2	Make clear goals Initiative; very sincere; lack of her own ideas
6	4	3	3	3	3	3	2	Good team members; not of enough self-confidence
7	4	2	4	2	4	4	2	Careful thinking; present a view of odd and even numbers; good problems solving ability; but there is a slight lack of communication skills

8	4	3	3	3	3	4	4	Put forward good idea; pragmatic; concern for all team members to participate
9	3	3	4	2	3	4	3	Results-oriented; assume responsibility; there is a slight lack of communication effect skills; sometimes there is no eye contact.
10	4	3	3	3	3	3	4	Focus on team work; awareness of activities; consider it was a “Pure physical labor work” about these activities, but the group didn’t challenge successfully because it was a little loose.
11	5	3	3	4	5	3	3	Initiative to take responsibility and put forward the proposal; pragmatic and be good at continuous improvement; dedicated; be good at learning; clear expression
12	4	4	5	4	4	5	4	Be good at mathematical operation; summarize methods; record activity process; make overall planning; summarize the abilities of the team members.
13	4	4	4	4	3	3	5	Present more ideas; ensure team members are clear about the rules; good communication skills

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GLOBAL DISTRIBUTED ENGINEERING STUDENT DESIGN TEAMS: EFFECTIVENESS AND LESSONS LEARNED

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ABSTRACT

Twenty-first century engineering student professional skills require the ability to work effectively in multicultural, globally distributed teams. Chalmers University of Technology (Sweden) and Penn State University (USA) have formed a collaboration to provide students with an experience in this environment to start requisite skill development. The activity is anchored by a corporate supplied project with realistic open-ended design requirements. The students are expected to mimic the operation of a multinational corporate engineering team to develop a design solution. The collaboration was initiated in September 2014 and launched in January 2015 with Volvo Group as the industrial partner. In addition to the traditional design experience outcomes, the learning objectives from a global perspective are to: (a) understand the impact of engineering in a global, economic, environmental, and societal context; (b) understand cultural/ethnic differences and develop the ability to work sensitively with them; (c) learn to function effectively in multinational teams; (d) communicate effectively in English, regardless of team members first language; and (e) develop the ability to organize and deliver communication around the globe. The paper discusses the integration of academic protocols from each university, the logistics and operation of the global student teams. At completion of the program a critique was performed from various perspectives to assess effectiveness and capture lessons learned. A pre and post survey was given to the students to assess effects on intercultural communication from the interaction. The Volvo Group personnel who interacted with the teams and supervising instructors were asked to critically evaluate the program. All information pointed to a successful program whereby the students delivered technically sound design solutions and gained professionally through the global experience. The paper concludes with a discussion of the keys to success for such a globally distributed university-corporate academic collaboration.

KEYWORDS

Global design teams, multicultural, industry sponsored educational project, CDIO Standards: 1, 3, 5, 6, 7, 8

INTRODUCTION

Corporations desire engineers who can enter the workforce and function effectively in the global economic and engineering worlds. An engineer in a global company must be able to easily cross national, cultural and language barriers to function efficiently in global product development teams. Engineering educations need to provide opportunities to prepare their graduates for the ever increasing global nature of engineering (Bourn & Neal, 2008).

Study abroad programs have traditionally been an effective tool to provide students with global experiences. However, these programs have not been widely embraced by engineering students. For example, engineering students comprise approximately 5% of the undergraduate population in the USA, with only 3% of the cohort studying abroad (Carlson, 2007). Reasons for the low participation include the rigorous prescriptive engineering curricula, the financial burden, and more fundamentally, international experiences have not been a traditional focus.

Improved communication technology has led to the increase of global virtual teams (GVTs) in industry. In GVTs, team members are globally dispersed and work together towards a common goal (Powell, Piccoli, & Ives, 2004). These teams offer benefits for the company such as round the clock progress, travel cost reductions, and improved creativity due to team diversity (Kankanhalli, Tan, & Wei, 2006). However, there are also challenges that arise in GVTs including cultural differences, communication delays, and time zone differences (Mannix, Griffith, & Neale, 2002; Qureshi & Zigurs, 2001). If not carefully managed, GVTs can create ineffective teamwork (McGrath, 1991). Teaching students to effectively work together in GVTs can help make students more effective global engineers and prepare them to be effective teammates and leaders. The GVT experience has the potential to introduce global engineering aspects and is capable of reaching engineering students en masse.

Successful implementation of a GVT in an academic setting is a challenge. To address these issues, an approach has been developed to create Global Student Teams which replicates the industry experience for students. The Global Student Teams are united by a carefully tailored industry supplied project. Each institution operates its respective culminating experience in its current format with the project driving the students to act as one cohesive team. The interaction between the Global Student Team members is facilitated by regular communication in a variety of forms (email, weekly video and teleconferences). The critical cohesive element is the interaction of the students with the global corporate project sponsor.

Penn State University (USA) Department of Mechanical and Nuclear Engineering and Chalmers University of Technology (Sweden) Mechanical Engineering program (Departments of Applied Mechanics and Product & Production Development) have joined with Volvo Group to implement Global Student Team concept. The activity merged the preexisting culminating engineering activities (i.e., Chalmers BSc Thesis and Penn State Capstone) at each respective university to minimize academic logistic issues. The program was launched in the Spring 2015 semester with two projects sponsored by the Volvo Group.

In the following sections the Global Student Teams approach will be discussed. The program organization, procedures and outcomes will first be presented. The program assessment extracted by observations from multiple sources is presented and analyzed. Finally, the lessons learned and keys to success will be summarized.

Educational Objectives

The Global Student Team concept is to provide a meaningful non travel based international design experience. The students are exposed to a real life design experience working on products for the global market. In addition to the traditional design experience learning outcomes, the added educational objectives from the Global Student Team structure include allowing the students to:

1. Understand the impact of engineering solutions in a global, economic, environment and societal context.
2. Understand cultural/ethnic differences and the ability to work sensitively with them.
3. Learn to function effectively in multi-national global team.
4. Learn to use English as the common communication language within a multilingual team.
5. Develop the ability to plan/organize and deliver communication effectively around the globe, leveraging information and communication technologies.

GLOBAL STUDENT TEAM OPERATION

Students enrolled in their respective culminating experience at either Chalmers or Penn State. Teams were formed with three students at each university. The student team activities were organized to operate in a similar fashion as a Volvo GVT. Chalmers and Penn State professors operated their respective courses in their current form with the project tasking providing the mechanism for the students to work together.

Prior to the project launch, the Chalmers and Penn State professors prepared a detailed, comprehensive schedule; including arranging major video conference dates and times with the Volvo project sponsors. The forced critical milestone scheduling helped keep the teams focused and resolved any potential conflicts with respect to national or school holidays. The milestone scheduling removed any uncertainty while trying to arrange meetings with many people across multiple time zones that could have potentially delayed the student progress.

The student teams were ultimately asked to develop intermediate milestones and deliverables around the faculty supplied schedule. In coordination with their Volvo sponsors, the students organized the tasking and separation of responsibilities. They leveraged the respective capabilities at each university to their advantages.

Project Development and Selection

Project selection was critical for program operation as it formed the cornerstone for the student collaboration. The project must be realistic, technically challenging and amenable to global engineering participation. Thoughtful project selection and tasking was critical to facilitate the separate yet integrated student activity. The projects originated from the Volvo Group, with one project each proposed and supervised from Volvo (Sweden) and Volvo (North America). Penn State and Chalmers professors worked very closely with the Volvo personnel to select projects which met the criteria. An overview of the two projects selected follow.

Device to Open/Close the Airflow through a Grille and Cooling Module

Reducing cooling airflow through a radiator and grille opening of a long haul truck, Figure 1(A), can decrease aerodynamic drag and fuel consumption. The students were asked to investigate different technical solutions for devices to control the cooling airflow through a truck. Specifically they were tasked with conceptualizing multiple solutions, selecting the most promising design solution, constructing a functional prototype and validating the prototype design.

Roof Mounted Aero Device with Actuator Positioning

A roof mounted fairing, Figure 1(B), directs the air flow around the nose of a trailer improving the aerodynamics and improving fuel efficiency. In some operations, trucks make trips without a trailer and the raised fairing creates unnecessary aerodynamic drag. The student team was asked to 1) design an automated lifting mechanism to raise and lower the roof mounted fairing and 2) to aerodynamically optimize the device shape and configuration to provide optimum performance in both the raised and lowered position. The team was tasked to construct a prototype to demonstrate the mechanical operation and to provide a computational fluid dynamics analysis of the aerodynamic performance.

(A) (B)

Figure 1. Volvo project photos: (A) Truck cooling grille, and (B) Roof mounted truck fairing.

Communication

Constant communication between the students was crucial to the team success. Initially web based video conferences were scheduled by the faculty. The video conferences were led by the professors and provided a platform for the students to meet each other and form effective team procedures. As the students became more familiar communicating effectively in this environment, they assumed control of the scheduling and leadership. The teams ultimately organized and held video meetings at their convenience.

At several critical points throughout the project, the students were required to deliver formal presentations to the Volvo project sponsors/mentors. The coaching from the professors helped refine the communication ability of the students in this video conference environment.

The student teams communicated almost daily via email. The students used a common electronic depository to store their files so any team member could access the most current information at any time of the day from anywhere. The students ultimately developed procedures to communicate very effectively exploiting many of the electronic collaborative tools readily available. Moreover, they also developed skills and routines to handle global CAE simulations and tools. In particular, they successfully developed common CAD, FEM and CFD models enabling simultaneous developments without conflicts.

Reporting and Student Evaluation

A separate yet integrated student reporting and evaluation scheme was used. A common reporting format was agreed upon by the professors and followed by the students. All reports were prepared in English, with the Executive Summary of major reports also presented in Swedish. Each university applied their respective standards and marking scale to the unified report.

Global Student Team Structured Protocol

The teams' success relied heavily on a structured operational protocol established a priori by the professors at Chalmers and Penn State. This structure gave the students specific tasks to be fulfilled to ensure the students were efficiently utilizing their time. This was important due to the short four months' time the students had to complete the project. The protocol included team building exercises, introduction to the sponsor, establishing team member responsibilities, developing a CAD system level design and fabricating prototypes.

The teams initially had team building exercises and were introduced to the Volvo sponsors through video conferences. Team building exercises included 1) having teammates give short presentations about themselves; 2) having USA and Sweden student cohorts deliver brief presentations about what it is like to live and go to school in their respective countries, and 3) having the student teams' work together to write a team contract which described how the members will function together on the project. The contract clarified the cooperative rules and how to handle a situation if a teammate does not fulfill the agreement. The teams also continued team building exercises midway through the semester when the Chalmers students had the opportunity to visit the Penn State, USA. During this visit the teams worked together on their projects in the machine shop. Social events were organized, including an American baseball game and a professional corporate style dinner. These virtual and in person team building activities helped to enhance the team spirit and allow for free flowing communication.

Both teams decided to have a rotating team leader scheme with two-week term for each member. The teams also decided to have a designated secretary on a rotating schedule. The role of the secretary focused on scheduling, documenting group meetings and ensuring that all material was available in the common depository. The teams appointed two contact persons, one from each site, whose main task was to be the industrial sponsor point-of-contact. Communication dates for eight web meetings throughout the course of the project were scheduled with the Volvo sponsors. Next, the student team prepared a Gantt chart to diagram the different steps, deadlines, deliverables and responsibilities.

The team followed a systematic development process that starting by investigating competitor's products and patents. The team established thorough requirement specifications and customer needs in close cooperation with Volvo. Several preliminary concepts were generated, first individually and then as a team to further develop concepts by creating new designs and by combining features from existing concepts. All concepts were evaluated in an elimination matrix. The most promising concepts were evaluated using Pugh and Keselring matrix selection methods and the concept that best fulfilled the customer needs was identified.

Next, a general system level design was developed with the cooperation of the entire team. The various component development work was divided among team members with clearly identified responsible persons. CAD models of different parts were developed, enabling work to be performed in parallel. Materials and processes were selected using CES EduPack software (Cambridge, United Kingdom). Finite element models (FEM) were used to conduct thermal, stress and deformation analyses on critical parts. Computational fluid dynamics (CFD) models were used to analyze the aerodynamic performance to ensure fulfillment of the requirements. The grill airflow behavior was modeled in both a closed and open position. The roof fairing air flow was similarly modeled in both upright and lowered positions. Design for Assembly (DFA) and Design for Manufacturing (DFM) analyses were conducted to ensure ease of production. Finally, cost analyses were completed using CES EduPack together with market prices for off the shelf components. Both teams were able to design, develop, and validate successful functional prototypes.

ASSESSMENT OF PROGRAM OUTCOMES

The technical outcomes, professional skill development outcomes, and benefits from an industry perspective were all assessed. It was found that the Global Student Teams approached offered numerous benefits to both student development and industry. The assessment of these outcomes is detailed in the following sections.

Assessment of Technical Project Outcomes

The global teams' technical solutions were remarkably good and the students benefited professionally from the experience. The students developed and deepened their technological knowledge and skills. Professional skills such as communication, teamwork and project management were enhanced by working in this global environment. Survey results showed the students found it extremely rewarding to work in an international team. They gained valuable experiences in how to handle time differences, different work cultures, and international communication. The specific technical outcomes of the two Global Student Teams are discussed in the following two sections.

Device to Open/Close the Airflow through a Grille and Cooling Module

The project produced a fully detailed CAD rendering, as shown in Figure 2, and the development of a functional full scale prototype. The prototype and CAD model contained numerous creative design aspects including unique aerodynamic grill blade design and a novel lightweight lattice frame design.

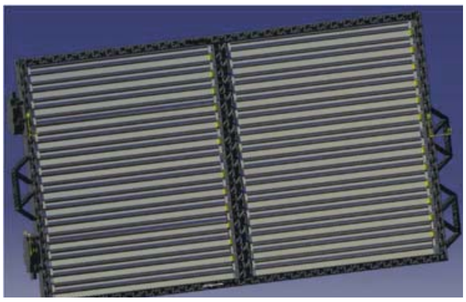

Figure 2: CAD model rendering of grill and cooling module developed by the global student team.

Roof Mounted Aero Device with Actuator Positioning

The team successfully designed and fabricated both a small scale and a full scale prototype of the automated roof mounted fairing. The team created a fully detailed CAD rendering, shown in Figure 3. The team developed several novel concepts including a folding design for the sides which allow for a flat profile when retracted, and a novel linkage system to allow for effective pneumatic actuation.

The students were confronted and solved many items not typically experienced in final year projects. They worked through international intellectual property, procurement issues and ultimately manufactured, assembled components designed around the globe into a functional prototype.

The solutions and project deliverables from the Global Student Teams were on par with the upper tier of industry sponsored teams comprised of capstone student teams completely at Penn State or Chalmers. The global distribution did not harm the technical project outcomes in any manner and the different educational and cultural perspectives actually enhanced the designs.

(A) (B)

Figure 3: CAD model rendering of faring in both (A) Up and (B) Down positions

Assessment of Professional Skill Development

Assessment of the students' professional and intercultural growth through the global teaming experience was performed by multiple methods. A pre and post survey was given to the students to evaluate the intercultural communication, teamwork and skill development. The survey was adapted from the work of Lu et al. (Lu, Chen, Trethewey, Litzinger, & Zappe, 2011) which was developed by professionals in intercultural communications and assessment. The survey results ultimately were difficult to quantitatively evaluate due to the small sample size of students. Hence the evaluations are qualitative in nature based upon the surveys, instructor observations and conversations with the students.

The students at both universities thoroughly enjoyed the experience and appreciated the opportunity to expand their international perspectives. The communication between the teams was very effective and professional. The mentorship of the corporate sponsors, in this regard, was beneficial. The students mastered the technology to enable international communication and exchange of information quickly. Through the regular video and voice conferencing the students rapidly became friends which helped drive the cohesiveness and teamwork effectiveness. Post program evaluation indicated that the experience piqued the students' interest in learning more about other cultures and working internationally. This was apparent in the USA students who are not as regularly exposed to other languages and countries as their European counterparts tend to be.

The overall excellent outcomes from the professional skill and communication perspective may have been facilitated by the similarities of both universities and students. The cultures, education and life experiences of both student nationality groups were far more similar than different. Hence, differences were small to begin with and easy to overcome if encountered. Furthermore, the ease of communication within the team can be attributed to the Swedish students' mastery of the English language, oral and written, and their comfort level to use it.

Assessment from the Industry Perspective

When hiring new student graduates, corporations must allow time for these new employees to become acquainted and familiarized with the way of working, which is usually substantially different from their educational endeavors – especially if the corporation is global. The newly employed could easily be overwhelmed by the way projects with colleagues spread over the world are run using email and phone as the main communication tools for delivering results into the project work.

Therefore, the Volvo Group highly appreciates the initiative between Penn State and Chalmers, who are both part of the Volvo Group Academic Partner Program, to allow students to experience a true working situation as part of their education. This incorporates not only experience solving a product oriented technical problem, but also understanding the need to be receptive to new cultures, tackle language barriers and to drive progress without meeting in person. These are important skills to be successful in a global corporation.

LESSONS LEARNED

The project success can be contributed to the three components that have been assembled for this program. 1) a group of serious, motivated and mature students; 2) engaged, responsive, patient and instructional project sponsors/mentors backed by strong Volvo Group corporate support; 3) adaptable and engaged professors backed by strongly supportive university administrations. Five key lessons learned for the creation of a successful Global Student Team project include:

1. Motivated students are critical to project success. The students who elected to participate in this pilot program were motivated by the global aspects of the activity. Much of the program success can be attributed to the drive and dedication of these students. Future challenges may arise when teams are comprised of students not predisposed to global participation.
2. Engaged industry sponsorship is crucial. Industry mentors who practice global engineering can anticipate the student pitfalls and help guide them. Furthermore, they can lead by example and show the students how to work effectively in this challenging environment.
3. Careful project selection is necessary as not all potential projects are amenable to being worked on by a Global Student Team. The project objectives should be well formed with separable items and tasks. The system integration serves to drive the interaction and communication.
4. It is critical that the instructional faculty at the partner universities have a strong working relationship. Close communication and team work on part of the faculty is necessary to guide the student teams and program success.
5. The students require access to video conferencing technology on their schedule with few hardware and facilities constraints. The universities need to have specially tailored video conference rooms to enable high quality web meetings to facilitate communication and technical information sharing.

SUMMARY

The inaugural offering of the Global Student Team concept between Chalmers University of Technology, Penn State University and Volvo Group was highly successful. The technical and professional growth of the students in Global Teams was on par with other high performing co-located domestic student teams. This offers evidence that the geographically distributed nature of the team has not been detrimental, but actually enhanced the project. Furthermore, the experience provides an added value with regard to global perspectives, intercultural and interpersonal skill development, and cross language communication.

The students report the program was very worthwhile and indeed delivered a meaningful international experience. The program created significant interest in the participating students' peer groups. The peer groups expressed their desire to have such an experience. The next step entails program expansion to deliver the experience to many more students.

ACKNOWLEDGEMENTS

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DRIVERS AND BARRIERS TO INDUSTRY ENGAGING IN ENGINEERING EDUCATION

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ABSTRACT

The CDIO Standards provide an excellent framework for the engagement of industry stakeholders in the development and operation of professional engineering degrees. This framework is echoed in the program accreditation requirements operated by Engineers Australia and other accreditation bodies. Implementing effective industry engagement is, however, increasingly challenging to both academics (faculty) and industry members, despite much mutual goodwill between the two sectors. This paper provides the findings of a recent study on the drivers and barriers to engagement by industry to engineering education. The theoretical framework for the study was that all aspects of engineering education should be comprehensively engaged with practice, thus endorsing the principles of CDIO. Data presented from a student survey reinforces the value of good industry engagement in the curriculum. The principal findings from the consultation with industry highlight barriers in terms of poor communication, different priorities and lack of resources; but also identify strong drivers for engagement in terms of industry and company visibility for recruiting and brand promotion, internal staff development, relationship development, and social (corporate and professional) responsibility. Consistent with the goodwill between engineering schools and industry, there is a general desire on the part of industry to see the barriers to engagement lowered. The broader project, of which this study is a part, provided a number of recommendations for engineering schools, individually and collectively to contribute to improved industry engagement practices.

KEYWORDS

Engineering education, curriculum development, industry engagement, partnerships, Standards: 2, 5, 7, 9, 12

INTRODUCTION

The CDIO Standards and Syllabus (Crawley, Malmqvist, Lucas, & Brodeur, 2011) provide an approach to engineering education that directly addresses the requirement for students to be exposed to engineering practice by placing elements of practice, namely conceiving, designing, implementing, and operating, at the heart of the curriculum. Several Australian engineering schools follow the CDIO methodology. All Australian engineering schools, however, have their professional engineering degrees accredited by the national professional body, Engineers Australia (EA), a member of the Washington Accord. EA stipulates that all students of accredited programs be exposed to engineering practice, to close the gap between education and practice, develop students' capabilities and identities, motivate them and ease their transition to practice.

Traditionally, the universities have implemented the exposure to practice requirement by mandating that students must undertake at least 12 weeks of in-industry work experience, ideally before commencing their final year of study. In addition, taught units in the curriculum are expected to be informed by lecturers' industry experience, and much of the students' design and project work would be sourced from industry. All three elements of this model have become increasingly difficult to realize, as student numbers have increased and the nature of Australian engineering industry has changed. In addition, fewer engineering academics (faculty) are appointed with recent industry experience outside research laboratories, (Cameron, Reidsema, & Hadgraft, 2011), making it difficult for academics alone to provide students with insights from contemporary practice within their teaching that adequately meet the CDIO Standards and EA accreditation expectations. Therefore, at many universities in Australia, improving the quantum and quality of industry engagement in engineering education has become critical to the success of engineering education programs.

The 12 CDIO Standards ("CDIO Standards v2.0," 2010) describe features of CDIO™ programs. Engaging industry members in curriculum development and implementation is directly relevant to meeting Standard 2 (*Learning Outcomes),* Standard 5 (*Design-Implementation Experiences),* Standard 7 (*Integrated Learning Experiences*), Standard 9 (*Enhancement of Faculty Competence*), and Standard 11 (Program Evaluation). Similar industry engagement, as a key stakeholder in the engineering education process, is required in several of the EA accreditation criteria (Engineers Australia, 2011). Thus, effective industry engagement is critical in contemporary engineering education. Engagement with the students will enhance their learning, motivation and future career prospects.

As stated earlier, Australia's engineering education schools have sought to retain in-industry experience as a program requirement, although it has become increasingly difficult to source such placements. During 2012-14, the Australian Council of Engineering Deans (ACED), the peak national body for the 36 universities providing accredited professional engineering degrees, was funded by government to explore how students' exposure to engineering practice could be enhanced. This paper briefly outlines the project and presents the theoretical framework, methodology and key findings that elucidate the research question: *What are the drivers and barriers to industry engaging in engineering education in Australia?*

THE ACED INDUSTRY ENGAGEMENT PROJECT

The project involved twelve university partners and seven peak industry bodies. Two parallel activities were undertaken (Male & King, 2014b), with essentially separate outcomes:

i. A consultative process was used to develop "Best Practice Guidelines" for effective industry engagement (Male & King, 2014a). These include recommendations to ,the universities, industry, and peak bodies and government. They were underpinned by a literature review, a survey of 16 universities, focus groups with engineering students at three universities, and five industry-university forums attended by 149 people. Additionally, in-depth interviews were conducted with 17 people whose roles in universities included engaging with industry, and with industry as described below.

ii. Seven universities developed and trialed “industry-inspired” projects to enhance their existing curriculum in core areas of engineering science and project management, mostly to large classes. In each university, an engineering academic in each university worked with an industry partner to develop suitable curriculum material, with the partner as a consultant and adviser rather than guest lecturer. That way, the new material is potentially transferable. Industry partners were supportive in allowing non company-sensitive material to be used.

Both of these project activities have contributed to the elucidation of the drivers and barriers to industry’s engagement with engineering education, discussed below. Since students are ultimately the focus of education, it is important to understand their perspectives. Early in the project, 215 final year bachelor and masters engineering students were surveyed to identify the types of industry engagement that significantly increased their understanding of engineering practice (Male & King, 2014b). The most highly valued types were, in order: 12 weeks of vacation engineering employment or equivalent part-time engineering work; guest lectures; engineering internships of six months or more; industry-based final year projects; hearing or reading about another student's workplace experience; teaching by staff with recent, non-research industry experience; industry visits and inspections; industry-based case studies; and problem solving, projects, or evaluation tasks with direct industry input of data and advice.

These findings validate the importance of including authentic industry experiences in the curriculum, and also should motivate industry’s engagement in the education process.

THEORETICAL FRAMEWORK

Figure 1 shows the Model for Effective Exposure to Engineering Practice in an Engineering Degree which was developed in the overarching project. Within the model, exposure to practice should support students to develop (Male & King, 2014b, p. 4):

- *more comprehensive and accurate understanding of engineering practice;*
- *a sense of belonging to the faculty and the profession;*
- *motivation for learning from recognition of relevance of the engineering program;*
- *improved learning through understanding context and connections.*

RESEARCH METHOD

Examples of effective engagement practice were identified by university representatives, literature, and through Engineers Australia. These, and the drivers and barriers to engagement were further explored though interviews and group consultations.

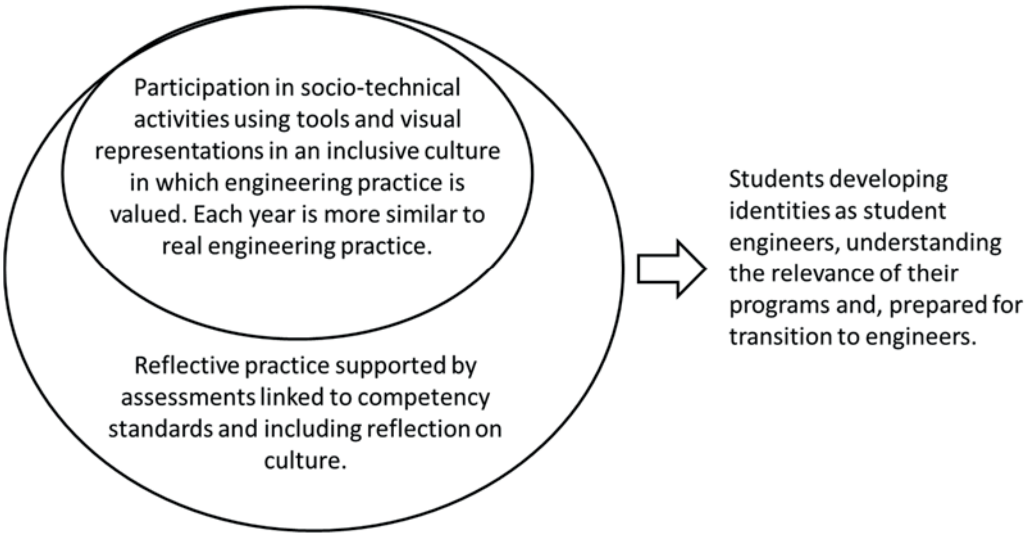

Figure 1. Model of Effective Exposure to Engineering Practice (Male & King, 2014b, p. 4)

Fifty five participants from universities and industry were interviewed as a purposive sample of informed participants. The focus on this paper is on those from industry. The 38 Industry participants included senior engineers, HR managers, or innovation managers who were essentially representing their organization; and individuals who were directly involved with engineering education and students. Their broad characteristics are summarised in Tables 1 and 2. Interviews began with an explanation of the project as already provided by email or telephone. All interviews were semi-structured, with planned core questions and additional prompts to delve into arising topics of most relevance, especially features relevant to the framework for effective exposure to engineering practice. The interview questions covered:

1. *How is your organisation/you engaged with students in engineering degrees?*
2. *What do you see as the benefits for individuals and the organization?*
3. *Could benefits be enhanced – how?*
4. *What are the features that make engagement possible or difficult?*
5. *Are there risks to the current engagement initiatives continuing?*
6. *Are there processes, structures, or other factors contributing to the initiative continuing?*
7. *What would improve the chances of your organization/you continuing with this engagement or expanding engagement?*
8. *Are there other forms of engineering education engagement that your organization/you would like to be involved in if the opportunity arose?*

Most interviews were 30 minutes in duration, but in about five percent of cases, continued for another hour. Most interviews were face-to-face but some were conducted by telephone or on-line. The interviews were all individual, except in three interviews each with two participants from the same company, and two interviews each with four participants from the same company. Notes and transcripts of the interviews were analysed to identify examples of effective industry engagement, informed by the framework for effective exposure, and to identify the drivers (benefits) and barriers for engaging in industry. In the following sections of the paper we have allowed our findings to be largely expressed by the interviewees.

Table 1. Current Level of Engagement of Industry Participants

Level of Engagement with Engineering Education	*N*
In organization involved in engaging with engineering education	25
Individual engineers engaging in engineering education	6
Industry-based engineers teaching in engineering faculties	5
Industry-based engineers interested in engagement	2
Total	**38**

Table 2. Type of Organisation at which Industry Participants were Based

Type of organisation	*N*
Consulting engineering company	11
Mining	6
Public utility	5
Engineering Procurement Construction Company	4
Oil and gas company	3
Construction company	2
Auto manufacturing	1
Auto parts manufacturing	1
Mineral sands company	1
Total	**34**

Note. Four ‘industry-based’ participants were retired from industry and do not have an organisation categorised above.

FINDINGS: BARRIERS TO EFFECTIVE INDUSTRY-UNIVERSITY COLLABORATION

Common reasons reported for not engaging are listed below with sample supporting quotations from interviews.

B1 Difficulties in Engaging with the University

The most common barrier to industry engagement was a lack of approach from universities or lack of a clear, convenient, coordinated system of contact in and across universities. The quotes below demonstrate the persistence of this problem.

> *I think it is very hard for employers if there's not that kind of role in uni: you know, whether it's a central career service or someone who is the focal point for industry in faculty. It is quite hard for employers to navigate around the university and how do they get in touch with students and can they get in touch with academics or lecturers and is that appropriate because some unis are okay with it and some aren't…. Some kind of industry relations or careers adviser and that being… a clear person who has probably got a good marketing background who… is out there talking to employers proactively. That's… the key to success.* (National head of human resources in an oil and gas company)

> *The difficulty is maintaining relationships to a number of universities…The five universities or so each with different structures and politics, with different expectations*

around support and different programs. (National head of human resources for a consulting engineering firm)

(Have you been involved on industry advisory boards or panels or anything like that?) *I find that the universities don't seek that out. I think it needs to be motivation from both sides but if the engineering deans were to be more specific about what they were looking for I think they'd be surprised at the sort of support they get… I think if there were industry consultation committees and things like that we would participate quite readily in those. If the universities or the engineering faculties were running them then we'd be more than happy to participate in those*. (CEO of mining company A)

Personnel changes, because the relationships – my relationships with people in both University A and University B, have only ever been – as far as the turning up in the classroom and say, hey look at me, have only ever been on a personal relationship level with that individual lecturer. (Engineering manager in oil and gas operator, referring to guest lecturing and why it discontinued)

B2 Perceptions that University People are Out of Touch with the Industry and Beyond

Interviewees and forum participants expressed perceptions that academics were not sufficiently aware of the needs of industry or society, as demonstrated by this quote:

I think it requires the universities themselves to recognise who the stakeholders here and what their stake is in the issue. It's not – it shouldn't be – the driver shouldn't be the curriculum and the funding and – that's there for a purpose which should be based on industry need and... in fact I think it's beyond that too. It becomes the social and physical climate as well because that's going to drive what becomes important in the near future, you know, we've got a megatrend is really… much more connected to society and that's bringing with it opportunities and real risks and that should be debated and discussed. (National head of human resources for a consulting engineering firm)

B3 Time and Inconvenience Involved in Supervising Students on Placement

Time and inconvenience involved in supervising students or engaging with teaching and especially placements in other ways can be a barrier to engagement, especially in a tight economic climate, as expressed by the human resource manager below. Much of Australian engineering work is contract based, with no provision for undergraduate or graduate training.

We're not set up just to get anyone come through the door any old time to do 12 weeks of work. Because we've got to fit in with all the project people are doing and what everyone's doing so it's a lot of effort. (Human resource manager 1 in mining company A)

B4 Industry Experience being Undervalued for Teaching, and Pay Disparity Between University and Industry

Engineers who had industry experience and taught in universities were at a time in their lives when the income was not critical and noted that their industry experience was not recognised in the university human resource system, and the university pay levels did not compete with those in industry. The engineer quoted below explained the impact of this on recruiting experienced engineers.

The disparity between the amount of money people out in industry and the amount of money paid for university lecturing, sessional lecturing is a big problem…. I've actually

> *been looking, and [another engineer who teaches] has too, for other younger people to be taking on this role. It's not worth their while. In their late 40s and early 50s when they've got a lot of work out there, it just isn't worth their while to forego a very sizeable amount of their income to come and lecture.* (Experienced engineer working as a sessional teacher in engineering)

FINDINGS: DRIVERS FOR INDUSTRY TO ENGAGE IN ENGINEERING EDUCATION

Benefits to engineers and organisations that engage with engineering education are important to the study because these are critical to gaining the ongoing and future support of industry partners. Reported benefits to industry partners included development of relationships with university researchers leading to future collaborations, access to university resources such as laboratories, libraries, and experts, in addition to the following.

D1 Enhancement of the Organisation's Brand among Future Engineers who become their Future Employees, Clients, Contractors and Alliance Partners

For people in senior levels in organisations, the benefit to their brand was important, as described by participants below.

> *I guess a lot of it is to do with the profile of the company, from my community point of view, as well as raising awareness of the organisation to engineering fraternity and engineering education fraternity. You see, at that time, we probably had a lower profile than we have currently. (*Senior engineer who was involved in establishing industry engagement of multiple types)

> *I actually approached the university. There was a couple of reasons for that. One was that we had just, that year, started to recruit graduates… seven or eight years ago. And I remember interviewing one of these students, and it's a thing that will stick with me for probably the rest of my career. I said to this student, 'What do you know about us as a company'? And they said, hand on head the student said 'I know you're a big company, but you're not as big as [company A that had engaged heavily by offering scholarships and funding projects at the local universities for decades]. And I thought, we were 25,000 people as a global organisation, and they're a great company, but they're about 4,000 people.* (Engineering manager in a company that performed engineering, procurement, and construction in the oil and gas industry)

D2 Improved Understanding of Working for the Organisation held by Prospective Graduate Recruits

In addition to visibility of the organisation, engaging with education was recognised as improving students' understanding of working for the organisation and therefore graduate retention:

> *We had a mechanical engineering student who did such a good job during the holiday employment that we kept him on during the year a couple of days a week to do bits and pieces for us to the point where he got a job afterwards and he's still here. That's a classic example of someone who, holiday employment, did really really well, got them involved in some more interesting stuff, they were like 'This isn't too bad, I like this place.* (Electrical engineer 1)

D3 Prospective Recruitment and Opportunities to Influence the Capabilities of Future Graduates

Several interviewees spoke of the value of industry placements for future graduate recruitment. Company expectations of students on placement may not be particularly high, so that students who do well and develop their skills and company knowledge are likely to be recruited as graduates. The fourth of the following quotes identifies the value of a company systematising its placement and university engagement program.

> *So the intent with the vacation program is ultimately if they're successful throughout their vacation duration. So they do the vacation program over two or three years, the intent would be that they would become our graduates in an ideal world. If they want to and if they perform to the level that we would like.* (Human resource manager 1 in mining company A)

> *Yeah you're seeing them perform, whether they're a good fit for the business. We don't get all of our graduates through our vacation program though.* (Human resource manager 2 in mining company A)

> *They can really hit the ground running [after graduation] because they've had that exposure*. (Human resource manager 1 in mining company A)

> *We'd get experienced people in and they'd work and finish an assignment and then leave and so we had no continuity. We had very little - they take away your body of knowledge… I started looking around and we had some quite good recruits from our own university who were managing the work that we were doing quite well. So I thought, look, I think we'd better spend some time developing the graduates, enticing them into the business and having a look at the quality of graduates available in engineering. I've been marking - they have external markers come in and help with the presentations at the end of fourth year…. We are recruiting from the graduates and we have a graduate program in our business and we're doing quite well out of it.* (Process engineer 1)

D4 Opportunities for Professional Development for Staff
Human resource managers and senior engineers recognised professional development opportunities for their employees in engaging with students on placement as described below.

> *At the undergraduate level, we – actually, we get involved every now and then with architectural schools, and that's really because it's good for our business. We do a lot of work with architects, so by going out and helping architects in their design tutorials and giving them feedback on their designs and structurally from other engineering points of view, we're building brand around architects and the future in our industry. And we're also giving our younger [engineers] good practice at the skills of going out and working up buildings with architects which is what they have to do in their careers.* (Principal engineer in a large consulting engineering firm)

D5 Appeal to the Organisation's Employees; Personal Satisfaction for those Engaged in Working with Students

Individual engineers reported great satisfaction in giving back to the profession and working with students, as described below.

> *I have mentored every year, I've done that for about five or six years as well… Every year I have an electrical engineering student and we come and chew the fat, talk about what it's like to be an engineer. That's really a rewarding project and thing to do as well because you're seeing the challenges of what the students have to do… It's more about being able to just talk to students about the different real practises of engineering as opposed to fourth order or differential equations. 'What is the actual*

thing I have to do when I become an engineer?'... A part of it is actually giving a little bit back as well it often helps you to explain where you're going in your own head because you're never really truly settled in terms of your own education as well. (Electrical engineer 1)

> *[Chairing the industry advisory board] is satisfying, I feel like I'm actually giving something back and doing something Look this is important. You don't want to see us in a situation where we don't have a continuous path at the flow of good engineers that you can actually use in the industry. It's not just me, it's not just [my employer], you'd hate it if we'd be in a situation where we don't produce our own engineers. That's just crazy.* (Electrical engineer 1)

> *I've been an engineering practitioner for over 30 years… I find it enormously satisfying to get through to young minds and expose them to particularly experiences I've had… I also find it satisfying to lift the lid on possible career paths for them and to try and motivate them… and I tell them about lots of other things they will never find in a text book.* (Experienced engineer who was teaching full-time at a university)

D6 Social License for the Organisation

Finally, senior staff for several organisations recognised that it was good for a company to be seen by the local community to be contributing:

> *And then I guess there is a third corporate citizenship piece right, say for a corporation like ours that is a larger player in industry, there is something that goes with us being able to give back a little bit.* (Head of human resources in mining company B)

CONCLUSIONS

The quotations above demonstrate that the benefits to industry stakeholders of engaging with engineering education are numerous and strong. However, universities are not doing a good job approaching industry members in a manner that is coordinated both within and between universities and convenient to potential industry partners. Even the formal processes of having industry advisory committees (which is a requirement of the Engineers Australia accreditation process) may not be widely known. The most important opportunity for enhancing industry engagement is for universities to ensure they have a proactive and coordinated system for contacting and maintaining relationships with industry partners. This is the principal focus of the Guidelines and Recommendations of the over-arching project of which this study was a part.

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APPLICATION OF CDIO IN NON-ENGINEERING PROGRAMMES – MOTIVES, IMPLEMENTATION AND EXPERIENCES

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ABSTRACT

The aims of the paper are to present a set of general recommendations for how to implement CDIO in non-engineering programmes, to show how they can be applied in practice, and to discuss associated benefits and challenges. The application of the recommendations is demonstrated in case studies of non-engineering programmes that have implemented CDIO. The subject areas of the programmes include art, science, food processing, business, and library science. The case descriptions are purposively relatively detailed aiming to enable a transfer of approaches and experiences from the cases to other non-engineering programmes. Common benefits of applying CDIO to non-engineering programmes include a stronger connection to the professional context, and strengthened programme development and quality assurance. Common CDIO implementation challenges for non-engineering programmes are found to be similar as for engineering programmes, for example, the training of faculty to teach skills beyond their subject specialty, such as design and communication.

KEYWORDS

Curriculum design, Non-engineering programmes, CDIO adaptation, CDIO standards 1 - 12

INTRODUCTION

CDIO originated in mechanical and aerospace engineering and is still dominated by engineering programmes. CDIO application in engineering has shown to be successful including positive effects on graduates' design, personal, and interpersonal skills, and outside perceptions of educational quality (Malmqvist et al., 2015). However, one may ask if CDIO is limited to application in engineering programmes, or may it be more widely applied? And, if so, how can this be achieved?

Crawley et al. (2014) argue that this is the case and claim that CDIO may also be applied to non-engineering programmes by:

- Developing a description of the profession's context of practice as a starting point for educational design (corresponding to CDIO standard 1)
- Working with stakeholders to identify their requirements on the graduates (CDIO standard 2)
- Adapting the pedagogical and curricular elements of CDIO (CDIO standards 3-11 mainly) to the discipline's needs
- Applying the CDIO curriculum development and quality assurance processes (CDIO standard 12)

Doan et al. (2014c) proposed the Generalized CDIO Standards as a version of the corresponding CDIO Standards by translating engineering domains into broad disciplines to make them more applicable to any programme. As seen in Table 1, in the seven essential CDIO Standards 1-3, 5, 7, 9 and 11, and in two supporting Standards 4 and 6, the term "*product and system lifecycle development and deployment*" has been generalized into "*profession's context of practice*", "*CDIO skills*" into "*professional competence*", and "*engineering practice*" into "*professional practice*", while Standards 8, 10, and 12 remained unchanged. Doan et al. also suggests that the tools designated in Table 1 can be helpful in adapting the generalized CDIO standards to specific programmes. Further, Malmqvist (2015) offers some examples of how to translate CDIO standards to non-engineering contexts, see Table 2.

However, whilst these principles and examples may offer some guidance for implementation of CDIO in non-engineering programmes, there is a lack of deeper descriptions as well as surveys of such implementations. Further, they only cover some of the CDIO standards. This paper aims to address this gap in the CDIO literature.

Specifically, the aims of this paper are to clarify:

- With which motives has CDIO been applied to non-engineering programmes?
- How this was achieved, including what modifications were made to contextualize the CDIO framework and tools to the situation?
- What were the effects of the CDIO implementation in these non-engineering programmes, including benefits, drawbacks and limitations?

The remainder of the paper is structured as follows: After this introduction, we first account for and motivate the research approach of the paper. This is followed by the case study section, were we describe six non-engineering programme that have implemented CDIO. In the discussion section, we compare the motives, implementations and experiences of non-engineering CDIO programmes. Finally, the paper is concluded.

Table 1. Generalized CDIO Standards and Tools for Implementation

CDIO Standards (Crawley et al., 2014)	Generalized CDIO Standards (Doan et al., 2014c)	Tools for Implementation (Doan & Nguyen, 2014a, & 2014b)
1. The context	1. The context: Adoption of the principle that profession's context of practice is the context for education	Outcomes-Based CF's templates for - Programme educational objectives - Programme learning outcomes
2. Learning outcomes	2. Learning outcomes: PLOs constructed in form of four sections of the PLOs Syllabus at 4-level of detail for disciplinary knowledge; personal and professional skills and attributes; interpersonal skills; and professional competence, consistent with programme goals and validated by programme stakeholders	
3. Integrated curriculum	3. Integrated curriculum: A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal and professional skills and attributes, interpersonal skills, and professional competence	Outcomes-Based CF's templates for - Programme ideas - Programme plan - Skill development routes - Curriculum design matrix
4. Introduction to engineering	4. Introductory course: An introductory course that provides the framework for professional practice, and introduces essential personal and interpersonal skills	Outcomes-Based CF's templates for - Course syllabus and plan - Skill progression matrices
5. Design-implement experiences	5. Professional practice experiences: A curriculum that includes two or more experiences of professional practice	
7. Integrated learning experiences	7. Integrated learning experiences: Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and professional competence	
11. Learning assessment	11. Learning assessment: Assessment of student learning in personal and interpersonal skills, and professional competence, as well as in disciplinary knowledge	
6. Engineering workspaces	6. Workspaces for professional practice: Workspaces and laboratories that support and encourage experiencing professional practice, disciplinary knowledge, and social learning	
8. Active learning	8. Active learning (unchanged)	
9. Enhancement of faculty competence	9. Enhancement of faculty competence: Actions that enhance faculty competence in personal and interpersonal skills, and professional competence	
10. Enhancement of faculty teaching competence	10. Enhancement of faculty teaching competence (unchanged)	
12. Programme evaluation	12. Programme evaluation (unchanged)	

METHOD

A case study approach was chosen as the research method, with two main considerations in mind: First, we wanted to study and account for the programmes in some detail in the paper, enabling others to transfer insights and approaches to their own approaches. Second, there are still a related limited number of non-engineering CDIO programmes, making it difficult to apply quantitative methods such as questionnaires.

Table 2. Examples of translation of CDIO standards to non-engineering professional contexts

CDIO Standard		Domain	Translation
1	CDIO as Context	*Medicine & health technologies*	• Diagnosis, treatment planning, operation, post-operative care of patients • Design, operate & improve medical facilities and equipment
		Education	• Designing, carrying out and assessing the effects of learning experiences on students
		Business management	• Design, operate and improve organisations (companies)
4	First-year experiences	*Library science*	• Introduction course to the library and information service field, professions, work environments, services, national and international networks
5	Design-Implement experiences	*Music*	• Create commercial music (Singapore Polytechnic)
6	CDIO workspaces	*Advertising*	• Student-driven advertising agency (Singapore Polytechnic)
7	Integrated Learning Experiences	*Medicine & health technologies*	• Explain surgical procedure to patient • Interview patient about prior history

The paper is based on case studies of the following six programmes:

- ***Food Science and Technology*** and ***Music and Audio Technology*** at Singapore Polytechnic, Singapore
- ***Business*** and ***Library and information Services*** at Turku University of Applied Science, Finland
- ***Chemistry*** and ***International Business*** at Vietnam National University-Ho Chi Minh City, Vietnam

The selection of case studies was made in order to cover a broad span of non-engineering programmes, including science, business, performing arts and other areas. For each of the programmes, we review its main goals profile and contents, its CDIO implementation and the positive and negative effects associated with its CDIO implementation.

CASE STUDIES

In this section, we describe the CDIO implementations of six non-engineering programmes. We start by reviewing the educational context and overall strategies of their host universities, and then move on to the specific programmes. The presentation discusses motives, the actions carried out in the CDIO implementation processes and the resulting effects, including benefits, drawbacks, and challenges.

Singapore Polytechnic, Singapore (SP)

Singapore Polytechnic has been a CDIO collaborator since 2004. Since then, the institution has adapted the CDIO framework for the institution-wide initiatives and, through these initiatives, applied the CDIO framework to non-engineering programmes like the Diploma in Music and Audio Technology.

Music and Audio Technology programme at Singapore Polytechnic, Singapore

The Diploma in Music and Audio Technology (DMAT) aims to provide foundational skills so that graduates can create music and audio content for the media industry. After implementing the programme for a few years, the programme team realized that they needed to systematically develop 'generic' skills in their students. They adopted the CDIO approach to infuse teamwork, oral communication, written communication and thinking skills into selected courses in the programme.

The CDIO syllabus v1.0 (Standard 2) was used as a basic template for the design of the programme. Technical learning outcomes relating to music and audio competence were first selected and articulated. Learning outcomes for teamwork, oral communication, written communication and thinking skills were then added to the programme's syllabus. The learning outcomes were then mapped to specific courses within DMAT. A distinction was made between where the skills needed to be explicitly taught and assessed, and where they were used. Care was taken to find courses where the generic skills could naturally be infused into the learning activities.

Initially, integrating the teaching of soft skills (Standard 7) into the various courses posed problems with some staff. There was a feeling among some lecturers that they were not qualified to teach certain topics, such as written communication. Coming up with appropriate learning activities to infuse these skills involved research, training and ingenuity on the part of the lecturers (Figure A1). Holding regular meetings/sharing sessions, where lecturers would show the learning activities in their course, helped this process. The benefit of explicitly infusing the teaching and assessment of generic skills into the programme is visible in the quality of the presentations and written work in the students' final portfolios.

In 2010, SP embarked on a strategic goal of "Providing Holistic Education" to its students. The CDIO skills (Standard 2) were adapted and the resulting set of six SP Graduate Attributes, consisting of Competence; Communication and Teamwork; Creativity, innovation and Enterprise; Ethics and Responsibility; Global Mindset; and Personal and Social Effectiveness were adopted institution wide and infused into all programmes. Detailed learning outcomes were developed for each of the graduate attributes (see Figure A2 for an example).

With the implementation of the Holistic Education initiative, the explicit teaching of the oral and written communication skills in DMAT were transferred to the new institutional courses, which were taught by experts in these areas. Effort was made to "twin" these courses with the appropriate DMAT courses. The lecturers teaching DMAT and the communication courses collaborated to create a common assignment, with one set of assessment criteria focused on communication, and another focused on music/audio related content (see Figure A1 for example). This has been quite successful.

Food Science and Technology

The Diploma in Food Science and Technology (DFST) is a three-year full-time programme. The aim of the programme is to develop food scientists and technologists who will be able to design innovative, safe, sustainable and quality food products and processes that excite the taste and imagination of today's adventurous consumers.

In 2013, the programme underwent a review, which resulted in a redesign of its curriculum and an update of its graduate attributes and learning experiences. The starting point of the curriculum review was the personas of its current and future students and the attributes of successful innovators in the industry. In addition to Communication, Teamwork and Time management skills, two key attributes of successful food innovators, Creativity, Innovation and Enterprise and Ethics and Responsibility (Figure A2), were identified and mapped into the curriculum and activities were designed to develop them (Figure 1).

In Year I, besides the foundational science courses like analytical, physical, organic and inorganic chemistry, the programme has an Introduction to Food Science course (Standard 4). In this course, the students discover the role of food science and technology in providing safe, sustainable and quality food products, from farm to consumers locally and globally. They examine various food materials and their technologies, such as beverage technology, cereal technology, egg and diary technology, meat and seafood technology, and fruit and vegetable technology. In Year 2, the students integrate their food science knowledge through projects and assignments that require them to transform raw materials and ingredients into consumer-focused end-products. They ideate food concepts (Conceive) and perform sensory evaluation (Design) (Standard 5, basic design-implement experience).

In the third year, the students develop processes and select food packaging that reduce food wastage and achieve sustainability of future food products. The students conceive new products using Design Thinking (Conceive); experiment with different raw materials, ingredients and appropriate processing methods to formulate and develop the product (Design); select the appropriate packaging and scaling up process of the product for shelf-life study (Implement); and finally pass the successful formulation to food companies for production (Operate). (Standard 5, advance design-implement experience). See example in Figure A3.

Effects of CDIO implementation at Singapore Polytechnic (SP)

The CDIO framework provided SP with a structured approach to enhance the design of our programs to better prepare students for professional work. In 2010, the CDIO syllabus were adapted into a set of six SP Graduate Attributes and applied to all programmes which included Business, Chemical and Life Sciences, Info-Communication and Media, and Design. The non-engineering programs were able to adapt and customise the Graduate Attributes for their own fields. Specific learning outcomes (standard 2) were written and activities identified. With the identification of the Graduate Attributes, the development of students' skills expanded from the initial skills of Thinking, Communication and Teamwork to include Creative, Innovation and Enterprise. The Design Thinking method was adopted to foster a user-centred approach to conceiving (C) and designing (D) new products and services. Using this method, all second-year students work in multidisciplinary teams to understand the communities' needs, draw insights from their interviews and observations, and co-create and prototype solutions. In summary, CDIO is applicable to both engineering and non-engineering programs and has become the foundational framework for other educational initiatives and developments in SP.

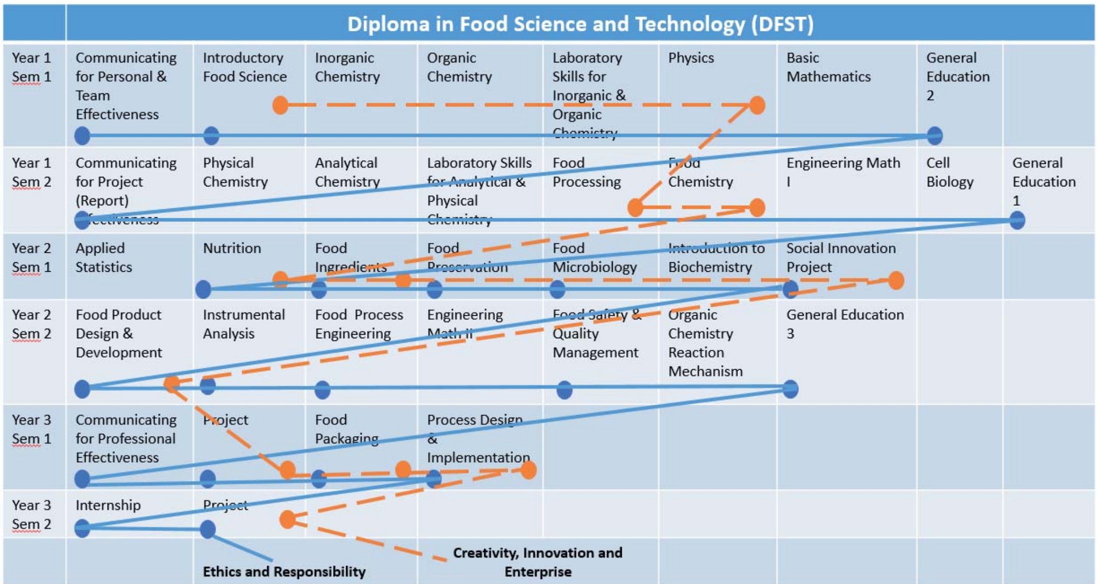

Figure 1: Map of Creativity, Innovation and Enterprise and Ethics and Responsibility in DFST

Turku University of Applied Science, Finland (TUAS)

Turku University of Applied Sciences (TUAS) is one of the biggest universities of applied sciences in Finland. TUAS' Faculty of Business, ICT and Chemical Engineering has bachelor and master programmes in engineering and in business administration. Since 2007, this faculty has used the CDIO approach for continuous education development.

TUAS had two main motives for applying CDIO: relevance to working life and quality of education. The starting point for a university of applied sciences is to have working life relevant education and to do applied research and development together with the industry and businesses. With its' CDIO initiative, TUAS aimed at strengthening this relevance and to better answer the challenges and problems recognized in our education. The challenges and improvement areas listed at the beginning were following:

- Improved introduction to -courses in every degree programme
- Increased use of active learning methods
- Improved assessment policies and methods
- Increased design-build experiences at earlier phase of studies
- Increased usage of our laboratories
- Decreased number of drop-outs
- More motivated students
- More motivated teachers.

Quality of education was another driver for the TUAS' CDIO membership. They saw that CDIO could provide them with coherent framework that approach education from different perspectives and provide tools to continuously evaluate and improve. They understood that CDIO is not a quality assurance tool itself, but it can surely influence education through the CDIO standards and syllabus.

In the beginning, the challenges and problems were quite similar in all TUAS' programmes. There were no proper introductory courses, use of active learning was scarce, laboratories and workspaces were underused to name few of the identified topics. Thus, TUAS decided at an early stage that the CDIO approach would be applied in all of the faculty's bachelor programmes - not only in engineering.

The CDIO implementation at TUAS has been strongly connected to faculty member's competence development. The key development areas have been planned for the whole faculty. The faculty development pathway has been described in a university report (Stenroos-Vuorio, 2012). The whole CDIO development started with a dedicated project that focused on introducing the faculty members to CDIO approach and to reflect TUAS' way of teaching and learning with CDIO (Kontio, 2007). At the end, main development areas were identified using the CDIO self-evaluation model (Standard 12). Based on the self-evaluation findings, TUAS wanted to enhance the use of active teaching and learning methods (Standard 8) and as a consequence provided a tailored training to its' faculty (Kontio, 2009a). At the same time, TUAS introduced industry periods for faculty members to strengthen faculty competences (Standard 9) in working life knowledge and product, process, and system building skills (Kontio, 2009b). Other faculty level initiatives have been competence based curriculum development (Standard 3) and assessment training (Standard 10). All the time development has been guided by the CDIO self-evaluation, which has been done six times on the programme level since 2007. The latest faculty level education development activities are common curriculum principles to all bachelor programs (Kontio, 2014 and Figure 2, right):

- The curriculum is based on relative large courses (15 credits or 25 % of a study year)
- The study year is divided in five periods (9 weeks, 7 weeks, 9 weeks, 7 weeks and 7 weeks)
- All programmes have introduction to – courses in the first semester
- There is a multi-disciplinary innovation project (15 credits) in the third year of studies,
- There are elective modules in the beginning of second and third year (15 credits each).

These principles confirm the role of introduction to –courses (Standard 4) and design-implement experiences in the curriculum (Standard 5). The innovation project (15 ECTS) is implemented in multidisciplinary teams of 6-8 mainly 3rd year students. During the course students develop a prototype solution to a problem or need of a real client. The innovation project is described in more detail in Kulmala et al. (2014) and additional information is provided on the course website (http://capstone.dc.turkuamk.fi/). With elective modules, TUAS is aiming for T model experts (Figure 2, left) that are required in the future working life.

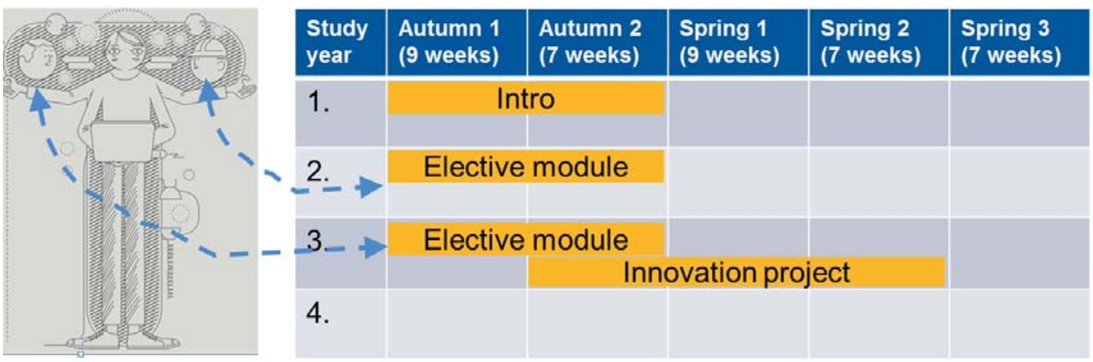

Figure 2. General structure of the curriculum at TUAS

Business and Library and Information Services programmes

The TUAS degree programme in *Business* aims to train the student to a business specialist with focus on one of the following: business development, entrepreneurship, or accounting. The programme emphasizes working with innovative attitude within and across business and modern ICT. The degree programme in *Library and Information Services* educates professionals who understand information behaviours and are prepared to guide information literacy skills. Students will graduate in profession where it is essential to be able to navigate in the world of information, collections and records despite the existing format. They will achieve the skills and knowledge in information organization and retrieval.

The degree programmes in Business and in Library and information services have followed the faculty level development and they have participated all the actions mentioned above. Both programmes have an introductory course at the beginning of their studies. In Business programme it is called nowadays Business start. This Business start module (15 credits) provides basics of business in a form of Practise enterprise. A practise enterprise is a simulated start-up company formed by the students. There is a real enterprise working in the background of the simulated practise enterprise to support business planning and to provide real-life information for start-up. Practise enterprises do business with each other in a global network of practise enterprises. Both programmes have elements that strongly take advantage of active learning. In core of the learning are real assignments and projects from our partners. These programmes have put a lot of effort in creating workspaces that support and encourage hands-on learning in business and library and information services. This is actually a good example of interpreting the CDIO approach outside engineering. Although CDIO Standard 6 is called Engineering workspaces it is possible to use it as a vehicle to improve the learning environment in a non-engineering programmes. To summarize: the non-engineering programmes of TUAS following CDIO have interpreted CDIO approach to fit into their field.

Effects at TUAS

TUAS has found out that their approach to implementing CDIO to all our programmes whether they are engineering or not has resulted in deeper multidisciplinary collaboration between both faculty and students. The innovation project and the elective modules are good examples where engineering and non-engineering students study and work together during their studies. In addition, TUAS pedagogical development projects have also become multidisciplinary were teachers in different disciplines share experiences and work together for better learning and teaching. The understanding of each programme’s special challenges and problems has grown. Sometimes CDIO has been questioned as suitable solution/framework for non-engineering programmes, but it has been easy to raise the level of discussion above the engineering specific issues and focus on education development in more general context. At the beginning there was a lot of discussion on the costs of doing teaching and learning in CDIO way. First, the CDIO-like courses seemed to be more expensive than traditional ones, but once the teachers learned the new pedagogical methods and understood CDIO better also this discussion has calmed down. In summary, the non-engineering programmes at TUAS have successfully used and implemented CDIO by interpreting and adapting CDIO into their own field.

Vietnam National University-Ho Chi Minh City, Vietnam (VNU-HCM)

Vietnam's increased integration into the global economy, through its membership in WTO (2007) and in ASEAN Economic Community (2015), has placed greater demand on Vietnam's higher education institutions (HEIs) to train a skilled labor force for societal needs. This demand entails improving education programmes, and developing quality assurance and accreditation processes (MOET, 2005). At national and university levels, a number of policy measures and initiatives have been implemented, such as Institutional Evaluation Standards; the Advanced Curricula; Programme evaluation by ASEAN University Network-Quality Assurance Criteria (AUN-QA); and ABET Accreditation. While the advanced curricula and the evaluation or accreditation criteria have provided models and specific requirements that a programme in specific discipline has to satisfy, Vietnam's HEIs still need a more comprehensive educational methodology or framework to prepare for their programme evaluation, accreditation, and continuous improvement (Phan et al., 2010) (Nguyen et al., 2013).

VNU-HCM found that the CDIO approach, an idea and methodology for engineering education reform, with its CDIO Syllabus and a set of 12 CDIO Standards, provides answers to the "what" and "how" questions in a systematic and un-prescriptive way, making it viable for undergraduate programmes in Vietnam to adapt CDIO according to their unique needs and conditions (Phan et al., 2010). For its strengths, the CDIO approach has been adopted at VNU-HCM as the basis for a model framework for curriculum reform (Phan et al., 2010, & 2011).

CDIO adaptation to non-engineering programmes at VNU-HCM

With the goal for developing the model framework for education programme reform based on the CDIO approach, five programmes (at University of Technology, and University of Science) including non-engineering where in 2010 selected as the pilots to implement CDIO systematically, providing students with the knowledge, skills, and attitudes desired by programme stakeholders. As a consequence, adapted and generalized curricular frameworks for non-engineering programmes have been developed. These frameworks include:

- The discipline-customized CDIO Syllabi, so-called Programme Learning Outcomes (PLOs) Syllabi (Doan et al., 2012a, & 2012b);
- The detailed framework and templates for integrated curriculum development complied with principles of the CDIO Standards 1-3, 7 and 11, so-called the CDIO-Based Curricular Framework and Guidelines for OBE Implementation (Doan & Nguyen, 2014a) (Outcomes-Based CF); and
- The Generalized CDIO Standards (Doan et al., 2014c).

These PLOs Syllabi, Generalized CDIO Standards, and Outcomes-Based CF have been adopted as Guidelines for CDIO Adaptation, and Guidelines for Outcomes-Based Curriculum Development (Doan & Nguyen, 2014b). They are now being used widely and have been parts of the Faculty Development Programme at VNU-HCM (Doan et al., 2014b).

After 3 years of successful CDIO application to the first five programmes, CDIO has been expanded to 15 additional programmes. Among these programmes, Chemistry (at University of Science) and International Business (at University of Economics and Law) have adopted and adapted CDIO to prepare for their AUN-QA evaluation and continuous improvement (Nguyen et al., 2015b) (Nguyen et al., 2015a).

CDIO adaptation to the Chemistry programme, 2013-2015

The CDIO adaptation to the Chemistry programme and its results are summarized in Table 3. The PLOs Syllabus for applied science disciplines (Doan et al., 2012a) was introduced to the programme. The general professional competence “*conceiving, designing, implementing, and operating or verifying”* (CDIO/V), and the common objects of professional practice “*problem, experiment, program, process, and system*” were defined into “*conceiving, designing, implementing, and operating or evaluating chemical products and processes*” (CDIO/E) (Nguyen et al., 2015b). Though it was recommended that PLOs should be designed according to the four sections of the PLOs Syllabus, the PLOs have been constructed by merging of the personal skills and interpersonal skills. As many university’s programmes adapt CDIO, all programmes should unify the structure of their PLOs as directed by the generalized CDIO Standard 2 (see Table 1), in order to make their PLOs recognized by each other, and to facilitate course development.

Significant changes have been made to the curriculum design and implementation. These changes include integrated curriculum, introduction course, and integrated learning experiences. To achieve integrated learning experiences, the Outcomes-Based CF’s templates for course design and implementation complied with constructive alignment principles were implemented for all programme’s courses. The Introduction to Chemistry course shown in Figure A4 to Figure A6 gives an example of a CDIO-based course. As specified by CDIO Standard 7, the course goals should include goals for disciplinary knowledge as well as generic skills, and must be linked to the related PLOs topics at x.x.x-level (see Figure A4). Teaching and learning activities are designed to align with the learning outcomes (see Figure A5). The spiral curriculum approach is utilized to structure the teaching and learning activities in a way that they build on each other in an ever more complex and sophisticated way from the beginning to the end of the sequence of class sessions or periods during a term. An effective way to organize these activities is to determine whether the material to be learned is being introduced (I) to the learner, is being thoroughly taught (T) to the learner, or is intended to be used (U) by the learner. The course plan aligns the course learning outcomes, teaching and learning activities, and assessment (see Figure A6). Assessment activities are developed to align with the learning outcomes and teaching activities (see Figure A5).

Table 3. CDIO Adaptation to the Chemistry programme at VNU-HCM

CDIO Adaptation to the Chemistry programme and results	
Std1	Programme educational objectives statement reformulated into more specific one, that describes adopting of profession’s context of practice as the context for education, and approved by University’s Board of Education: *“Chemistry, an experimental discipline that includes organic, inorganic, analytical, and physical chemistry. The Chemistry program aims to provide students with comprehensive knowledge, skills, and attitudes required to conceive, design, implement and operate or evaluate (CDIO/E) such chemical products and processes…”* (Nguyen et al., 2015b)
Std2	Specific, detailed PLOs added, reviewed, and validated by faculty, students, alumni, and representatives of employers; and approved by University’s Board of Education. *“(1) Disciplinary knowledge and scientific reasoning, (2) professional skills and attributes, (3) personal skills and attributes, and interpersonal skills, and (4) competence in CDIO/E chemical product and process in the research, enterprise, societal, and environmental contexts”* (Nguyen et al., 2015b)
Std3	The programme plan renewed with restructuring of Math and English courses; adding of courses in core chemistry fundamental knowledge, and internship; and re-arranging of courses in advanced chemistry fundamental knowledge. The programme ideas, skill development routes, and curriculum design matrix added

Std4	Introduction to Chemistry added as a mandatory course. The course delivered since 2014, and reviewed each year. *"Introduction to chemical product lifecycle development and deployment; the tasks and responsibilities of chemists, and the use of disciplinary knowledge, methods and tools in executing those tasks; and the impact of chemistry on society. The course provides basic training on personal and interpersonal knowledge, skills, and attitudes, problem solving and design skills through the course project leading to a design of simple experiment in the general chemistry laboratory, and project report and presentation"* (Nguyen et al., 2015b)
Std5	Design-implement experiences redesigned and integrated into four mandatory courses and co-curricular activities to cultivate design and interpersonal skills. The courses delivered since 2014. *Introduction to Chemistry; Advanced design course; Internship; and Final project* (Nguyen et al., 2015b)
Std6	Laboratories for chemical practice re-arranged supporting experiencing design and applying skills.
Std7 Std8 Std11	All courses redesigned complying with constructive alignment, and providing integrated learning experiences, and active and experiential learning. The courses delivered since 2014. Learning assessment uses a variety of methods matched appropriately to learning outcomes.
Std9	Training courses on enhancement of faculty competence in communication and teamwork skills, and project management, for junior teachers, added and conducted in 2013.
Std10	Training courses on enhancement of faculty teaching competence (Std7, 8, and 11) for all faculty members, and support for faculty participation in faculty development programmes, added and conducted for 2013-2015. Majority of faculty competent in course design and instruction with constructive alignment. Teachers required to provide self-report on course teaching, learning, and assessment.
Std12	Instructor reflections, and follow-up studies with alumni and employers to be regular course evaluation activities, since 2015.

CDIO adaptation to the International Business programme, 2013-2015

The CDIO adaptation to the International Business programme and its results are summarized in Table. 4. The PLOs Syllabus for Business disciplines (Doan et al., 2012a) was introduced to the programme. The general professional competence "*conceiving, designing, implementing, and evaluating"* (CDIE), and the common objects of professional practice "*problem, plan, project, model, procedure*" were defined into "*conceiving, designing, evaluating, and improving business projects*" (CDEI) (Nguyen et al., 2015a). The PLOs have been designed according to the four sections of the PLOs Syllabus.

Table 4. CDIO Adaptation to the International Business Programme at VNU-HCM

CDIO Adaptation to the International Business programme and results	
Std1	Programme educational objectives statement reformulated into more specific one, that describes adopting of profession's context of practice as the context for education, and approved by University's Board of Education. "…*The International Business program aims to provide students with comprehensive knowledge, skills, and attitudes required to conceive, design, evaluate and improve (CDEI) business projects in international context*…" (Nguyen et al., 2015a)
Std2	PLOs constructed in form of four sections of the PLOs Syllabus at 4-level of detail added, reviewed and validated by faculty, students, alumni, and representatives of employers; and approved by University's Board of Education. *"(1) Disciplinary knowledge and reasoning, (2) personal and professional skills and attributes, (3) interpersonal skills, and (4) competence in CDEI business projects in the enterprise, societal, and environmental contexts"* (Nguyen et al., 2015a)
Std3	The programme plan renewed; the programme ideas, skill development routes, and curriculum design matrix added
Std4	Introduction to International Business added as a mandatory course. The course delivered since 2014, and reviewed each year.

	"Introduction of the professions, ethics, and the use of disciplinary knowledge; training of problem solving, project management and design, and teamwork and communication skills through a project leading to a business concept and plan, and report" (Nguyen et al., 2015a)
Std5	Design-evaluate experiences redesigned and integrated into five mandatory courses and co-curricular activities to cultivate design and interpersonal skills. The courses delivered since 2014. *Introduction to International Business; International Business 1&2; Internship; and Final project* (Nguyen et al., 2015a)
Std6	New CDEI workspaces and Centre for Economics Study built in order to support and encourage experiencing CDEI business projects
Std7 Std8 Std11	Same as for the Chemistry programme (see Table 3)
Std9	Training courses on enhancement of faculty competence in personal, communication, and teamwork skills, and project management, added and conducted.
Std10	Same as for the Chemistry programme (see Table 3)
Std12	Instructor reflections, and follow-up studies with alumni and employers to be regular course evaluation activities, since 2014.

Effects of the CDIO implementation in Chemistry and International Business programmes

Three years into implementing CDIO Standards, the curricula have been thoroughly reformed. Curriculum components added, and renewed, especially for the first time, include: specific and detailed generic skills and professional competences validated by programme stakeholders; integrated curricula; relevant introductory courses; and course syllabi complying with constructive alignment. The greatest achievement in implementing CDIO is that majority of faculty are competent in providing integrated learning experiences, active and experiential learning, and learning assessment that make themselves more innovative in their instruction in order to improve student learning outcomes. These changes supported International Business programme to be accredited by the AUN-QA evaluation in 2015 with positive reviews for curriculum design, teaching facilities, teaching and learning strategy, and student assessment (Nguyen, et al., 2015a); supported Chemistry programme underwent VNU-HCM's internal evaluation by AUN-QA criteria in 2015 (Nguyen et al., 2015b); and both for their continuous improvement.

DISCUSSION

Let us now compare the studied implementations of CDIO in non-engineering programmes, within this group, and with CDIO experiences from engineering programmes as reported by Malmqvist *et al*. (2015). Table 5 summarises motives, modifications to the CDIO framework, effects and challenges.

Amongst motives, we notice aims to better connect to working life practices, to improve educational quality, to improve design & innovation skills and to improve generic skills. We can notice that these are four out of the five most frequently mentioned motives for applying CDIO in engineering programmes (Malmqvist et al., 2015). It would seem reasonable to claim that these non-engineering programmes are applying CDIO for the same reasons as engineering programmes. There is some variation, though. In Vietnam, the educational system wanted to establish its international credentials and comparability, motivating a strong interest in the use of CDIO to prepare for an accreditation. In Singapore, design and collaboration skills were brought forward.

All of the programmes have made modifications to the CDIO framework to fit the context. However, it is shown in the paper that these modifications are minor. Also engineering programmes assessed that it was easy to customize the CDIO framework to fit their (engineering) context (Malmqvist et al., 2015). It would seem that the CDIO framework can be customized to different contexts, while not being over-generalized, i.e. so abstract that it no longer provides concrete support and guidance for programme development.

The (self-reported) positive effects of CDIO implementation closely mirrors the motives for applying CDIO, i.e. it seems that this group of programmes have been successful in their implementation projects: the students have improved their skills in the desired direction, accreditation has been achieved and so on.

As in many educational development projects, it is noted that faculty resistance to change is a main challenge. In these cases, the inclusion of generic skills (teamwork, communication, ethics etc.) in regular courses seems to be a common concern amongst faculty who are used to teaching only their subject matter. However, integrated learning is a key characteristic of CDIO. The solutions to manage this challenge applied by the studied programmes include both faculty training in the teaching of generic skills in the context of their subject matter course and inclusion of generic skills specialists in teacher teams for courses. The Singapore programmes show that you may start with the faculty training approach, but then evolve to a format where regular faculty and communication (etc.) specialists co-teach in courses. In any case, it is clear that faculty training is an important element of any CDIO implementation project.

Common for the studied programmes is also that CDIO implementation has been done across the whole university and university system (VNM-HCM case) including both engineering and non-engineering programmes. This should mean that the university has the competence in pedagogical development required to carry out a CDIO implementation. This has probably been a helpful factor in these cases, and it might be that non-engineering programmes who lack this support may find it harder to translate CDIO to their context and thus to implement CDIO.

Table 5. CDIO experiences in non-engineering programmes

Aspect		Programme / University				
	Music & audio technology	*Food science & technology*	*Business*	*Library & information services*	*Chemistry*	*International business*
Targeted professional role(s)	Professionals who can create music and audio content for the media industry	Food scientists and technologists	- Entre-preneur - Accountant - Business professional	- Librarian - Information service assistant/ expert	- Research chemist - Analytical chemist	- Import/ export agent - Foreign sales rep - Intern management consultant
Motive	- Need to systematically develop generic skills. - Need to develop creative skills and ethical attitudes	- Need to develop creative skills and ethical attitudes	- Strengthen relevance to working life - Improve quality of education		- Strengthen relevance to working life - Prepare for evaluation by AUN-QA/ accreditation by ABET criteria	

Modifications to CDIO framework	CDIO syllabus 3.1 (Teamwork), 3.2 (Communications), 2.4 (Attitudes, Thoughts and Learning) and 4.2 (Enterprise and Business context) were adapted and customised at the x.x.x level.	CDIO syllabus 2.4 (Attitudes, Thoughts & Learning), 2.5 (Ethics, Equity & other Resp) and 4.1 (External, societal and Environmental context) were adapted and customised at the x.x.x level.	Engineering specific parts have been adapted and transformed to business context	Engineering specific parts have been adapted and transformed to programme context	Engineering domains have been transformed into generalized ones to make them more applicable to any programme: - CDIO Syllabus has been transformed into discipline-customized CDIO Syllabi - CDIO Standards have been transformed into Generalized CDIO Standards
Benefits	- The teaching and utilisation of the skills were made explicit. - Improvements were observed in the quality of students' presentations and written work.	- Integrated critical & creative thinking and ethics & responsibilities - Students have a framework to guide the concept-ualisation, design and development of innovative food products.	- Improved relevance to working life - Programme development has been better managed - Multi-disciplinary collaboration amongst staff and students		- Programme has been reformed systematically - Improved faculty pedagogical competence - Programme has successful in its evaluation, and in continuous improvement
Limitations/ drawbacks	Relies on staff to effectively learn to teach soft skills	Due to the nature of the different projects students do, not all of them go through the full CDIO process	Syllabus – not for business context	Syllabus – not for library and information science context	Unidentified
Challenges	Some staff needed a lot of convincing of the value of infusing generic skills into their teaching. Finding appropriate activities in the courses to infuse generic skills	Buying in from staff to incorporate these skills into the modules.	Some resistance at the beginning – how can an engineering education framework help us? How to adapt engineering focused standards to business context?		Train faculty to be more accountable and innovative in their instruction in order to improve student-learning outcomes in large classes with limited number of teaching assistants.

CONCLUSIONS

In this paper, we have shown that the CDIO approach can be applied to non-engineering disciplines given that a general description of CDIO is applied, a professional context of the education can be identified, and that the CDIO standards are translated to the context in question. Rich descriptions of six non-engineering programmes that have implemented CDIO support and exemplify this claim. We further demonstrate that the CDIO development tools are helpful also when designing non-engineering (and non-professional) programmes.

The motives for implementing CDIO amongst the studied non-engineering programmes include aims to improving teaching of design skills and of generic skills, to strengthen the connections to the working life, and to enhance educational quality, both in terms of continuous improvement, and in terms of meeting international accreditation requirements. A further motive to select CDIO as an approach for educational development amongst these programmes is that they are offered by universities that have CDIO as a strategy for all their programmes.

The obtained benefits are very well aligned with the motives and it can thus be argued that the programmes' CDIO implementations have been successful.

Overcoming faculty resistance to teaching skills outside of their subject specialty was the major challenge that the programmes experienced when implementing CDIO. Faculty training and co-teaching with generic skills specialists was applied to address these challenges.

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Assignment: Cycle Based Composition
Overview: This exercise is designed to focus your awareness on using the basic music materials (timbre, texture, rhythm, melody and harmony) to create a large(ish) scale musical form.
Objectives:
Through this assignment, you should be able to:

- Understand the role of repetition to create cohesion.
- Create a piece, making use of the software synthesizers available in Logic.
- Use the approach of “design a **performance system**, then realize a piece”.

Guidelines

- Your performance system should consist of many small repeating patterns.
- The piece should have 4 contrasting sections and should last between 5 and 10 minutes.
- There should be other musical elements, such as bass parts, melodies etc. that are not MIDI loops.
- The overall form should be shaped via by the automation system. Some cycles should be created with the Ultrabeat step time sequencer and Cycle MIDI recording.

Report:
You are to submit a write-up with a minimum of 200 words to describe the process that you used to create the piece. This write up should be structured around the metacognition model discussed in class. This means there should be sections detailing:

- Generating Possibilities: how you created the cyclic midi regions.
- Analysis: what attributes of the midi loop you used decide how it is to be used?
- Comparison and contrast: how are the regions similar/different?
- Inference and interpretation: do any of the regions suggest/imply particular usage?
- Evaluation: how was the final choice of presentation of the material made?

Figure A1: A DMAT assignment that incorporates written communication and thinking skills

1 Creativity, Innovation and Enterprise (CDIO syllabus 2.4, 4.2)

1.1 Apply critical and creative thinking skills in problem solving (CDIO syllabus 2.4.3, 2.4.4, 2.4.5)

1.1.1 Use a range of critical thinking skills (e.g., analysis, comparison and contrast, inference and interpretation, and evaluation)
1.1.2 Use the creative thinking process (e.g., generating possibilities, incubation, illumination)
1.1.3 Identify barriers to effective thinking (e.g., traits, dispositions, working memory, perception, lack of information)
1.1.4 Identify contradictory perspectives and underlying assumptions
1.1.5 Use metacognition in monitoring the quality of personal thinking

1.2 Able to develop products, processes and services, in a business or entrepreneurial context (CDIO syllabus 4.2.3)

1.2.1 Recognize entrepreneurial opportunities to develop products, processes and/or services
1.2.2 Use a range of critical and creative thinking approaches (e.g., Design Thinking, Systems Thinking) and tools (e.g., Brainstorming, Mindmapping)
1.2.3 Reframe and take a range of different perspectives
1.2.4 Identify the business focus in the design of products, processes, or services

Figure A2: Example of SP Graduate Attributes and its Accompanying Learning Outcomes

Food Packaging Course
Design Project

You are employed as a Food Technologist at Happy Family Food Pte Ltd (same company as Process Design & Implementation course). As part of your training, you are required to develop the packaging of the assigned food product to enhance their freshness and shelf life.
Food product assigned: ______________________

PART 1 RESEARCH ON PACKAGING (CONCEIVE)

1. Conduct a literature review on the issues/ problems encountered and technologies available to package your product.
2. Go shopping in supermarket and/ or wet market to research on how the product is commonly packaged.

PART 2 EXPERIMENTAL DESIGN (DESIGN)

1. Research on how to improve the shelf life of your product by means of packaging technology.
2. Design the experiments to evaluate the effectiveness of the packaging technique(s) or material(s) on the shelf life of the product. Decide on the shelf life of your product.
3. Decide on the storage conditions i.e. temperature and relative humidity.
4. Present your proposal (including packaging materials, techniques, sampling plan).
5. Fine-tune your proposal and upload to Blackboard by 26 Jun 2015.

PART 3 SAMPLE PREPARATION AND SHELF LIFE EVALUATION (IMPLEMENT)

1. Prepare samples of the product (including control).
2. Carry out the experiment based on your final proposal. You are not allowed to deviate from your experimental design.
3. Collate your data and analyse your results.

PART 4 PACKAGING DESIGN

1. Based on your results, select the technique(s) or material(s) to be used to package the product.
2. Prepare a prototype of the packaging (including the label).
3. Present a 15 minute presentation*.
   * Combined presentation for Food Packaging module and Process Design & Implementation courses.

Figure A3. Food packaging design project description

Introduction to Chemistry

Course Description: Introduction to chemical product lifecycle development and deployment; the tasks and responsibilities of chemists, and the use of disciplinary knowledge, methods and tools in executing those tasks; and the impact of chemistry on society. The course provides basic training on personal and interpersonal knowledge, skills, and attitudes, problem solving and design skills through the course project leading to a design of simple experiment in the general chemistry laboratory, and project report and presentation.

Course Goals (Gx.)

Gx.	Related LOs topics	Required level of competence	Description
G1.	4.1.1, 4.1.2, 2.2.2	2	*Accept* the chemical product lifecycle development and deployment, the tasks and responsibilities of chemists, and the impact of chemistry on society
G2.	2.2.2, 2.4.1 - 2.4.7	2	*Accept* the essential one's attitudes, thoughts and learning for effective learning
G3.	4.3.4	2	*Understand* principles of project management, and *apply* to the course project
G4.	4.3.1, 4.3.2 4.4.1 - 4.4.3 1.1.x - 1.3.x	2	*Understand* the chemical product design process and approaches, and utilization of knowledge in design, and *apply* to an experiment design in the course project
G5.	3.1.1 - 3.1.4	2	*Understand* principles of teamwork, and *apply* to the course project
G6.	2.1.1, 2.1.2, 2.1.5, 4.4.3	2	*Understand* concepts of problem solving, and *apply* to an experiment design in the course project
G7.	3.2.1 - 3.2.4, 3.2.6	2	*Apply* written and electronic communication, and oral presentation
G8.	2.5.1 - 2.5.4	2	*Accept* the ethics, equity and other responsibilities of chemists

Figure A4. Introduction to Chemistry's Course Description and Goals

Introduction to Chemistry

Course Learning Outcomes (CLOs), Teaching, and Assessment

A (individual or group assignment), **E** (exam), **P** (project work individual or in team)

CLOs	Description	Teach. levels	Assessment
G1.1	*Describe* the chemical product lifecycle development and deployment, the professions, the tasks and responsibilities of chemists, and the impact of chemistry on society	T	A1. group assignment A2. group presentation
G1.2	*Select* and *describe* one's own intended future careers	U	A3. individual essay
G2.1	*Describe* the essential personal skills and attitudes for effective learning	T	A4. group assignment A5. group presentation
G2.2	*Define* one's own learning methods for the Introduction to Chemistry course; and *describe* one's own learning goals and plans for the 1st semester	T, U	A6. individual assignment
G3.1	*Describe* tasks of project management, and the functions of OPPM^{TM} (One Page Project Manager)	T	E1. midterm exam
G3.2	*Explain* the course project plan created by using OPPM	U	P1. course project plan
G4.1	*Describe* the chemical product design process, and design process phasing and approaches	T	E2. midterm exam
G4.2	*Define* the experiment design process and approaches used in the course project	T, U	P2. design process and approaches
G4.3	*List* the courses teaching underlying mathematics and sciences, and chemistry fundamentals in the Chemistry programme	I	P3. utilization of knowledge in design
G4.4	*Explain* utilization of knowledge in experiment design of the course project	T, U	
G5.1	*Describe* team roles and responsibilities for the course project	T, U	P4. team formulation
G5.2	*Explain* the course project schedule created by using OPPM	T, U	P5. team operation
G6.1	*Describe* problem solving methods	T	A7. group assignment
G6.2	*Select and explain* using problem solving methods for the experiment design	T, U	P6. problem solving
G7.1	*Demonstrate* preparing the course project poster with coherence and flow	T, U	P7. written communication
G7.2	*Demonstrate* preparing the course project electronic presentation with supporting media, and answering questions effectively	T, U	P8. electronic communication & oral presentation
G8.1	*Describe* the basic professional ethical standards and principles of chemists	T	A8. group assignment
G8.2	*Define* one's professional skills and attitudes to be developed	U	A9. individual essay

Figure A5. Introduction to Chemistry's Course Learning Outcomes, Teaching, and Assessment

Introduction to Chemistry

Lesson Plan

T (Teacher), S (Student in class), H (Homework)

Session	Contents	CLOs	T&L activities	Ass.
1.	1. Introduction to chemistry	G1.1 G1.2	T: introduces the course, gives lecture, and guides students through information research; S: discuss topics and do group assignment; H: prepare group presentation	A1
2.			S: deliver group presentation; T: gives lecture; H: do individual assignment	A2 A3
3.	2. Personal skills and attitudes for effective learning	G2.1 G2.2	T: gives lecture; S: discuss topics and do group assignment H: prepare group presentation	A4
4.			S: deliver group presentation; T: gives lecture; H: do individual assignment	A5 A6
5	3. Project management	G3.1 G3.2	T: gives lecture and assignment to project teams, and guides students through project planning using OPPM; S, H: work in team to create the course project plan using OPPM	
6	4. Design in chemistry	G4.1 G4.2	T: gives lecture, and guides students through experiment design process and approaches; S, H: work in team to define experiment design process and approaches used in the course project	
7	5. Chemistry fundamentals	G4.3 G4.4	T: introduces underlying mathematics and sciences, and chemistry fundamentals, and utilization of knowledge in design; S: discuss topics; H: work in team to do the course project	
8	**Midterm exam**		Written exam Midterm project defence	E1-E2 P1-P3
9	6. Teamwork	G5.1 G5.2	T: gives lecture, and guides students through team formation and operation S, H: work in team to formulate team working rules and contract, and schedule project using OPPM	
10	7. Problem solving	G6.1 G6.2	T: gives lecture, and guides students through selection of problem solving methods for the experiment design; S: discuss topics and do group assignment; H: work in team to design an experiment in the general chemistry laboratory	A7
11	8. Communication	G7.1 G7.2	T: gives lecture, and guides students through making the course project poster and Powerpoint presentation; S, H: work in team to accomplish the poster and ppt presentation.	
12	9. Ethics, equity and other responsibilities	G8.1 G8.2	T: gives lecture; S: discuss topics and do group assignment; H: do individual assignment	A8, A9
13	**Final exam**		Final project defence	P4-P8

Figure A6. Introduction to Chemistry’s Lesson Plan

SELF-DEVELOPED MODEL FOR EXTERNAL PROGRAMME REVIEW AT CHALMERS UNIVERSITY OF TECHNOLOGY – STAKEHOLDER NEEDS AND PERCEPTIONS

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ABSTRACT

Swedish models for evaluation of Quality in Higher Education (QHE models) have historically been designed by national agencies for higher education (HSV, UK-ämbetet). However, the proposal for the coming national QHE model assigns more responsibility to individual universities to develop their own QHE models. Chalmers University of Technology is developing such a local QHE model. In this paper, we focus on one of its components, namely a framework and process for programme evaluation by external reviewers, the Chalmers Programme Review Framework (Chalmers PRF). The Chalmers PRF aims to provide an external and international perspective from independent academic and industrial experts on the targeted programmes and their operational environment in the context of global best practice. The paper further accounts for the experiences from pilot testing of the evaluation framework on two MScEng (Sw. Civilingenjör) programmes – Electrical Engineering as well as Automation and Mechatronics Engineering. In particular, the relevance and utility as perceived by programme stakeholders – industry, university management, teacher and students are discussed. Even though this external programme evaluation model was developed for an institution in the Swedish context, it may be easily adapted to institutions beyond Sweden for states with engineering accreditation systems, and those without.

KEYWORDS

Education Quality Assurance, Programme Review, Standard 12

INTRODUCTION

Across the world, governments and professional bodies have developed frameworks and standards that address the level and contents of engineering programmes at universities. If a programme meets these standards, it will graduate professionally competent and responsible engineers. Examples include EUR-ACE (2015), Engineers Australia (2008) and ABET (2015).

In Sweden, the models for evaluation of Quality in Higher Education (QHE models) have historically been designed by the government's national agencies for higher education (HSV, UK-ämbetet).

The international frameworks are relatively stable over time. By contrast, the Swedish national models for evaluation of higher education have had different aims and designs for each review cycle. In the 2006 review of engineering programmes (Högskoleverket, 2006), the focus was on processes, pre-conditions (e.g., grade point average of entering students) and throughput. In the framework applied in the 2013 review (Högskoleverket, 2010), the focus was on achieved learning outcomes, as demonstrated in final degree reports.

From 2016, a new Swedish national system for quality assurance of higher education (Regeringskansliet, 2015) will be introduced that gives universities the responsibility to self-develop processes for programme quality assurance. The Swedish Higher Education Authority (UK-ämbetet) will then review these processes rather than the actual programmes. As a baseline, local QHE models should consider the output of the education in the relation to the national goals. However, the new proposal also opens opportunities for universities to develop local QHE models that, in addition to addressing outcomes in relation to national goals, also evaluate the university's standing towards its internally defined goals, for example to validate that the education at the university holds up to high international quality indicators. Chalmers University of Technology is developing such a local QHE model.

Malmqvist et al. (2015) reviewed a number of self-developed QHE models, including those from Massachusetts Institute of Technology (2015), the Technical University of Denmark (DTU, 2014), University of Strathclyde (2015) and Reykjavik University (2011) and found that the self-developed frameworks put the emphasis on improvement and development beyond the thresholds set by accreditation requirements. Evaluations made at the request of the own university have the advantage that they elicit honest and constructive feedback. This may not always be the case during a review made for an accreditation or similar. The reason is that in a third party review, the ambition is to come out well and avoid criticism. Thus, discussions of weaknesses may be suppressed. However, Malmqvist et al. also found that self-developed QHE models (just like national models) can differ substantially with regards to aims, scope and panel composition. Hence, self-developed QHE models must be carefully designed, and their development requires a significant investment in time, resources and money from the university, as well as a number of iterations to make improvements and adjustments based on pilot experience with applying the model.

In this paper, we present and discuss on one such model, namely a process for external programme evaluation, the Chalmers Programme Review Framework (Chalmers PRF). The Chalmers PRF aims to provide an external and international perspective from independent academic and industrial experts on the targeted programmes and their operational environment in the context of global best practice. The Chalmers PRF was developed and piloted on two MScEng (Sw. Civilingenjör) programmes – Electrical Engineering as well as Automation and Mechatronics Engineering during the spring of 2015.

In particular, we focus on the relevance and utility of the Chalmers PRF for its customers, i.e. the stakeholders for Chalmers educational programmes: industry representatives, university management, programme directors, faculty, students, and government. We will compare their views on quality in higher education, and their impression of the Chalmers PRF in itself as well as in comparison with other QHE models that they have experienced.

This study was designed to follow up the pilot test of the Chalmers PRF reported on in Malmqvist et al. (2015). It was carried out as an interview study with relevant stakeholder representatives, i.e., industry, students, university management, programme directors and faculty. Two representatives from each stakeholder category were interviewed, i.e. ten in total. No government representatives were interviewed in the study, due to the future Swedish national system for evaluation of higher education not being finalized at the time of the interviews (March 2016). The interviews comprised circa 20 questions in the categories personal information, views on educational quality, views on the Chalmers PRF and outlook. The interview duration was typically one hour. The interviews were transcribed. Data analysis was conducted by the KJ method and to some extent quantified.

The remainder of the paper is structured as follows: We first account for the Chalmers proposed framework and process. This is followed by a presentation of the results from the stakeholder interviews. The discussion reflects on the fulfillment of the requirements from government and from Chalmers. The last section wraps up the paper by stating conclusions and identifies needs for future work.

CHALMERS PROGRAMME REVIEW FRAMEWORK (CHALMERS PRF)

The design of Chalmers PRF was guided both by compliance requirements derived from governmental frameworks, and “improvement” opportunities suggested in the self-developed frameworks. A review done according to Chalmers PRF must verify that national degree requirements are satisfied, but also guide Chalmers' development towards its own goals and ambitions, including providing world-class education.

Review aims

The primary aim of Chalmers PRF (2015) is to be a key tool in enhancing the competitiveness and quality of Chalmers’ programmes. It achieves this aim by providing an external and international perspective of independent industrial and academic experts on the targeted programmes, set in the context of global best practice.

Review framework & parameters

The review considers four perspectives (student, resources, directions, and impact) each with 3-5 criteria. For example, the impact dimension includes criteria related to the value, employability, knowledge transfer and international standing of the programme. Figure 1 shows the structure and components of the framework.

As can be seen in Figure 1, a number of the Chalmers PRF review criteria are also found in accreditation/national evaluation models, including, e.g., learning environments and quality assurance processes. These standard criteria provide the basis of Chalmers PRF, and well positions a Chalmers programme that passes the review to also pass a national evaluation/accreditation.

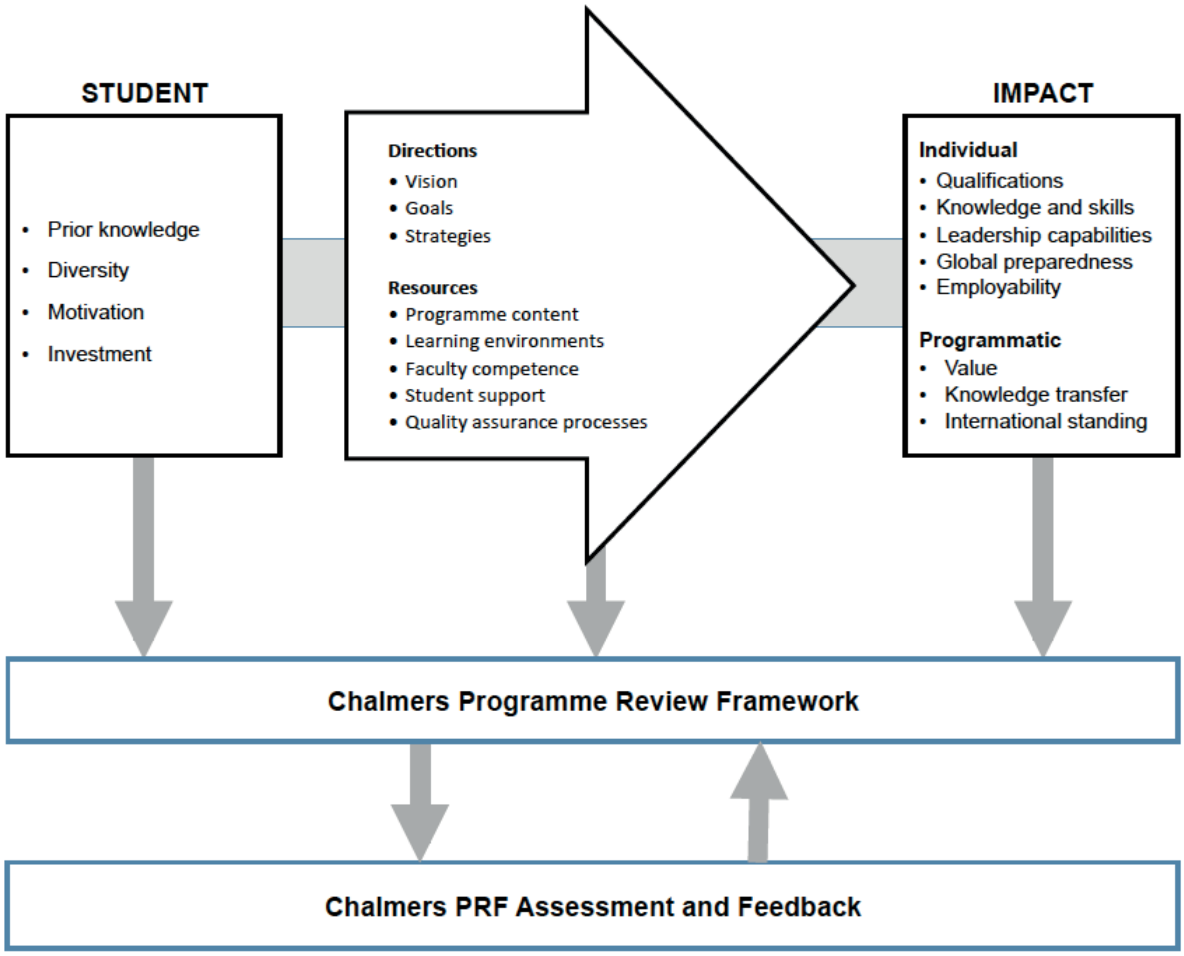

Fig 1. Chalmers Programme Review Framework.

However, a number of criteria have been added to the framework, targeting specific aims for Chalmers' programmes. The Chalmers-specific review criteria include:

- ***Leadership.*** To what extent the programme prepares to assume leading roles in the development and operation of product, systems and processes?
- ***Global preparedness.*** How does the programme prepare for a globally mobile career including international employment?
- ***Value.*** What are the unique selling points/profile of the programmes? What are the perceptions of stakeholders of the unique benefits of the programme graduates?
- ***Knowledge transfer.*** How do graduates bring new knowledge from academia to industry? How many patents and new companies created by students and recent graduates? What is the role of the programme in the local innovation ecosystem? Do students publish research papers in peer reviewed journals and conferences?
- ***International standing.*** Are courses found to be of high international standing through international benchmarking or review? Are master theses of high quality in an international perspective?

Review methodology & and process

The methodology and process of the review is similar to that of a standard external review, i.e. planning, self-evaluation, site visit, post-visiting reporting and response, and follow up. However, special attention is given in the planning phase to customize review questions and objectives to Chalmers' current interest and strategies, in order to target the review at relevant issues. Moreover, international participation is sought in the review panel, both regarding academic domain experts and industry experts.

Review deliverables

The review report accounts for the review preparation and process but its main substance is stated in terms of strengths, weaknesses and recommended actions, organized into:

- Commendations. Identified aspects where Chalmers has strengths, particularly with respect to an international reference point.
- Recommendations. Identified issues that Chalmers should address along with recommended actions to resolve the issues.
- Opportunities. Somewhat more generally formulated actions that Chalmers might consider in order to improve its standings and operations.

Pilot testing

Chalmers PRF was tested during 2015 on two MScEng (Sw. Civilingenjör) programmes: Electrical Engineering (E) as well as Automation and Mechatronics Engineering (Z). The commendations and recommendations set comprised 13 commendations, 3 priority recommendations, 16 general recommendations, 8 recommendations common to E and Z, 8 E-specific recommendations, 7 Z-specific recommendations and 5 general opportunities, i.e., 50 recommendations and opportunities in total. The pilot test has demonstrated that the Chalmers PRF provides a rich set of proposals for educational improvement. A more detailed discussion of the results can be found in Malmqvist *et al*. (2015).

STAKEHOLDER NEEDS AND PERSPECTIVES

In this section, we account for the results from the stakeholder interviews. We will present their views on characteristics of quality in higher education, on quality improvement work, the importance of the various stated purposes of the Chalmers PRF and how effective it had been in the pilot test, and the stakeholders views of strengths and weaknesses of the Chalmers PRF in comparison with other quality assurance models that they had experience of, as well as what the stakeholders identified as development needs of the Chalmers PRF.

Stakeholder views on quality

The university respondents bring forward a view of quality as consisting of many aspects: the results of the education, the educational processes, the way that students are met by and supported through their studies, the university quality assurance processes, elements of industry involvement, engaged and highly competent teachers and the attitudes amongst professors to continually develop their courses and teaching approaches were all mentioned. Hence, it would appear that a QHE model should also be multidimensional or holistic.

Alternatively, that it would be realized that any single QHE model might only address parts of the issues, and that a university would need several complementary QHE models.

One industry representative described a quality education as one that combines theory and practice in a synergistic way. On one hand, he argued that deep working knowledge of theory is essential to solve really hard problems, on the other hand that fresh graduates lacking of understanding of practice would tend to bring forward unrealistic ideas and be perceived as naïve. This industry representative further emphasized the importance of preparing for leadership, and of the importance of equipment and infrastructure that supports hands-on learning. The other industry representative argued that a high quality combines mastery of modern engineering tools with social skills ("*technical knowledge is not sufficient*"). It can be noted that both industry interviewees brought forward quality characteristics that are at the core of a CDIO-based programme.

Quality improvement work

The university leadership interviewees described their quality improvement practices in a rather diverse way, although two tendencies could be discerned: one approach that relied on processes and instruments, one on the personal interaction with people: "*I work by walking around and talking to by people*". These tendencies are mirrored in what features of the Chalmers PRF that the individuals had appreciated. For the instrumentalists, the structured approach is the value, but for the respondents who emphasized dialogue, the personal interaction with the panel members was an essential incentive of the Chalmers PRF, as discussed further.

When asked about barriers to quality improvements in higher education, the university respondents identified the strongest barriers as the status of teaching, especially in a research-intensive university, and as faculty time: there is always competition with other opportunities and responsibility. The students, however, also argued that some teachers are reluctant to change despite criticism. Hence, a typically less articulated challenge for a QHE model is to appear rewarding for involved actors and to create attention for the associated educational development. For the Chalmers PRF, the programme directors identified the dialogue with international experts as particularly rewarding. The industry representatives emphasized the importance of frequent meetings and of steering the university-industry meetings toward dialogue, not only information from the university side.

Stakeholders' assessment of the Chalmers PRF

The respondents were asked to assess Chalmers PRF through a quasi-quantified assessment of the importance of the Chalmers PRF's purpose and the effectiveness of the review to deliver recommendation pertinent to the purpose; and in through open-ended questions on review outcomes and associated development needs.

Ratings of importance and effectiveness

The Chalmers PRF has a number of stated purposes. The interviewees were asked to rate the importance and effectiveness of the pilot set in addressing the purposes. A five-level rating scale was used for both assessments, ranging from < not important at all (1) – very important (5) > and < not at all (1) – very significantly (5) >. The ratings are shown in Table 1, including averages and ranges.

Table 1. Stakeholder ratings of the importance of the purposes of the Chalmers PRF, and of the effectiveness of the process in providing support for each purpose

Purpose	**Importance**		**Effectiveness**	
	Avg	**Range**	**Avg**	**Range**
Provide an external and international perspective of independent industrial experts on the targeted programmes	4.3	3-5	3.7	3-5
Provide an external and international perspective of independent academic experts on the targeted programmes	4.1	2-5	4.1	3-5
Secure that national degree requirements are fulfilled	4.1	3-5	2.7	1-2
Guide Chalmers development towards its own ambitions, including education of a higher international standing	4.3	3-5	4.1	3-5
Indicate to what degree Chalmers programmes have a positive impact on society (relevance, employability, knowledge transfer)	4.1	3-4	2.6	1-3
Indicate to what degree the educational programmes are supported by an appropriate institutional environment (leadership, faculty competence, support staff, learning environments etc)	4.3	4-5	4.0	3-5
Indicate to what degree Chalmers internal quality assurance processes are purposeful and effective	4.3	4-5	3.4	1-5

We observe that all purposes are assessed as important (4) or very important (5). The ratings concerning effectiveness were a bit lower, but the generally close to or above the “significant” level (4.0). However, two purposes stand out as less effectively delivered *“Secure that national degree requirements are fulfilled”,* and *“Indicate to what degree Chalmers programmes have a positive impact on society (relevance, employability, knowledge transfer)”*. These purposes will be further discussed below.

As general strengths of the Chalmers PRF, the interviewees especially mentioned the value of being exposed to external and international perspectives.

Improvement needs

Many of the respondents pointed out that they had expected more programme-level focus in the review findings. Instead the review findings tended to be directed towards the university level leadership routines, including roles, responsibilities and accountability, quality systems, and how these were implemented. To some extent, the programme directors were disappointed with this balance. They had made a major effort to prepare for the review, and felt that they got less concrete and less numerous recommendations in return. Clearer instructions, compiled overview of available material, and ample time to the review the material were suggested in order to get more of the review at the programme level, alternatively a different introduction to the programme directors of the purpose of the review to set the correct expectations would be useful.

The programme directors further argued for the need to minimize the effort to produce the documentation for the review. The current list of data and documents is rather extensive, and the programme directors felt that only a fraction was accessed by the review panel and visible in the analysis. A clarification of what documentation that would be required and for what specific analysis was requested, along with database systems that could gather data (e.g. number of first-hand applicants) over time and enable trend analysis, comparisons with other programmes etc.

A unique element of the Chalmers PRF is the assessment of impact. This purpose was assessed as very important by the stakeholder but the recommendations in the review less significant. This element must be given more attention in further reviews, starting from elaborating the data to be collected, how it should be analyzed etc.

The low rating of effectiveness for *"Secure that national degree requirements are fulfilled"* along with comments from the interviewees that it may not be obtain to accommodate both a focused, development-oriented dialogue and an extensive, control-oriented examination within the same framework and occasion. In the pilot, development was prioritized (nevertheless, a number of the recommendations were of control and accountability character. The respondents agreed that this should be the priority. However, this also leaves a gap, since the Swedish government, if the current proposal stands, is not going to make programme-level evaluations in the future. Possibly, this may lead to that some Swedish universities opt to apply for accreditation by EUR-ACE or ABET in order to secure that their programmes meet international threshold standards.

Teachers, students and industry representatives generally were less certain about the results of the evaluation, with many "*I cannot assess*" replies concerning effectiveness. It is clear that there needs to be a comprehensive and broad result communication activity as part of the framework, if the results are going to be well known outside of the circle of university management and programme directors.

The interviewed teachers voiced concerns of what they viewed as the top-down perspective of the framework, and of some recommendations that emphasized accountability. They argued that the university should to a higher degree trust its teachers; provide them with autonomy and design programmes starting from the teachers' actual competence, rather than on a pre-defined list of programme learning outcomes. The question is how to design a programme review framework so that it also is perceived and rewarding and constructive for individual faculty to participate in?

In conclusion, however, the respondents were in agreement that the Chalmers PRF will be a central component in Chalmers education quality system and essential for the future quality improvement at Chalmers.

DISCUSSION

This study was made with input from a limited number of respondents. The pilot test together with this study and that of Malmqvist *et al*. (2015) provided limited grounds for arguing that the findings are transferable to other universities. More test and evaluation is needed.

The pilot test was also limited in some ways. Firstly, the time scale to prepare and conduct the programme reviews was compressed, since they were a pilot conducted on the tail of designing the framework itself. This constrained the ability to conduct a detailed examination of the programme details. Secondly, and most importantly, the review panels only consisted of two individuals: the second and third authors of this paper. With larger review panels, some more specific feedback on programme and course contents and level would likely have been obtained.

CONCLUSIONS

Local models for evaluation of Quality in Higher Education (QHE models) complement national models by enabling a stronger focus on locally relevant issues, by including an international perspective and benchmark, and by being more development-oriented than the national control-oriented models.

Chalmers PRF is such a model. Particular to the Chalmers PRF is the consideration of evaluation criteria regarding: leadership, global preparedness, programme value, knowledge transfer and international standing were added.

The stakeholder interviews reported in this paper suggest that an extensive dialogue between review panel and evaluated programmes is essential to reach the development-oriented ambitions of the framework. The interviews further indicate that it will likely be difficult to use this framework to both guide development and to secure that national degree requirements are met. Hence, it may be proposed that the Chalmers PRF is focused on development, while other QHE frameworks are applied to secure compliance with national criteria.

It is suggested that the Chalmers PRF may be easily adapted to institutions beyond Sweden for states with engineering accreditation systems, and those without.

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BIOGRAPHICAL INFORMATION

Johan Malmqvist is a Professor in Product Development and Dean of Education at Chalmers University of Technology, Göteborg, Sweden. His current research focuses on information management in the product development process (PLM) and on curriculum development methodology.

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THE INNOVATION ELEMENT OF THE DIPLOMA (B.ENG.) PROGRAMS AT DTU

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ABSTRACT

In September 2014 the first version of the newly developed CDIO-based diploma (B.Eng) programs were launched at DTU (Nyborg et al., 2015). The programs are the result of a comprehensive merger process of former diploma programs, namely the programs at Engineering College of Copenhagen (now DTU Diploma) and the Technical University of Denmark.
The most significant new activity in the programs is the introduction of a common 10 ECTS compulsory course in innovation in the later part of the programs.
The idea behind this course is to give students the opportunity to collaborate on inter-disciplinary real-life projects. This course strengthens not only innovation skills but personal and interpersonal skills as well.
In this paper we will discuss the organization of the Innovation Pilot course. In particular we focus on:

- Structure of programmes
- Organization of the Innovation Pilot course
- The didactical considerations
- Scaling up the course from 50 to 500 students

KEYWORDS

CDIO-based study programs, Stakeholder involvement, Innovation, Standards: 1, 2, 3, 6, 7, 8 9,11

INTRODUCTION

In general, innovation can be seen as the process of translating an idea into a good or service that creates value for which will. Hence, innovation includes an economical aspect and can be considered as the results that occur when new ideas are matured and marketed by a company in order to satisfy the needs and expectations of the customers. In a learning context innovation can be understood as a process where an organization creates and defines problems and then actively develops the necessary knowledge to solve them (Nonaka 1994, p. 14).

In 2011 the CDIO syllabus was updated to version 2.0 (Crawley et al., 2011). Particularly attention was given to innovation, invention, internationalization and sustainability. Modifications in content and in labeling have been incorporated into the new version of the syllabus. In essence innovation is considered as a market-oriented view of what the CDIO Syllabus defines in Sections 4.2 through 4.6.

At DTU, innovation is considered multidisciplinary and involves companies in the process. In order to support innovation as an educational element, this calls for three important things in the curriculum design:

- Establishing a platform for collaboration between different study lines
- Creating a learning space where students can acquire innovation skills
- Scaling up the course

At DTU it was decided to create a compulsory 10 ECTS course "Innovation Pilot" (Technical University of Denmark, Course description 62999), focusing entirely on interdisciplinary-innovation and including the parts mentioned above.
The idea behind the course is, as the name suggests, that students should be trained to act as pilots for innovation projects in collaboration with companies.

STRUCTURE OF PROGRAMMES

All B.Eng. programs at DTU follow a common structure (Figure 1). On the first four semesters, all courses are compulsory. With some variation, this is followed by a semester with elective courses, a semester with industry internship and a semester with the final B.Eng. thesis.
Each semester consists of a lecture period (13 weeks) and a lab-period (three weeks).
On the first four semesters, the projects are design-build projects. The projects are attached to a 10-ECTS-point course with contributions from one or more supporting courses. Typically these projects range from simple design-build projects focusing entirely on the "DI" part of CDIO (Nyborg et al., 2010), to stand alone projects where all elements i CDIO come into play (Sparsø et al., 2011). The projects not only provide the students technical knowledge but also train the students' personal- and interpersonal skills.

Period	13 week	3 week
ECTS	25	5
1. Semester	Compulsory courses + CDIO project	
2. Semester	Compulsory courses + CDIO project	
3. Semester	Compulsory courses + CDIO project	
4. Semester	Compulsory courses + CDIO project	
5. Semester	Elective courses (20 ECTS + **Innovation Pilot course (10 ECTS)**	
6. Semester	Industry internship	
7. Semester	Elective courses (10 ECTS) + final thesis (20 ECTS)	

Figure 1: Semester structure (example)

The Innovation Pilot course is placed after the compulsory part of the curriculum. Beyond the technical content, the students have at that point gained experience in CDIO syllabus categories 2, 3 and 4 through semester CDIO projects. The ability to collaborate on each study line is well developed.

ORGANIZATION OF THE INNOVATION PILOT COURSE

The overall course schedule is shown in Figure 2: Course structure and schedule.

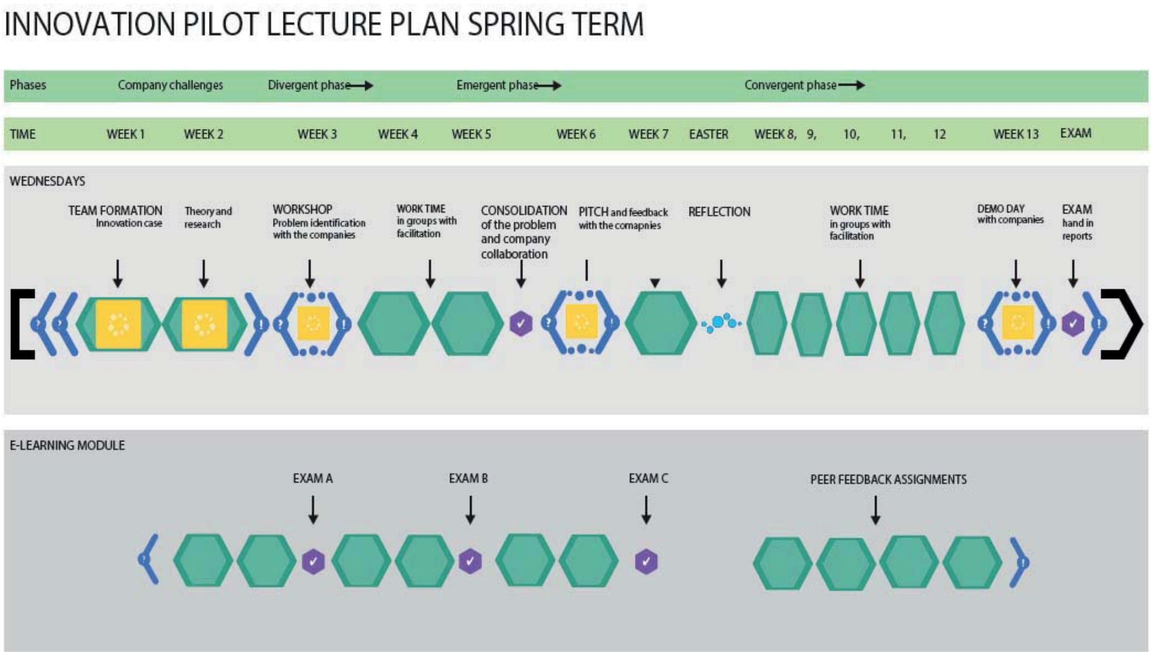

Figure 2: Course structure and schedule

The Innovation Pilot course is offered three times a year in the two lecture periods and as an intensive summer school (6 weeks). There are 17 study programs (disciplines) involved, and it is expected that up to 500 students will take the course at the same time. They are divided into smaller units, thematic labs of up to 40 students, running in parallel. The teams are formed so that they consist of 4-6 people with a minimum of two disciplines present and 2 teams are expected to work with the same companies or similar external partners. The students are responsible for finding ways to apply their unique skills and knowledge to create value in the projects. The structure and example of lab themes are shown in Figure 3: Structure of labs.

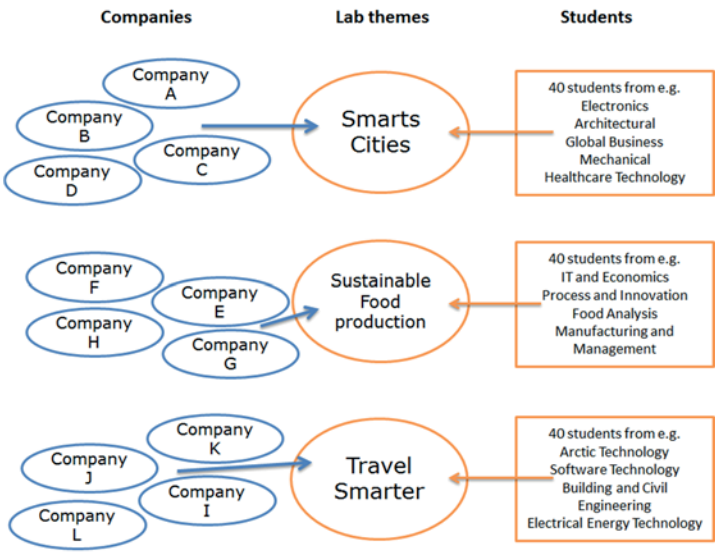

Figure 3: Structure of labs

The course will be facilitated by *lab leaders,* teacher teams of engineering experts and innovation experts that will act as supervisors ensuring a high academic level in both areas and stimulating the inter-disciplinary learning environment.
The course is run as a blended learning course with use of e-learning, and peer feedback alongside the weekly classes. (Norman et al, 2014) This to optimize the time the students have, to work together in teams (one full day a week) and free up supervisor time to facilitate and work with the teams.
The projects take a starting point in actual needs experienced in the partner companies, they are then reformulated as open-ended projects and explored holistically by getting out of the building involving users, customers, stakeholders etc. see Figure 4.

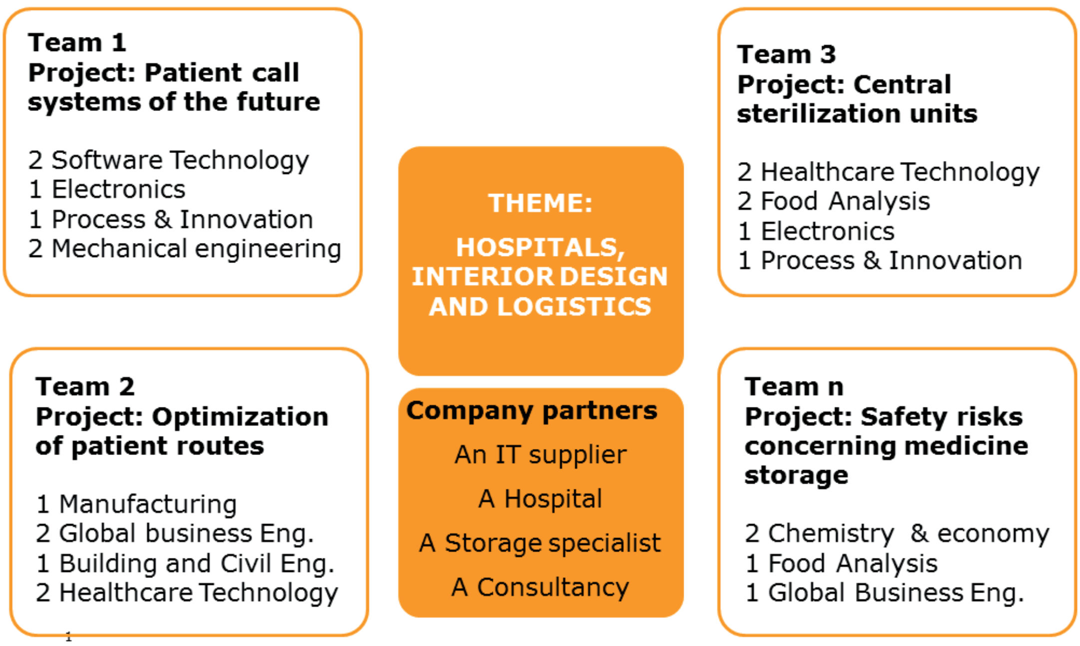

Figure 4: Example of projects in a lab

The team then narrows in on a problem and after adjusting expectations with the company, work towards a corresponding solution. All the way through the course they work on creating prototypes or mock-ups in the labs.
On the final day of the course, a Demo Day is held where all projects gather and the students pitch their findings and demonstrate their prototypes to their company partners and get feedback on these. The feedback is included in the reflection report.
The process and work with acquisition of teamwork and innovation competencies is evaluated in a reflection report building on weekly reflections from individuals and teams. The reflection concerns: The teamwork and how the team has managed to bring their diverse knowledge and contributions into play, the use of innovation methods and how they have managed the company collaboration.
The course is evaluated as a written exam. In order to attend the exam the students must have a participation rate above 80% and have uploaded the weekly assignments and logs. The evaluation is an overall assessment of the following elements: a) An innovation proposal and a prototype, b) a reflection report and c) 3 smaller multiple choice exams from the e-learning module. Part a and b each weigh 40 % and c 20%.
The intention is to balance the assessment of the process oriented development of personal skills and the product oriented results of the innovation project in the format of an innovation proposal and prototype and finally the knowledge aspect which is measured in the multiple choice exams.
The course is supported by a course responsible working with a small administrative unit that support the acquisition and screening of company projects, the formulation of lab themes, the selection and training of supervisors (teachers) and the events held in connection with the course.
The themes serve as platforms of common interest for students, supervisors and companies. They have to be broad enough to be relevant for all 17 study lines, concrete and interesting enough for the students to choose the theme and not least relevant for the company challenges.

ESTABLISHING A PLATFORM FOR COLLABORATION

The main challenge in establishing a platform has been to have the students actually meet in interdisciplinary teams. Each study line has had the freedom to place the course freely on the 5^{th} or 6^{th} semester depending on their study plans. This has created a need to offer the course both in the spring and fall semester. Furthermore, the students are also encouraged to take their electives semester abroad creating a need for the course to be offered as an intensive course outside of regular study periods. All in all it is very hard to predict numbers as well as what study lines will be present at what time.
This is further complicated by the different sizes of study lines that range from 30 students to 200 students per semester and the fact that some study lines are offered twice a year while others only once.
The Innovation Pilot course is therefore offered three times a year in the two lecture periods and as an intensive summer school (6 weeks). This creates flexibility for the study lines and not least for the students but on the other hand have costs on how detailed it is possible to plan for each specific study line and the freedom of choice each individual student has.

DIDACTICAL CONSIDERATIONS REGARDING CREATING A LEARNING SPACE WHERE STUDENTS CAN ACQUIRE INNOVATION SKILLS

The course design has been influenced by innovation literature in a number of focus areas concerning:

- Innovation seen as knowledge creation
- The role of diversity
- The teacher role when teaching new competencies
- The role of motivation and the company context

They will be elaborated upon in the following section.

Innovation as a knowledge creation process

In order to teach students the skills needed to create and implement value creating innovations, an understanding of what innovation entails is needed. According to Nonaka (2007) innovation equals knowledge creation which means that we surpass the expectations of the CDIO syllabus that only strive for knowledge discovery (Crawley et. al. 2011).
"The essence of innovation is to re-create the world according to a particular vision or ideal. To create new knowledge means quite literally to re-create the company and everyone in it in a nonstop process of personal and organizational self-renewal." (Nonaka, 2007, p.164)
This is aligned with the perspective of the student as knowledge creator rather than capturer of knowledge (Normann et al., 2014, p. 3) and underlines the need to create a lab where students can experiment with this knowledge creation.
In Innovation Pilot this is addressed in that the students will work with the company unfolding the original problem the company has provided and spend the first half of the course learning to create knowledge by openly exploring the problem and the assumptions behind it before trying to solve it.

Innovation is created with others – the role of diversity

An important aspect is that innovation learning is richer when performed by a diverse group bringing in both more knowledge as well as more ignorance. However, as diversity so often is only present but not actively used (Justesen, 2007), the knowledge creation however calls for social skills as well as motivation for using it.
Darsø (2012) introduces, based on her empirical studies of innovation, two dynamics that should be navigated when creating innovation learning. The knowledge dynamic between knowledge and ignorance and the communication dynamic between concepts and relations. The knowledge-ignorance dynamic is important as she found that just as important subject knowledge was, just as stifling to the innovation process could it be when expert statements were taken for granted and not examined. In this way, the misunderstandings arising when different disciplines work together become an important source for innovation.
As for the concept and relations dynamic, she argues that the relations are what enhances the ability of the team to use the knowledge and ignorance effectively. She sums up innovation competencies as:

"The ability to create innovation by navigating together with others under complex situations."

It consists of two types:

- Socio-innovative competencies: Mastering social interaction that enhances innovation.
- Intra-innovative competencies: Consciousness & sensitivity in relation to own and others' talents, preferences & potential for development and innovation. (Darsø, 2012)

In Innovation Pilot these are addressed by placing the students in interdisciplinary teams of 4-6 people with a maximum of two representatives from the same discipline and then include a huge focus on their team collaboration in both the course and the examination. This because although all have extensive experience with project- and team work, they are not necessarily very practiced in working actively with the communication dynamic between concepts and relations and the consciousness regarding own and others' talents.
However as this course is also a first for most of the students, flipped classroom techniques have been applied (Normann et. al 2014) and an Innovation Basics e-learning module has been developed. The idea is that the students spend time on their own acquiring this knowledge and time together practicing the application.
In order to create constructive alignment they are during the exam measured on their ability to *"Use their own as well as other's skills, preferences and potential in an interdisciplinary project. In addition, be able to argue for major decisions, put in relation to both own and other's skills.*(ibid)

Teaching personal competencies creates a new teacher role

Advances in innovation pedagogics demands that the teacher role changes to facilitator, focusing just as much on the process of the teams as the outcome of the project work (Darsø, 2012). This is experienced as a huge shift for the supervisor compared to regular engineering project supervision (Christiansen et al., 2014)
In Innovation Pilot, a mandatory preparatory course is given to all teachers participating in the course and they are offered supervision and help from a support staff regarding this role.

Innovation learning requires motivation

That learning is enhanced by motivated students is probably a universal truth. However, acquiring innovative skills entails unlearning previous ways of thinking in order to create new knowledge, in other words: Transformative learning (Illeris, 2004). Furthermore, handling ambiguity in an open-ended project with team members emphasizes this need. Amabile who has done extensive research points to that motivation, expertise and creative thinking skills (Amabile, 1998) are needed to create creativity – the predecessor of innovation.

In the Innovation Pilot course the intrinsic motivation is challenged by it being a mandatory course. This is a challenge for more reasons. First of all, there is an added pressure to pass the exam tipping the balance towards extrinsic motivation. Secondly, not all students, nor their teachers see the need or relevance to study innovation as part of their engineering studies. Thirdly, it seems to have a motivation-lowering effect when students are matched up in teams where motivation levels are unbalanced.

Amabile (1998) recommends four initiatives to boost intrinsic motivation:

1. Match the right people with the right assignment
2. Let people know that their work matters
3. Give people freedom within the company's goals
4. Allocate appropriate amounts of time and project resources

The first one is impractical as the projects are open-ended and logistics involved in creating interdisciplinary teams make it hard to predict which types of students that will be in each lab and team. Instead, the course works with the principle of shaping the project to be right for the team. This involves encouraging the students to be not only objective but instead together with the knowledge they create, let their personal preferences and disciplinary strengths, guide the problem definition and determine the focus of their final solution.

The company collaboration plays a huge role in motivating the students. Furthermore, successful engineers from the industry are invited to talk about the importance of innovation skills. Also on a university level there has been an effort to stimulate ambassadors among students and teachers to stimulate a sense of relevance.

The before mentioned logistics also do not allow the students to neither choose favorite co-workers nor the specific company to work with. To allow them a freedom within the frame, each lab-unit of 40 students is matched with an overall broad theme such as FinTech or Smart Cities and the students themselves prioritize what themes they are most interested in. This also creates a first common ground for the teams that again are formed by the students themselves. The direction of the project is likewise a student decision although it has to be negotiated with the company.

The fourth factor is addressed in the process of scoping company problems that can be addressed within the semester period and the students' innovation competencies as well as the course plan. This will have to be balanced through experimentation in the first implementations.

The company context as arena for learning

The first principle of CDIO is that "the conceiving-designing implementing-operating of products, processes and systems should be the authentic context of engineering education." (Crawley et al., 2011). This is a good match for the *Complex situation* that is core of the innovation competency (Darsø, 2012).

The complex situation in the Innovation Pilot course is that the problem is owned by a company and that the knowledge generating process should involve their reality. In this way the implement-operate part of CDIO is addressed by the business approach to the solutions. The students cannot make generic technological solutions, not taking into account the context they are made in. Instead they have to spend time analyzing the company they work with, and address in an innovation proposal as well as pitch why this particular solution makes sense for their partner company from a business, society, organizational, operational and technological perspective.
This will obviously entail a risk that the students are affected by the company's perception of what is possible and not possible, and therefore is another focal point in the training of their supervisors.

SCALING UP THE COURSE

In the spring of 2016 a pilot course is held as an elective for approx. 50 students. In the autumn when it starts to be mandatory, 230 students are expected to enroll and that number grows to 500 in the spring of 2017. This also means that the teacher group grows from 4 in the first run to 12 in the autumn and to 24 in the spring of 2017.
There is a paradox between a very individualized facilitation of the development of personal competencies between students, with very different prerequisites, and the need to deliver a standardized learning outcome of the course.
The teacher job is very complex, as the facilitator of the team should facilitate individually among 40 students. The overall design of the course involves a standardized frame for running the course and an e-learning support module. Beyond that, there is a huge degree of decentralized freedom for the supervisors to facilitate the teamwork. Another choice has been made to only do a written exam, which has demanded for a varied hand-in of material in order to evaluate the learning and collaboration. This has been further complicated by Danish law stating that all written material must be traced back individually going directly against the pedagogical intent of having the team collaborating closely. This has been attempted mitigated by asking for a shared schematic overview of all contributions including writing but also other teamwork contributions related to the innovation process.

CONCLUSION AND FINAL REMARKS

Interdisciplinary innovation arises from the positive effects that result when stepping across the technical and social boundaries by which we normally structure knowledge.
In the knowledge economy, it is often the case that the right knowledge to solve a problem is in a different place than the problem itself. Also, many problems today need more than one kind of knowledge to solve them, so interdisciplinary innovation is an essential tool for the challenging problems of today.
All engineering disciplines have their own way of addressing a problem. On one hand this means a highly specialized knowledge, but on the other hand it also narrows the way of thinking and hence not always asking the right questions.
The Innovation Pilot course defines a framework for collaboration between different engineering disciplines. It is anticipated that the synergistic effect that occurs, breaking those discipline boundaries, will lead to smarter solutions to problems that companies might have.
By designing the course in this way it has been possible to scale a single course to quite a few students while maintaining a focus on teaching innovation competencies.

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USING SELF-EVALUATIONS FOR COLLABORATIVE QUALITY ENHANCEMENT - A CASE STUDY

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ABSTRACT

This paper describes the application of a process to enhance the quality of higher education. At the heart of the process is a cross-sparring collaborative model, whereby the two institutions are critical friends. The cross-sparring is set up in a way where a study programme first self-evaluate (on criteria that among other things include the CDIO standards) (step one), the institutions that can learn-and-inspire each other are pairied based on three - five criteria each institution have chosen (step two). Following that, the institutions visit each other and discuss the criteria each institutions wants to learn-and-inspire (step 3). At the end, each institution reflects and identifies possible enhancements criteria (step four).

This article describes a case study of this process where the Health Care Technology Bachelor programme at Aarhus University and the Health Informatics Bachelor programme from Helsinki Metropolia University of Applied Sciences were critical friends. The article focuses on the third and fourth step in the above described process and reports on the outcomes from the cross-sparring.

KEYWORDS

Quality Assurance, International Collaboration, Faculty Development, Standards: 1, 10, 12

INTRODUCTION

Quality enhancement and development is in the forefront of almost all higher education institutions. In many countries, education is seen as one of the key element to keep the competiveness and development of the country. One example is he so called Modernisation Agenda presented by the European Union (European Union, 2011). More specifically, with this agenda, a goal has been set to improve the quality and relevance of higher education.

Throughout history, the quality in higher education institutions has been expressed in dissimilar ways. At least three different systems have been found (Amaral, 2012). The old English universities of Cambridge and Oxford were self-governing institutions where quality was defined by the professors. The quality system there resembles the quality system of journal - peer-review. The professors had the power to remove unsuitable employees and hire new staff.. The University of Paris had a ‘top management quality system’; the Chancellor of Notre Dame was the rector and had all the power to make decisions. Finally in Bologna, the students have the power to ‘hire and fire’ professors. This is more a quality system driven by customer satisfaction.

In general, quality in higher education institutions was not on the general public's agenda before the 1980's (Neave, 1994). Amaral (2012) argues that the reason for the quality need (as seen by government) was based on four factors: massification of higher education, market regulation, new public management and a loss of trust in higher education institutions and their professors.

This has - in many countries - led to the development of accreditation bodies. They can be either national (like the Danish Accreditation Institution (2016)) or accreditation bodies that cover an area like engineering (e.g. EUR-ACE (ENAEE, 2016)). Accreditation is - however - a control system that typically ensures that the quality system is in place. Unfortunately, in many cases, the focus is very much on quality assurance, not the steps towards improvement, are not fully considered. This tension is captured extensively in the literature (see e.g. Filippakou & Tapper (2008) or Houston (2008)).

In many instances, accreditation is seen as a process with a very limited value for the participants. It is seen as a process where the institutions delivers "proofs" for the chosen quality criteria, but do not receive much back that can help to improve the quality. Consequently, a model that focuses on developing quality by using light-weight processes already known from accreditation could be useful. With such a model it would afford the community the opportunity to establish international collaborations and to improve international comparability across HEIs

In order to address this weakness, an EU funded ERASMUS+ project has been initiated (Kontio, et al., 2015).The project comprises 8 institutions and their mutual interest was in the implementation and development of the CDIO (Conceive Design Implement Operate) Approach to engineering education. The eight European universities are Reykjavik University, Iceland; Turku University of Applied Sciences, Finland; Aarhus University, Denmark; Helsinki Metropolia University of Applied Sciences, Finland; Umeå University, Sweden; Telecom Bretagne (a French Grande Ecole), France; Aston University, United Kingdom; Queens University Belfast, United Kingdom.

However, the 12 CDIO standards are not the only one in focus. By looking in many different sources, a total of 28 criteria were chosen. For a more in-depth description of the criteria and the sources of inspiration, see (Clark, et al., 2015)

THE PROCESS

This section gives a short overview of the process, the steps and artifacts involved

This is based on a prior self-evaluation, where the institution/programme identifies quality criteria it wants to improve.

The process is done in four steps:

1. **Self-evaluate**. Evaluate own programme/institution. This evaluation is based on 28 criteria. The criteria are a superset of different self-evaluation frameworks including the CDIO self-evaluation. When the self-evaluation is finished, you identify 3-5 criteria you want to improve (called learn-and-inspire criteria).
2. **Pairing**. Two institutions are pairied. A good match is two institutions where the difference between their self-evaluation scores on the learn-and-inspire criteria are rather large.
3. **Cross-sparring**. The two institutions visit each other to learn and inspire each other

4. **Enhance**. Based on inspiration and what is seen, actions to develop one's own programme/institutions are planned (and hopefully executed)

The self-evaluation is based on a continuous model like the capability-maturity model (CMMI Product Team, 2006). Each criterion are measured on a 0 - 5 scale; zero indicates that no focus on the criterion what so ever, 5 that there is a continuous improvement process based on solid evidence in place. The same scale is used in the CDIO self-evaluation rubric (see Bennedsen, Georgsson, & Kontio (2014))

The pairing is done by calculating the distance between the score of the learn-and-inspire criteria from the self-evaluations. As an example consider the following (part of a) self-evaluations:

Criterion	Institution A	Institution B	Institution C
1) A holistic view of learning	4	2	1
2) Appropriate learning outcomes (developed from required competences)	3	4	3
3) An integrated curriculum	2	4	3
4) A sound subject foundation	1	4	3
5) Active learning approaches	3	3	5
6) Appropriate workspaces and equipment	3	3	3

The gray cells are the learn-and-inspire criteria for the institutions. Here the distance would be 7 between A and B, 6 between A and C, and 3 between B and C. The distance between A and B is 7 since the learn-and-inspire criteria involved are 1, 3, 4 and 6. The distance in learn-and-inspire criterion 1 is 2 (4-2), criterion 3 is 2 (4-2), criterion 4 is 3 (4-1) and criterion 6 is 0 (3-3).The best match will then be A and B.

The cross sparring will start by both institutions exchange self-evaluations. When institution A is visiting institution B, the focus of the agenda is criteria 3 and 4 since that is what institution A wants to improve. When institution B is visiting institution A, the agenda will focus on 1 and 6.

During the cross-sparring, the visiting institution takes notes and at the end of the visit prepares a list of actions that could be seen as beneficial to implement for enhancing its own study programme.

THE AARHUS EXPERIENCE - AND VISIT TO METROPOLIA

This section describes the process that Aarhus University, School of Engineering have gone through. The focus is on the rationale, the time used and the outcomes.

Preparation

As described above, a self-evaluation was done as a starting point of the cross-sparring. The self-evaluation was done by the responsible for the study programme in focus. The programme responsible has done several self-evaluations using the CDIO rubric, so the concept of self-evaluations was not new to her. Besides a genuine interest in development of the study programme, the study-programme is going to be accredited in the fall. This gave the programme responsible additional motivation to do the self-evaluation.

Learn and inspire
As described above, a self-evaluation was done. The self-evaluation showed some criteria where the score was low and the programme responsible wanted to improve. In Table 1 the selected learn-and-inspire criteria are given together with the score and rationale for the score.

Table 1 Criteria that Aarhus University wants to learn-and-inspire

Criterion	Description	Score	Argumentation
Appropriate work-spaces and equipment	Learning environments, artefacts and resources that support and encourage engaging professional learning are needed to bring the discipline alive and ensure meaning is being made. The building of disciplinary knowledge and skills is best achieved in workspaces that are student-centred, user-friendly, accessible, and interactive.	3	There are workspaces available for students working alone or in groups. We are working on improving group facilities for project work. Professional learning is trained in laboratories and by hands-on learning. Interdisciplinary is highly valued in this programme and is trained in a workshop with nursing students in 3^{rd} semester and collaboration with hospital staff in 4^{th} semester.
Faculty develop-ment (knowledge and teaching)	Actions that enhance faculty disciplinary competence, professional and teaching skills need to be undertaken. This ensures subject relevancy is maintained and that teaching practices promote learning and a positive student experience.	3	Regarding teaching practise: we have a two year programme for new teachers in pedagogics planned by our CDIO Development Lab (CDL). CDL also plan one day per semester for all staff, where pedagogical development and new pedagogical methods are discussed. Regarding disciplinary knowledge, we want to do better by implementing more R&D opportunities for our staff. Right now we lack staff and funding to be able to do better.
Feedback is timely, appropriate and formative	An important feature of the assessment process is the provision of feedback to students on their work. If the feedback is timely, appropriate and formative it allows students the opportunity to learn more deeply and develop effective skills in addressing the assessment tasks they are set.	2–3	Blackboard gives a range of possibilities which are explored by several teachers, in many courses there are tests during semester to give students feedback, students get feedback in Blackboard courses and exercises.

Research is used in teaching	Research informed teaching is embedded within the programme for example in the form of student engagement in research and course content that is enriched with research results. This suggests that the education provided is topical and at the forefront of current thinking in the discipline, thus ensuring the currency of the students on graduation.	2	According to the Danish education system we are a professional bachelor education, and hence not research based. We joined Aarhus University in 2012 and are working on establishing more research and development projects, searching for funding, training staff, employing new staff etc. We are working on replacing and supplementing textbooks with research articles.
Problem solving opportuni-ties (links to the research process)	Problem solving opportunities are embedded in the learning and research approaches used throughout the programme. This is aimed at developing the students' ability to question and critique situations in search of new knowledge, ideas and solutions, something that is of value in the world of work.	3	We work very much on employability and engineering problem solving, CDIO is implemented as an engineering work process. Students work on engineering problems, learn to work structured with engineering methods, to do literature searches, to read research papers, to integrate knowledge from R&D in bachelor projects. Historically we are an professional bachelor programme, but since we joined the university mere emphasis is laid on research

The entire self-evaluation was send to Metropolia as well as the selected learn-and-inspire criteria. A couple of weeks before the actual cross-sparring meeting, Metropolia sent a proposal for an agenda

The cross-sparring

The actual cross-sparring took place on November 25-26 2016. From Aarhus two persons participated - the programme leader and a colleague. The effective meeting time was 24 hours (flying from Aarhus to Helsinki takes approximately five hours).

The meeting was arranged around three major elements:
1. Introduction to Metropolia
2. Visit to teaching facilities and labs
3. Discussion of the learn-and-inspire criteria

Introduction to Metropolia

The introduction was indeed a good thing and helps understand the context and the "specialities" of the Finnish system. We all have our own understanding of how an educational system is and operates. By starting with an introduction to the general system, the university and the study programme, many misunderstandings were avoided.

Teaching Facilities

A walk-through of teaching facilities was done. It was inspiring to see the different facilities, even though the facilities at Metropolia are older and (from the viewpoint of Aarhus) not supporting either project- or lab work better than the facilities we have in Aarhus.

Discussion of Learn-and-Inspire

Metropolia had gone through a major revision of their study programme in the summer, so many of the things discussed ware either obsolete (since they have been changed) or there were no experience so far. However, using the criteria to focus the discussion was very useful; prior to the visit we had knowledge of Metropolia's status (strengths and weaknesses) so that the discussion could stay on track and be very detailed.

The findings and action plan

It was an inspiring and fruitful visit to Metropolia. The study programme at Metropolia and Aarhus were at the "same age" so we have had many of the same experiences and problems - and therefore easy to find common grounds.

One of the major changes was the introduction of a common first year for all study programmes with a major IT component. We had detailed discussions about the cons and pros of this approach - and at Aarhus University we decided that it is not the way for us to go forward since one of the consequences was a major drop in the intake of female students. However, Metropolia's strong focus on the well-being of the first year students was indeed an inspiration. At Aarhus we have a project each semester - we intend - inspired by Metropolia - to put a more systematic follow-up on student's presence and well-being on the project supervisors.

THE METROPOLIA EXPERIENCE - AND VISIT TO AARHUS

This section describes the process that Metropolia has gone through. The focus is on the criteria where Metropolia considers having the most added value to learn from Aarhus University.

As the programmes belong to the same discipline, many of the content based matters were addressed and in addition thoughts about future cooperation in projects and courses were discussed. That was considered as adding value, and combining the interest of quality management expert and content expert.

Preparation

The programme of Health Technology at Metropolia executed the self-evaluation in two steps, adopting the method developed earlier in the KOLA project (Schrey-Niemenmaa, 2011). The process included 5 persons (Dean of the department, head of the programme, key teachers and coordinator of the project). Firstly all involved studied, answered and scored the questions alone, then a consensus meeting was held. In the consensus meeting all the questions were discussed and a common understanding created. Additionally the proposed development actions were collected for further decision making. Each of the participants had used from 2 to 4 hours for the preparation and additionally the consensus meeting took a further 6 hours.

Learn and inspire

The Self-evaluation board of Metropolia's programme of Health Technology identified following 6 issues to be addressed during the cross-sparring session:

1. Programme evaluation to promote continuous improvement
2. Collaborative learning
3. Technology to engage in learning
4. Wider stakeholder input to programme development
5. Student retention
6. Work placements are promoted

These criteria and their argumentation are explained in more details in the table 2.

Table 2 Evaluation criteria that Health Technology programme of Metropolia wants to learn-and-inspire

Criterion	Description	score	Argumentation
Programme evaluation to promote continuous improvement	Programme evaluation is required to determine the programme's effectiveness and efficiency in reaching its intended goals. To achieve this, a system that evaluates the programme against defined criteria, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement is essential.	1	Programme is evaluated by various internal parties: students, faculty, peers and management and external parties like Industrial advisory board and national organisations of colleagues. The outside stakeholders' contribution concerning the new study plans should be made systematic. The alumni should participate in the development of new study structures. The programme is so new that alumni is still rare. Programme evaluation was recognised as an important method for further development. Plenty of feedback is collected from students and will be used for curriculum and course development. Weekly teacher meetings take place for planning and coordination.
Collaborative learning	Collaborative learning opportunities should be provided throughout the programme in the form of projects or other similar learning experiences. These opportunities are a valuable introduction to the world of work beyond higher education.	3	Team works, lab exercises and visits to industry are included. Is it the correct goal to measure collaborative learning only in course level - or should it be the learning experience in the context of working life and society. Collaborative learning approach is implemented for the first year and the approach will be applied also to higher grade-levels.
Technology to engage students in learning	Technology is a valuable resource when considering the design of engaging learning experiences. It is important that technology is used throughout a programme in a thoughtful way that adds value to learning. The modern world is technology rich and today's students are often very tech-savvy.	3	Platforms for supporting various learning activities are in daily use. Digital learning environment could be more promoted, facilitated and supported There is a recognised need to expand their usage both on-campus and off-campus Plenty of hands on laboratory working is a regular practice.

	Incorporating technology into learning and teaching can also help to develop the students' technology competences further.		
Wider stakeholder input to programme developme nt	With a focus on preparing students for life beyond higher education, it is important that programme development takes place in a way that engages a range of internal and external stakeholders e.g. Industry Advisory Board and Benchmark Statements. This ensures that the programme is 'fit-for-purpose' and has the potential to produce the best possible graduates.	3	Industrial advisory board meets four times a year. Students' continuous visits to companies are executed. Projects are done from authentic changing topics relevant to industry. More systematic way of collecting, analysing and using the needs of stakeholders should be developed.
Student retention	The retention and progression of students is continuously monitored and acted upon to ensure the health of the programme.	3	First year of 4 times 15 ects modules encourage students to effective commencement of studies. Four modules serve as an introduction to studies in engineering giving a holistic view to the profession. Similar kind of module system is also used in Health Technology major. The University cannot kick out students due to their performance. If less than 55 ects are gained, University does not get respective funds from the ministry.
Work placements are promoted	In order to best prepare students for their life after higher education, opportunities should be provided at points in the programme to allow students to engage in work based activities.	4	Work placements are compulsory elements of the curricula - they are well established and evaluated. The communication with the employer could be more structured. School tries to organise internships to those who do not manage to find the place by themselves.

The reason to choose those criteria originates from the feeling that Metropolia needs to find a more systematic way of collecting feedback and using it as a source of information for development activities. Additionally the financing of the university is dependent on the student retention, graduate, and employability. We think that most of the above mentioned questions reflect these criteria.

The cross-sparring

The principal lecturer and project coordinator from Metropolia made a two-day cross-sparring visit to Aarhus University in December. The actual time spent including travels was 38h - two working days and one evening when the cross-sparring issues were spoken in a more relaxed way over dinner.

Two days seems to be sufficient to go through the well prepared questions. Additionally it would have been beneficial and interesting to have more time to interview students and other teachers and visit some lectures and lab works. However the couple of discussions with the teachers and students which were included were very good.

The findings and action plan

The process was very fruitful for Metropolia. Ideas how to improve students' possibilities for team working and other collaborative learning efforts were found. The visit was strengthening the value of some practises Metropolia has already implemented - however those need to be developed further. Student retention needs even more attention - and according to Aarhus model, that could be done by supporting students with their efforts of finding internships and coaching them, tracking the advancement of the studies more frequently and enabling distance education to create flexibility. Employability can be improved by strengthening the involvement of industry by industrial reviewers in exams and thesis works.

CONCLUSIONS

In general the use of an extended self-evaluation brightened understanding of the strengths and weaknesses of the study programmes involved. Both of the institutions found the time spend on the self-evaluation gave a good payoff.

The actual cross-sparrings were seen as worthwhile. Both study-programmes involved are at the same development point and had many mutual challenges like the lack of literature for the certain subjects and the difficulty for the students to figure out what Health Technology Engineering is.

Many examples of good practices were discussed and gave inspiration to both programmes. The fact that Metropolia's study programme just had gone through a major revision naturally made it difficult to see how things are done in detail. However, the way they focus on lowering the retention rate by focusing on the integration and well-being of each individual student was a major inspiration to Aarhus University. Metropolia's major inspirations were in the area of "soft skills" like learning to work in teams with the help of mentality and working style analysis. Additionally the use of distance learning and coached internships inspired Metropolia.

FUTURE WORK

The idea of cross-sparring is seen as a productive way to initiate study-programme development. Discussion is continuing on how the pairs should be matched - in the future it might be beneficial to give the participating units an opportunity to tell their preferences not only based on the evaluation criteria, but also based on the match of discipline. More experience is needed to create a working market place to fulfil the needs of different programmes.

ACKNOLODEGEMENT

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UPDATED RUBRIC FOR SELF-EVALUATION (v.2.1)

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ABSTRACT

On November 13, 2015 the CDIO Council approved an updated version of the self-evaluation rubric. This paper will present the updated version of the rubric along with some general thoughts on how to work with it. In this paper we will also present the process that started with a paper in the 2014 CDIO world conference identifying inconsistencies in the version 2.0 of the CDIO rubric for self-evaluation and ended in the proposed rubric.

KEYWORDS

Self-assessment rubric, quality assessment, continuous improvement, CDIO rubric, CDIO standards, Standard: 12

INTRODUCTION

One of the cornerstones of CDIO is a continuous improvement strategy. This is reflected in standard 12 — Program Evaluation: “A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement” (CDIO, 2010). As an aid for performing the self-evaluation a rubric was presented in 2010. In 2014 we presented our first paper on suggested changes (Bennedsen, Georgsson, & Kontio, 2014) that was followed by an updated proposal presented in (Georgsson, Kontio, & Bennedssen, 2015) and discussed at the CDIO Fall Meeting in Belfast in November 2015. The CDIO council approved the changes at their meeting on November 13 2015.

The outline of the paper is as follows: Firstly, the updated rubric will be presented, then an introduction on how to think about the levels of the rubric will be given along with some theoretical foundation. Lastly the process of developing the new rubric will be described.

THE UPDATED RUBRIC

Since this document is intended to serve as a description of the latest version of the CDIO rubric for self-evaluation it will be listed here in its entirety. We have chosen to list it alongside the old version of the rubric for comparison.

Table 1 Rubric for standard 1

Level	Old version of the rubric	New version of the Rubric
5	Evaluation groups recognize that CDIO is the context of the engineering program and use this principle as a guide for continuous improvement.	Evaluation groups where all relevant stakeholders are represented endorse CDIO as the context of the engineering program and use this principle as a guide for continuous improvement.
4	There is documented evidence that the CDIO principle is the context of the engineering program and is fully implemented.	There is documented evidence that the CDIO principle is the context of the engineering program and is implemented in all years of the program.
3	CDIO is adopted as the context for the engineering program and is implemented in one or more years of the program.	CDIO is implemented in one or more years of the program.
2	There is an explicit plan to transition to a CDIO context for the engineering program.	There is an explicit plan to transition to a CDIO context for the engineering program.
1	The need to adopt the principle that CDIO is the context of engineering education is recognized and a process to address it has been initiated.	There is a willingness to adopt the principle that CDIO is the context of engineering education.
0	There is no plan to adopt the principle that CDIO is the context of engineering education for the program.	There is no plan to adopt the principle that CDIO is the context of engineering education for the program.

Table 2 Rubric for standard 2

Level	Old version of the rubric	New version of the Rubric
5	Internal and external groups regularly review and revise program learning outcomes, based on changes in stakeholder needs.	Internal and external groups regularly review and revise program learning outcomes and/or program goals based on changes in stakeholder needs.
4	Program learning outcomes are aligned with institutional vision and mission, and levels of proficiency are set for each outcome.	NO CHANGE
3	Program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives.	Course **and/or** program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives and levels of proficiency are set for each outcome.

2	A plan to incorporate explicit statements of program learning outcomes is accepted by program leaders, engineering faculty, and other stakeholders.	A plan to incorporate explicit statements of learning outcomes at course/module level as well as program outcomes is accepted by program leaders, engineering faculty, and other stakeholders.
1	The need to create or modify program learning outcomes is recognized and such a process has been initiated.	The need to create or modify learning outcomes at course/module level and program outcomes are recognized and such a process has been initiated
0	There are no explicit program learning outcomes that cover knowledge, personal and interpersonal skills, and product, process and system building skills.	There are no explicit learning outcomes at course/module level nor program outcomes that cover knowledge, personal and interpersonal skills, and product, process and system building skills.

Table 3 Rubric for standard 3

Level	Old version of the rubric	New version of the Rubric
5	Internal and external stakeholders regularly review the integrated curriculum and make recommendations and adjustments as needed.	NO CHANGE.
4	There is evidence that personal, interpersonal, product, process, and system building skills are addressed in all courses responsible for their implementation.	There is evidence that the students have achieved the intended learning outcomes concerning personal, interpersonal, product, process and system building skills.
3	Personal, interpersonal, product, process, and system building skills are integrated into one or more years in the curriculum.	The approved integrated curriculum concerning personal, interpersonal, product, process, and system building skills is in use.
2	A curriculum plan that integrates disciplinary learning, personal, inter-personal, product, process, and system building skills is approved by appropriate groups.	The curriculum that integrates learning outcomes of personal, interpersonal, product, process, and system building skills is approved and a process has been initiated to implement the curriculum.
1	The need to analyze the curriculum is recognized and initial mapping of disciplinary and skills learning outcomes is underway.	NO CHANGE.
0	There is no integration of skills or mutually supporting disciplines in the program.	The curriculum has no courses known to integrate learning outcomes of personal, interpersonal, product, process, and system building skills.

Table 4 Rubric for standard 4

Level	Old version of the rubric	New version of the Rubric
5	The introductory course is regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.	The introductory course is regularly evaluated and revised as needed, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the introductory engineering course.	NO CHANGE
3	An introductory course that includes engineering learning experiences and introduces essential personal and interpersonal skills has been implemented.	NO CHANGE
2	A plan for an introductory engineering course introducing a framework for practice has been approved.	A plan for an introductory engineering course introducing a framework for practice has been approved and a process to implement the plan has been initiated.
1	The need for an introductory course that provides the framework for engineering practice is recognized and a process to address that need has been initiated.	The need for an introductory course that provides the framework for engineering practice is recognized and a planning process initiated.
0	There is no introductory engineering course that provides a framework for practice and introduces key skills.	NO CHANGE

Table 5 Rubric for standard 5

Level	Old version of the rubric	New version of the Rubric
5	The design-implement experiences are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.	NO CHANGE
4	There is documented evidence that students have achieved the intended learning outcomes of the design-implement experiences.	NO CHANGE
3	At least two design-implement experiences of increasing complexity are being implemented.	NO CHANGE
2	There is a plan to develop a design-implement experience at a basic and advanced level.	NO CHANGE
1	A needs analysis has been conducted to identify opportunities to include design-implement experiences in the curriculum.	NO CHANGE
0	There are no design-implement experiences in the engineering program.	NO CHANGE

Table 6 Rubric of standard 6

Level	Old version of the rubric	New version of the Rubric
5	Internal and external groups regularly evaluate the impact and effectiveness of workspaces on learning and provide recommendations for improving them.	The program leaders, students, teachers and external stakeholders regularly evaluate the functionality and purposefulness of workspaces on learning and provide recommendations for improving them.
4	Engineering workspaces fully support all components of hands-on, knowledge, and skills learning.	NO CHANGE
3	Plans are being implemented and some new or remodelled spaces are in use.	Development plans of engineering workplaces are being implemented and some new or remodelled spaces are in use.
2	Plans to remodel or build additional engineering workspaces have been approved by the appropriate bodies.	Workspaces, their functionality and purposefulness for teaching are being evaluated by internal groups including stakeholders
1	The need for engineering workspaces to support hands-on, knowledge, and skills activities is recognized and a process to address the need has been initiated.	NO CHANGE
0	Engineering workspaces are inadequate or inappropriate to support and encourage hands-on skills, knowledge, and social learning.	NO CHANGE

Table 7 Rubric of standard 7

Level	Old version of the rubric	New version of the Rubric
5	Courses are regularly evaluated and revised regarding their integration of learning outcomes and activities.	Courses are regularly evaluated and revised regarding their integration of learning experiences and the impact of these experiences.
4	There is evidence of the impact of integrated learning experiences across the curriculum.	There is evidence of the impact of the implementation of integrated learning experiences according to the integrated curriculum plan.
3	Integrated learning experiences are implemented in courses across the curriculum.	Integrated learning experiences are being implemented in courses across the curriculum according to the integrated curriculum plan.
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.	NO CHANGE
1	Course plans have been benchmarked with respect to the integrated curriculum plan.	NO CHANGE
0	There is no evidence of integrated learning of disciplines and skills.	NO CHANGE

Table 8 Rubric of standard 8

Level	Old version of the rubric	New version of the Rubric
5	Internal and external groups regularly review the impact of active learning methods and make recommendations for continuous improvement.	Internal and/or external groups regularly review active learning activities on outcome based learning across the curricula and make recommendations for continuous improvement
4	There is documented evidence of the impact of active learning methods on student learning.	There is documented evidence that active learning has been implemented suitably all across the curriculum
3	Active learning methods are being implemented across the curriculum.	NO CHANGE
2	There is a plan to include active learning methods in courses across the curriculum.	There is a plan and process to include active learning methods in courses across the curriculum.
1	There is an awareness of the benefits of active learning, and benchmarking of active learning methods in the curriculum is in process.	There is an awareness of the benefits of active learning and it is encouraged to introduce it across the curricula.
0	There is no evidence of active experiential learning methods.	NO CHANGE

Table 9 Rubric for standard 9

Level	Old version of the rubric	New version of the Rubric
5	Faculty competence in personal, interpersonal, product, process, and system building skills is regularly evaluated and updated where appropriate.	NO CHANGE
4	There is evidence that the collective faculty is competent in personal, interpersonal, product, process, and system building skills.	NO CHANGE
3	The collective faculty participates in faculty development in personal, interpersonal, product, process, and system building skills.	Where needed, the faculty participates in faculty development in personal, interpersonal, product, process, and system building skills.
2	There is a systematic plan of faculty development in personal, interpersonal, product, process, and system building skills.	Where needed, there is a systematic plan of faculty development in personal, interpersonal, product, process, and system building skills.
1	A benchmarking study and needs analysis of faculty competence has been conducted.	The need of faculty competence development plan in personal, interpersonal, product, process and system building skills is recognized.
0	There are no programs or practices to enhance faculty competence in personal,	NO CHANGE

	interpersonal, product, process, and system building skills.	

Table 10 Rubric for Standard 10

Level	Old version of the rubric	New version of the Rubric
5	Faculty competence in teaching, learning, and assessment methods is regularly evaluated and updated where appropriate.	NO CHANGE
4	There is evidence that the collective faculty is competent in teaching, learning, and assessment methods.	There is evidence that the faculty is collectively working on their competences in teaching learning and assessment methods
3	Faculty members participate in faculty development in teaching, learning, and assessment methods.	Faculty members participate continously in faculty development in teaching, learning, and assessment methods.
2	There is a systematic plan of faculty development in teaching, learning, and assessment methods.	A systematic plan of faculty development in teaching, learning, and assessment methods is developed and budgeted.
1	A benchmarking study and needs analysis of faculty teaching competence has been conducted.	A need for enhancing teaching competences is recognized and accepted within the team
0	There are no programs or practices to enhance faculty teaching competence.	NO CHANGE

Table 11 Rubric of standard 11

Level	Old version of the rubric	New version of the Rubric
5	Internal and external groups regularly review the use of learning assessment methods and make recommendations for continuous improvement.	NO CHANGE
4	Learning assessment methods are used effectively in courses across the curriculum.	There are evidence of aligned learning assessment methods
3	Learning assessment methods are implemented across the curriculum.	Learning assessment methods are aligned with the learning goals across the curriculum.
2	There is a plan to incorporate learning assessment methods across the curriculum.	There is a plan to align learning assessment methods with the curriculum.
1	The need for the improvement of learning assessment methods is recognized and benchmarking of their current use is in process.	The need for the improvement of learning assessment methods is recognized.
0	Learning assessment methods are inadequate or inappropriate.	Learning assessment methods are inadequate, inappropriate or not aligned

Table 12 Rubric of standard 12

Level	Old version of the rubric	New version of the Rubric
5	Systematic and continuous improvement is based on program evaluation results from multiple sources and gathered by multiple methods.	There is documented evidence that systematic and continuous improvement is based on continuous program evaluation results.
4	Program evaluation methods are being used effectively with all stakeholder groups.	There is documented evidence that program evaluation methods are being used with key stakeholders including students, faculty, program leaders, alumni and working life representatives.
3	Program evaluation methods are being implemented across the program to gather data from students, faculty, program leaders, alumni, and other stakeholders.	Program evaluation methods are being implemented across the program to gather data from majority of including the stakeholders (such as students, faculty, program leaders, alumni, working life representatives)
2	A program evaluation plan exists.	A continuous program evaluation plan exists.
1	The need for program evaluation is recognized and benchmarking of evaluation methods is in process.	NO CHANGE.
0	Program evaluation is inadequate or inconsistent.	Program evaluation is non-existing.

HOW TO WORK WITH THE LEVELS OF THE RUBRIC

There are six levels in the rubric describing levels of maturity. As shown in Table 13, the levels range from 0: there is no documented plan or activity related to the standard, to 5: evidence related to the standard is regularly reviewed and used to make improvements. In general, in order to be at level n, level n-1 should also be fulfilled. In this sense the levels of the rubric form a hierarchy, as described in Figure 1.

Table 13. A generic description of the CDIO rubric.

Level	Rubric
5	Evidence related to the standard is regularly reviewed and used to make improvements
4	There is documented evidence of the full implementation and impact of the standard across the program components and constituents.
3	Implementation of the plan to address the standard is underway across the program components and constituents.
2	There is a plan in place to address the standard.
1	There is an awareness of need to adopt the standard an a process is in place to address it.
0	There is no documented plan or activity related to the standard.

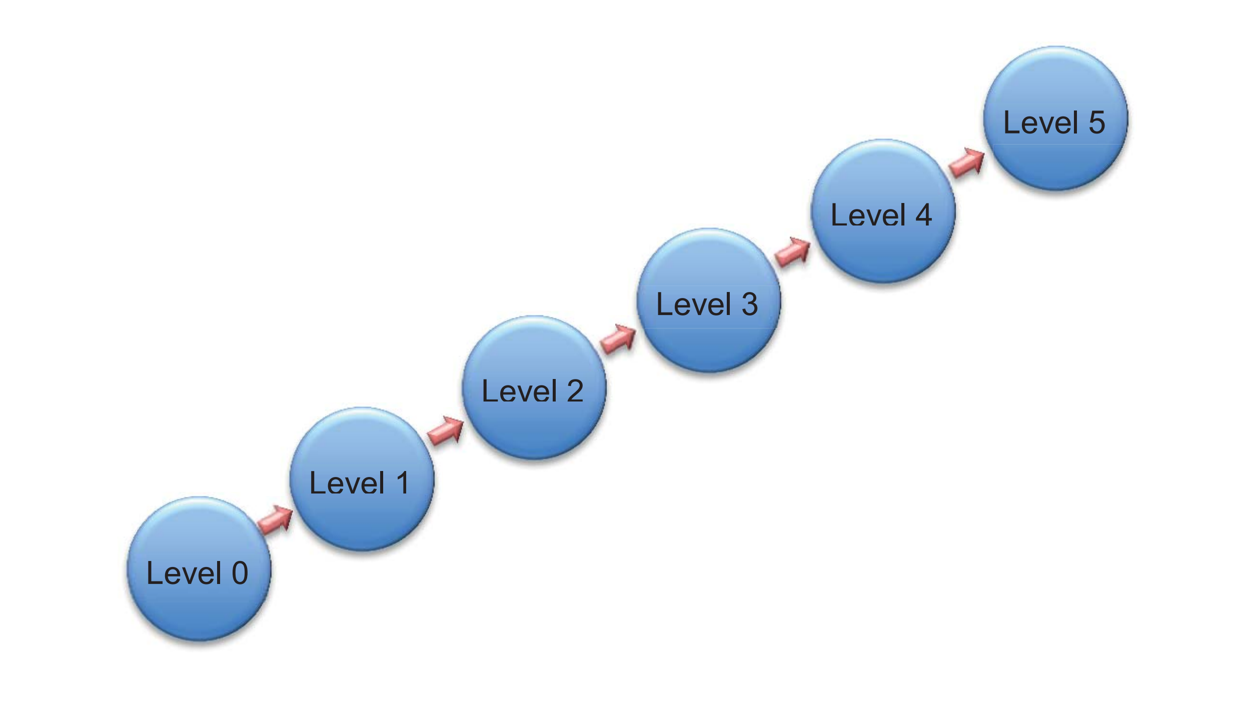

Figure 1 A hierarchical view of the levels of the rubric

One problem with this view is that you could be tempted to view level 5 as a final state, indicating that you in some way have "finished" your quality work when you self-assess yourself at this level (as indicated in Figure 1). It can even be so that you run into trouble when it comes to level 4: There is documented evidence of full implementation, which tells us that we have reached a satisfactory implementation of the standard and you might be tempted to stop the developing process there. At this point we must stress that the correct interpretation of level 5 is that you have made sure you have a satisfactory level of implementation (level 4) and that you have processes in place that guarantee continued improvements, i.e. you can never state that you are finished when it comes to improving yourself.

We suggest that it could be helpful to think about the levels of the self-assessment rubric as shown in Figure 2: First we have to conceive what the standard is all about, during that process we are at level 1. When we start designing how we should address the implementation of the standard we are at level 2. When we start implementing the design we are at level 3. After level 3, we leave the linear implementation phases and enter an operation phase where we repeatedly assess that we have an accepted level of implementation (level 4) but still systematically address the shortcomings of our implementations (level 5). With this view of self-assessment it is obvious that we never will be finished.

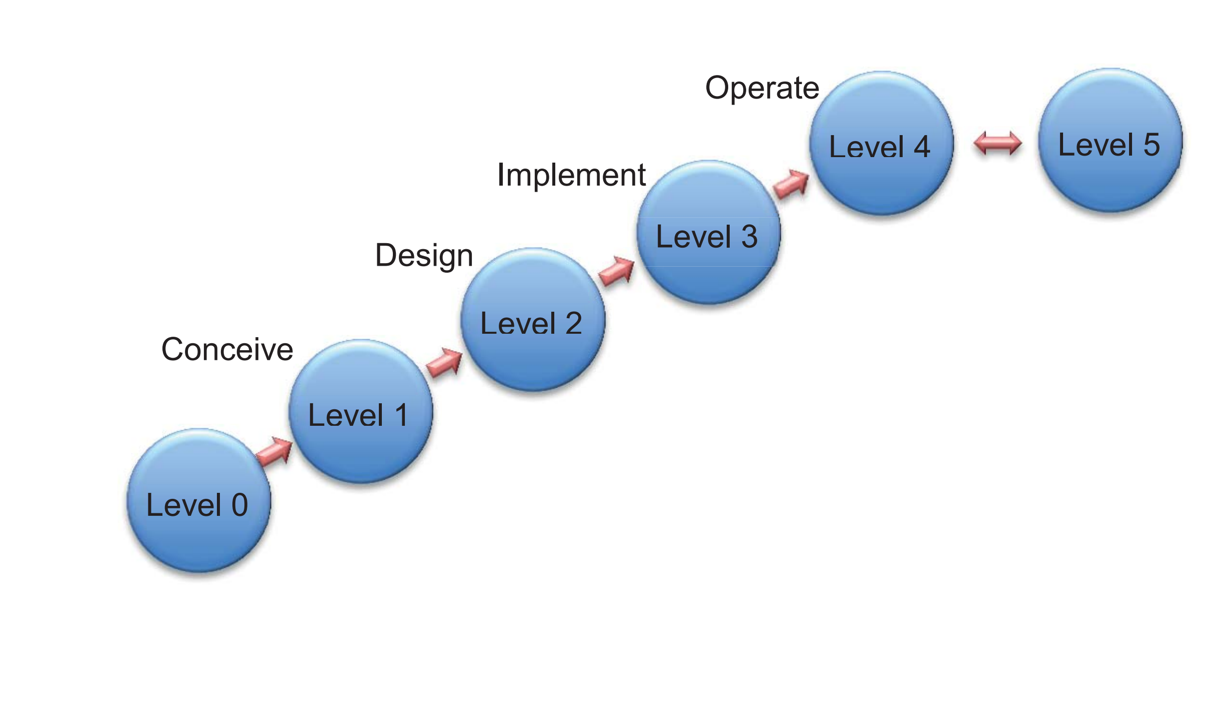

Figure 2 Process focus of the levels of the rubric

THE RUBRIC VS. OTHER QUALITY ACCREDITATION SYSTEMS

Improving quality of the higher educational systems, its universities and programmes are very much in focus all over the world. In many (most?) countries, accreditation bodies are in place that will ensure the quality of a program or an institution. Such bodies exist in many shapes and forms; private bodies like ABET (ABET, 2016), public bodies like the Danish Accreditation agency (The Danish Accreditation Institution, 2016), bodies covering one country like (CTI, 2016) and bodies covering many countries like EURACE (ENAEE, 2016). All of these have their own accreditation system. For a description of accreditation systems see (Bennedsen, Clark, Rouvrais, & Schrey-Niemenmaa, 2015)

The accreditation systems of today are mostly inspired by quality models like EFQM (EFQM) or the Capability Maturity Model used for software development (Paulk, Curtis, Chrissis, & Weber, 1993) where the focus is on process maturity and continuous improvement rather than a measurement of the current status (although the evaluation of the current state is an important part of the quality process).

Boele at al. (Boele, Burgler, & Kuiper, 2008) describe the EFQM model like this:

> *The EFQM (European Foundation for Quality Management) model basically looks at an organization, its results, and the way the results lead to learning, improvement and innovation. It was developed for firms but can be applied to any kind of organization.*

An accreditation system typically consists of an assessment model, an assessment process and a measurement framework (Rouvrais & Lassudrie, 2014). The assessment process describes how and when the assessment is done (how data is collected and validated and how the planning is done). The process focuses on the roles and responsibilities of the involved stakeholders, the inputs and the outputs. The assessment process is supported by an assessment model. The assessment model is based on a reference model that defines a set of best practices (or standards) related to the domain that needs to be assessed. It is measurement against these standards that is important as this is then the basis for improving quality. The measurement framework defines the maturity levels to be considered and contains a set of assessment indicators which support the ratings against the various standards. The CDIO rubric is therefore NOT an accreditation system; we have only described the measurement framework and that even without a set of indicators that could be used to indicate on what level a given programme/institutions is with respect to a given standard.

We have chosen NOT to include these elements since the rubric's main purpose is for internal use. It is therefore not important that it is reliable (i.e. that the rubric gives the same score when applied by different individuals on the same programme and/or that it is possible to compare self-evaluations from different institutions)

THE METHOD, MATERIAL AND DATA OF UPDATING THE RUBRIC

The process for updating the rubric has had several cycles. At the beginning the authors were discussing about CDIO self-evaluation and compared their experiences in using CDIO standards for self-evaluation. It became obvious that CDIO standards with the rubrics were in active use in the authors' universities, but we all had noticed some challenges with the exact definition of the rubric levels, usability of the rubrics as well as the coherence of the rubrics. The discussion started a development process where each of the authors worked with four standards and produced a new proposal of those rubrics. The standards were then cross-checked and at the end first modified version of the rubrics was published in CDIO conference in Barcelona (Bennedsen, Georgsson & Kontio, 2014). The feedback received in Barcelona showed that rubrics still need modifications and especially opinions from other CDIO collaborators were hoped. We ourselves shared this opinion and wanted to get feedback from the CDIO community. The CDIO council asked the authors to continue this development work aiming at new version of CDIO rubrics to the 12 standards. The goal was set to produce CDIO standards with rubrics v. 2.1.

The next development cycle started with the aim of getting feedback in a more systematic way. We wanted to evaluate the proposed improvements and modifications among the other CDIO members. We wanted to hear whether they see the proposed changes necessary at all and whether the new proposed rubrics are more understandable. In addition, we wanted to see if there are needs to further modify and improve the rubrics. The data collection had two phases: a web questionnaire and short semi-structured interviews with selected CDIO collaborators. The web questionnaire was sent to all CDIO collaborators representing the CDIO member universities at the end of 2014. In addition, more detailed comments were acquired with a short semi-structured interview with selected CDIO collaborators and a session at the 2014 fall meeting with experienced CDIO members. Based on the feedback an improved version of CDIO rubrics was presented and processed in a workshop during the CDIO conference in Chengdu 2015 (Georgsson, Kontio & Bennedssen, 2015). The workshop in Chengdu once more processed, checked and provided input for final improvements.

The third development cycle used the results of the Chengdu workshop and tuned the final nuances of the rubrics. The final version of the rubrics was presented in CDIO council meeting in Belfast 2015. The proposed changes were accepted as presented in this paper. The whole process of rubrics development is shown in Figure 3.

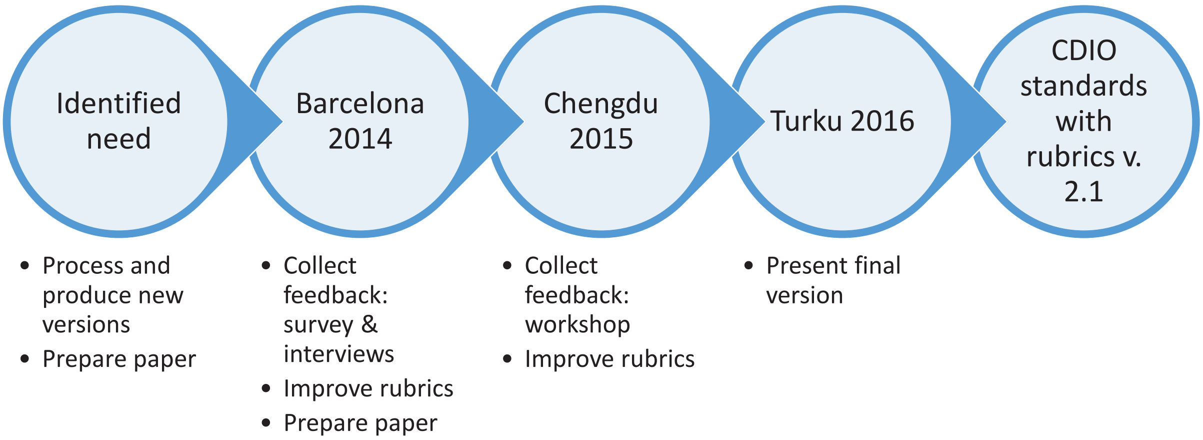

Figure 3. Overall process of rubrics development.

CONCLUSION

Based on the rubrics development the overall change process within CDIO-framework can be generalized into following:

1. Have an idea on what to change
2. Find others that are willing to discuss it
3. Inform the council about the wish to change
4. Perform an analysis – that is analyze current presentation based on theory, existing documents etc.
5. Conduct a survey or in some other way collect the opinion of the CDIO-members
6. Document including analysis and proposed changes, normally together with additional CDIO collaborators that want to contribute. The style of the paper should be to clearly compare what exist to what is proposed and for every change clearly justify why it is proposed.
7. Present at CDIO conference, preferably in workshop-format where you collect feedback on proposed changes in a structured comparative way.
8. Revise suggestion based on feedback and present to the council.
9. Once the change is accepted by the council, report the final version at a CDIO-world conference.

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ENHANCING QUALITY TOGETHER WITH CDIO COMMUNITY

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ABSTRACT

The CDIO self-evaluation is a valuable tool for any program to enhance quality. The self-evaluation provides information on your progress in continuous development, it shows your strengths and your weaknesses too. This information has traditionally used within the program although it could provide interesting and remarkable observations and possibilities to other programs too. Too often this information is hidden in the program itself and seldom is it opened to other universities for benchmarking and critical observations. CDIO community shares the ideology to continuously improve engineering education and is thus an obvious possibility for sharing information and learning from others. Based on this idea a series of externally funded projects have been established introducing self-evaluation, cross-evaluation and critical friendship. Two first projects operated in Scandinavia and in the Baltic Sea region. The latest project is European wide and number of partners have doubled since the first project. Projects have aimed at improving existing quality assurance tools and at developing new tools for quality enhancement. The projects introduced new programmes to each other and programmes have identified new areas of development as well as common development areas. These projects have shown that the strength of CDIO community in enhancing quality is clear and it should be utilized much more.

KEYWORDS

Quality enhancement, Program development, International collaboration, Self-evaluation, Cross-evaluation, Cross-sparring, ENQA, Standards: 12

INTRODUCTION

A report of the European Commission places high expectations to the quality assurance in higher education by stating that it is at the heart of efforts to build a coherent, compatible and attractive European Higher Education Area (EHEA) (European Commission, 2009). Quality assurance in higher education is based on the responsibility of the institutions for the quality of their programmes (ENQA, 2015). In Europe the standards and guidelines for quality assurance in higher education are defined by European Association for Quality Assurance in Higher Education (ENQA). Their guidelines divide quality assurance in three parts (ENQA, 2015): 1) Internal quality assurance 2) External quality assurance and 3) Quality assurance agencies. In the CDIO initiative quality assurance and quality enhancement is supported with the Standard 12 – Program evaluation. This standard presents a system that evaluates programs against twelve CDIO standards, and provides feedback for students, faculty, and other stakeholders for the purposes of continuous improvement. The CDIO program evaluation and ENQA internal quality assurance can be seen focusing on similar aspects of higher education. In CDIO, a key function of program evaluation is to determine the program's effectiveness and efficiency in reaching its intended goals thus serving as the basis for continuous program improvement.

The CDIO program evaluation – self-evaluation – is done for analyzing the program's development and for targeting the continuous improvement goals. It is a tool for your program's quality enhancement. However, the program evaluations could provide fruitful information and help other programs too. There is a possibility that other programs could learn from the self-evaluations and identify good practices for their development. In addition, others might also act as critical friends to the other program by providing different viewpoints and aspects to the self-evaluation and program development. Although one of the strengths of the CDIO initiative is the broad community of engineering educators from around the world of higher education institutes, we have not used this power of CDIO community much. However, there are also successful examples of using this power of CDIO community and critical friends. First example started in 2009 with four collaborators, second example started in 2011 with six collaborators and the third example started autumn 2014 with eight collaborators and continues until September 2016. All these efforts have been externally funded projects. One of the ideas in these efforts was to complement internal quality assurance with external quality assurance including an external assessment with a site visit and a report resulting from the external assessment.

The first project focused on self-evaluation and cross-sparring within Scandinavia. It was very strongly based on CDIO standards and a one-day site visit activity was included. Four programs from four different universities participated. The second project had partners from Finland, Sweden, Denmark, Estonia and Lithuania. Four new programs from the participating universities worked on their quality enhancement during this project. The project had three main phases: workshops, self-evaluation, and cross-evaluation. The workshops were supporting pedagogical development, quality assurance and evaluation phases in partner universities. The latest project is an European-wide project and has higher ambitions.

This paper reflects the projects and their influence on quality enhancement. It looks back to the external quality assurance recommendations and reflects them at CDIO too. The paper also discusses the various possibilities within CDIO community to enhance quality together.

CDIO AND ENHANCEMENT OF QUALITY

The European Commission report (European Commission, 2014) underlines the importance of developing quality culture in higher education institutions and points to the value of institutional evaluation which it states "empowers academics and HEIs to build curricula and to ensure their quality, avoiding the need for the formal, external accreditation of each individual programme". The CDIO approach uses standard-based program evaluation model to describe how well a program is implementing CDIO and is building the culture of continuous improvement (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014). The CDIO approach answers quite well to the internal quality guidelines of ENQA as shown in table 1. ENQA has 10 different guidelines for internal quality assurance.

Table 1. ENQA guidelines and CDIO approach.

ENQA Internal Quality Guideline	The CDIO Approach
Policy for quality assurance	CDIO does not focus on policy, but CDIO implementation does support implemention of the policy for QA too.
Design and approval of programmes	CDIO standards 2 (Learning Outcomes), 3 (Integrated Curriculum) and 7 (Integrated Learning Experiences) cover part of topics described in this ENQA guideline, but CDIO does not go as deep, it does not look programmes as thoroughly and as widely.
Student-centred learning, teaching and assessment	Standards 8 (Active Learning) and 11 (Learning Assessment) focus exactly same topics as this ENQA guideline.
Student admission, progression, recognition and certification	CDIO approach does not focus on student admission, progression, recognition and certification, but it surely aims at better progression of the student.
Teaching staff	Standards 9 (Enhancement of Faculty Competence) and 10 (Enhancement of Faculty Teaching Competence) focus on staff development similarly as this ENQA guideline.
Learning resources and student support	Standard 6 (Engineering workspaces) is about physical learning resources, but is does not deal with teacher resources and student support.
Information management	This is not present in CDIO model.
Public information	This is not present in CDIO model.
On-going monitoring and periodic review of programmes	Standard 12 (Program Evaluation) emphasizes continuous periodic review of programmes.
Cyclical external quality assurance	CDIO does not encourage to external quality assurance, but standard 12 (Program Evaluation) defines reports from external evaluations as one of the possible sources to be used in programme evaluation.

The second part of quality assurance guidelines by ENQA emphasizes external quality assurance. According to the guidelines external quality assurance processes should be reliable, useful, pre-defined, implemented consistently and published (ENQA, 2015). As mentioned already in table 1, the CDIO approach does not emphasize external quality assurance. The projects described in this paper aimed at producing methods and tools for this external process. ENQA defines the following processes for implementing external quality assurance (ENQA, 2015):

- a self-assessment or equivalent
- an external assessment normally including a site visit
- a report resulting from the external assessment
- a consistent follow-up.

EXAMPLES TO ENHANCE QUALITY TOGETHER WITH CDIO COMMUNITY

CDIO community is built on the common vision on improving engineering education. It is typical that CDIO community shares experiences during the international CDIO conference, Fall meeting and regional meetings. However, it is not typical that CDIO programmes work closely together on sharing information on their self-evaluation and on their development challenges not to mention site-visit focusing on quality enhancement. This possibility exists and it has been tested in three European projects since 2009. Based on the idea of sharing best practices and learning from other members of CDIO community a series of externally funded projects have been established introducing self-evaluation, cross-evaluation and critical friendship. Two first projects operated in Scandinavia and in the Baltic Sea region. The latest still running project is European wide and number of partners have doubled since the first project. All these projects have aimed at improving existing quality assurance tools and at developing new tools for quality enhancement. These three projects are listed in table 2 and they are introduced shortly in next sections.

Table 2. Quality enhancement project examples.

Project name	Project period	Number of partners	Funded by
Quality assurance in higher education 1	Oct. 2009 – Oct. 2011	4	Nordplus
Quality assurance in higher education 2	Aug. 2011 – Sep. 2012	6	Nordplus
Quality assurance and enhancement marketplace for higher education institutes	Sep. 2014 – Aug. 2016	8	Erasmus+

QA in HEI 1

The first project – Quality Assurance in Higher Education - focused especially on self-evaluation, but cross-sparring element was introduced too. The main goal was to develop and implement a self-evaluation model in the participating Higher Education Institutes (HEIs) to support their quality assurance work and continuous curriculum development. The self-evaluation model was strongly based on the CDIO standards. The project had four partners: the Turku University of Applied Sciences (TUAS) (Finland) as the coordinator, and the Swedish Royal Institute of Technology (KTH), the Technical University of Denmark (DTU), and Helsinki Metropolia University of Applied Sciences (Metropolia) (Finland) as other partners. Each partner had one pilot degree programme that participated into the project.

The project defined an external quality assurance process with five steps:

1. Create the program description
2. Make the self-evaluation
3. Time for improvement and development
4. Preparing for cross-wise evaluations
5. Cross-evaluations.

The program description was a maximum 10 pages providing key understanding about the programme. This description was supposed to be specific enough to enable the assessment of the programme (Step 2). The self-evaluation was based on programme description. It was supposed to contain the actual CDIO ratings of the programme and recommendations for improvements. Furthermore the three best practices were expected to be presented. Preparations for the cross-wise evaluations consisted the description of actions taken after self-evaluation and selection of five theses. The final step was cross-wise evaluations which included a site-visit. After the visit, a cross-wise evaluation report was expected as well as the evaluation of the actual process. The project is described in more detail in (Kontio et al., 2011; Kontio, Roslöf, et al., 2012).

QA in HEI 2

The second project continued the themes and ideas of the first project including self-evaluation and cross-evaluation but it also introduced a new phase in the project: workshops. Workshops were supporting pedagogical development, quality assurance and evaluation phases in partner universities. This second project had the same partners as the first one and two new partners from Baltic countries: the University of Tartu from Estonia and the Vilnius University of Applied Sciences from Lithuania. During the project four new programs worked on their quality enhancement during this project. The main goal of the project was to disseminate the quality assurance methods and tools developed in Quality Assurance in Higher Education Institutes project (2010-2011) to new partner universities from Baltic countries and to new programmes on the old partners. In this follow-on project the Nordic partners acted as mentors by guiding new partners through the quality assurance process and familiarizing them with CDIO framework which provides the methodological basis for educational quality assurance.

The project organized three workshops in pedagogical development and quality assurance:
- Pedagogical CDIO workshop I
- Self-evaluation and QA workshop
- Pedagogical CDIO workshop II.

The workshops were defined to provide support for the pedagogical development and quality assurance work. The workshops were delivered by representatives of two project partners: the Turku University of Applied Sciences and the Royal Institute of Technology. Each workshop had around 15-20 participants.

Besides the workshops, this second project had the same self-evaluation and cross-evaluation phases. This project is described in (Kontio, Granholm, et al., 2012).

QAEMP

The latest project is an European-wide project and has higher ambitions. The tools and processes developed in the preceding projects functioned quite well, but the partners wanted to do more to support continuous quality enhancement. The first two projects provided valuable input and experiences when Erasmus+ funded was created. The partners identified a need for more flexible evaluation models and processes with peers compared with the inertia of heavy accreditations/evaluations in HEIs. The aim was to create more practical level quality assurance model that sustains continuous reform between accreditation rounds. The Quality Assurance and Enhancement Marketplace for Higher Education Institutes (QAEMarketPlace4HEI) –project (Figure 1) proposes a flexible and constructive/collaborative methods, processes and tools for program evaluation, as a complement to weighty/ponderous accreditations.

Figure 1. QAEMP project logo.

QAEMP-project has eight partners of which only the Finnish partners have participated in both preceding projects too. The project partners are Turku University of Applied Sciences (Finland), Reykjavik University (Iceland), Aarhus University (Denmark), Helsinki Metropolia University of Applied Sciences (Finland), Umeå University (Sweden), Telecom Bretagne (France), Aston University (United Kingdom) and Queens University Belfast (Northern Ireland, UK). The project is coordinated by Reykjavik University.

One of the key results of this project is the Marketplace. The Marketplace is a web-based tool where programmes can enter their self-evaluation results and based on these the system will pair programmes with the best match for cross-sparring. The idea is that programmes can learn from each other's strengths and weaknesses. Thus programmes are paired together to support their continuous development.

In addition, this project did a lot of improvements to the self-evaluation and cross-sparring methods. As noticed, this project uses term cross-sparring instead of cross-evaluation to emphasize the ideology of learning and supporting in the process. Furthermore, this project has arranged a number of workshops introducing the developed processes and to activate collaboration between HEIs. This project will end in August 2016. A general presentation of the project can be found in (Kontio et al., 2015) and descriptions of the cross-sparring activities between project partners as shown below:

- Turku University of Applied Sciences (Finland) and Aston University (UK) (Clark, Kontio, Roslöf, Steinby, & Thomson, 2016)
- Queens University Belfast (Northern Ireland, UK) and Umeå University (Sweden) (McCartan, Hermon, Georgsson, Björklund, & Pettersson, 2016)
- Aarhus University (Denmark) and Helsinki Metropolia University of Applied Sciences (Finland) (Bennedsen & Schrey-Niemenmaa, 2016)
- Reykjavik University (Iceland) and Telecom Bretagne (France) (Rouvrais, Auðunsson, Sæmundsdóttir, Landrac, & Lassudrie, 2016).

DISCUSSION

The presented projects aimed at the external quality assurance although they had strong focus at the beginning in internal state of the programme with the self-evaluations model and guidelines. In these projects 16 very thorough self-evaluations have been done and 32 cross-evaluation/cross-sparring sessions have been held.

Table 3 compares the ENQA processes proposed in external quality assurance with the processes in these three projects. The first two projects focused on the same things with different programmes while QAEMP took bigger step towards real collaboration in quality enhancement together with other universities.

The developed models worked well, but they all had some very time consuming elements. On the other hand, putting more effort on the quality assurance and enhancement activities it rewards one with better and deeper understanding about the programme. Therefore we could say that it is valuable to be forced to look closer at one's own programme.

The cross-evaluations and cross-sparrings required commitment and willingness to succeed, but they proved to be the most rewarding parts of these projects. Even a short site-visit gives you much better understanding of the other programme than only going through the self-evaluation documentation.

The workshops in QA in HEI 2 and QAEMP projects proved necessary. In QA in HEI 2 they served as training sessions for people who were not so familiar with the self-evaluation and CDIO. Similarly QAEMP workshops have given valuable input to the functionality of the developed tools and at the same time they have shown us that there is a need for the marketplace to pair and connect CDIO programmes with quality enhancement.

Table 3. ENQA external guidelines and QA project activities.

ENQA guideline	QA in HEI 1	QA in HEI 2	QAEMP
Self-assessment or equivalent	Self-evaluation toolkit produced and tested/used	Self-evaluation toolkit improved and tested/used	Used existing self-evaluation tools, but created a list of parameters to be checked after self-evaluation
An external assessment normally including a site visit	Included a one-day site visit; focus on finding additional development areas and identifying best practices; Emphasis on evaluating the partner and providing feedback for their development (Cross-evaluation)	Included a one-day site visit; focus on finding additional development areas and identifying best practices; Emphasis on evaluating the partner and providing feedback for their development (Cross-evaluation)	Included a two-days site visit; focus on finding additional development areas and identifying best practices; Emphasis on sparring the partner programme (Cross-sparring)
A report resulting from the external assessment	Short A4 summary report produced	Short A4 summary report produced	Broader report written together with the evaluators and evaluated produced.
A consistent follow-up	Each program responsible of their own follow-up	Each program responsible of their own follow-up	Each program responsible of their own follow-up; Encourages common development activities with the sparring partner

CONCLUSION

This paper has introduced three examples from CDIO community where CDIO programmes enhance quality together. The CDIO universities have developed tools and methods for self-evaluation, cross-evaluation and cross-sparring. These tools are then tested and used in pilot programs. Based on the CDIO community activities these programs have undergone thorough self-evaluation process and they have joined cross-evaluation/cross-sparring activities. These projects have proven the strength of collaborating and since universities in CDIO community already share a common approach to education development a common language can easily be found. During these activities, 16 programmes around Europe have visited another university usually in another country. They have learnt from the other programmes but this has also been a good journey for them to learn about themselves. The projects introduced new programmes to each other and programmes identified new areas of development as well as common development areas.

These projects have shown that the strength of CDIO community in enhancing quality is clear and it should be utilized much more. To summarize the possibilities to enhance quality and support continuous development together with the other CDIO programmes could be:

1. Increase the awareness of CDIO self-evaluation
2. Support newcomers on the usage of CDIO self-evaluation
3. Joint pedagogical workshops
4. Participation in cross-sparring and visiting other programmes
5. Identify common development themes and initiate common development actions.

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ADAPTING CDIO TO CIVIL ENGINEERING: INVESTIGATE – PLAN – DESIGN – CONSTRUCT – OPERATE AND MAINTAIN

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ABSTRACT

The aim of this paper is to propose an alternative expression for engineering practice in the context of the civil engineering and built environment sector. Our first objective is to demonstrate that the CDIO approach can, with these modifications, be applied in developing civil engineering and built environment programs. Our second objective is to showcase the adaptability of the CDIO approach, thereby encouraging other thoughtful modifications and transformations. We outline the ideas underpinning the original expression, and identify the role it plays in the CDIO methodology for curriculum development. Taking these factors into account, a modified expression is proposed to describe the engineering process in civil engineering and built environment. We divide the process into '*investigation – planning – design – construction – operation and management*'. Further, to '*products, processes and systems*', we propose the addition of '*environments*'.

KEYWORDS

Civil engineering, built environment, conceive-design-implement-operate, adaptations of CDIO, Standard 1.

BACKGROUND

The fundamental aim of the CDIO Initiative is to strengthen the ways in which graduates prepare for engineering practice in their education. The CDIO approach refers to an image of engineering practice as "*conceiving, designing, implementing and operating products, processes and systems*"; hence the acronym CDIO. The words were carefully chosen to be as inclusive as possible, as the intention was in fact to broaden the conception of engineering practice. When the CDIO Syllabus was first published (Crawley, 2001) it was claimed to be "*universal, in that it has deliberately been written to be applicable to all engineering disciplines*" (p. ii). However, Crawley recognises a possible bias on the detailed levels of the Syllabus, and recommends customization "*to the needs and objectives of the specific local program and disciplinary field*" (p. 13).

Despite the clear ambition to achieve universal appeal, engineering programs have to various degrees felt included in the phrasing, and this has been a challenge in promoting the CDIO approach as suitable for programs in all fields of engineering. When trying to explain the essence of CDIO in its most succinct form to engineering faculty, the message is basically that the aim is to strengthen the professional side of engineering education (not at the expense of disciplinary understanding but through a purposeful integration of these two sides of education). However, it is easy to get stuck in explaining the actual acronym and its components, and this can take most of the time in an “elevator pitch’” situation. Our impression is that the terms do not possess immediate face validity in relation to programs such as civil engineering, chemical engineering, engineering physics etc.

In January 2015, Luleå University of Technology (LTU) became a CDIO Collaborator and a pilot project is currently underway implementing CDIO in four programs, one of which is the five-year Master of Science in Civil Engineering. The implementation project takes its starting point in a self-evaluation in relation to the CDIO Standards with rubrics (CDIO, 2010). In the process of joining CDIO, and in the early phases of program analysis and development, we find that the terminology is different to the language normally used by the faculty in civil engineering and built environment. The expression “*conceiving, designing, implementing and operating products, processes and systems*” was seen as unfamiliar, and reminded more of fields closer to mechanical engineering. This led us to search for an alternative expression more appropriate for civil engineering.

We note that both the open architecture of CDIO as a concept and the inclusiveness of the CDIO Initiative, serve as excellent strategies for maximising dissemination for the sake of engineering education stakeholders worldwide. Since the essential aim of CDIO is to promote educational reform to strengthen the professional aspects of engineering education, it is important that programs are developed based on a good understanding of its own professional context. The dialogue around the program will benefit from using language that can resonate with internal and external stakeholders.

In this paper, we begin by investigating whether earlier CDIO implementers in civil engineering have reported any similar experiences. Then, before we start discussing possible alternative phrasings, we must consider whether such customization is acceptable and reasonable. CDIO is certainly open for adaption to the particular contexts. However, what we are contemplating could be seen as a reformulation of *the fundamental idea* underpinning the whole CDIO approach – and is that something that can actually be changed? To analyse possible consequences of our proposed adaptation, we will therefore identify the functions fulfilled by the expression in the core definitions of CDIO, i.e. in the *CDIO Syllabus*, in the *CDIO Standards*, and in the name of the *CDIO Initiative*. Finally, we discuss the terminology normally used in the context of civil engineering practice, and end by proposing a new expression.

PREVIOUS IMPLEMENTATIONS OF CDIO IN CIVIL ENGINEERING PROGRAMS

Literature in CDIO conferences

The issue of adapting CDIO to civil engineering is mentioned already in the first CDIO Conference. In the 2005 Swedish national evaluation of MSc engineering programs, a self-evaluation according to the CDIO Standards was mandated as a component in the national scheme. Summing up the experiences, Malmqvist, Edström, Gunnarsson, and Östlund (2005) note that Standard 1, The Context, “*caused problems concerning interpretation and relevance*”. Anticipating this, programs had been encouraged to modify Standard 1 to define their particular context. One civil engineering program had decided on the wording: “*The principle is to educate engineers to meet the needs of the construction industry, i.e. for planning, design, engineering, production, operations and maintenance*” (p.10). We have not, however, found any documentation of continued discussions on this issue within the CDIO community.

The lack of discussion should not be taken to suggest that there are few CDIO implementers within civil engineering. The CDIO status survey (Malmqvist, Hugo, & Kjellberg, 2015) was sent to approximately 120 Universities all around the world in order to map in what disciplines CDIO is applied and further on to evaluate the effects on implementing CDIO and to identify the needs for the future. The survey had 47 responses from 22 countries and the results showed that 31.9% of the institutions applied CDIO to civil engineering programs. Despite this widespread participation of civil engineering programs, the remarks by Xiong and Lu (2007) still seem valid. They found that little material on using the CDIO initiative is available for civil engineering programs and point out that the suggested CDIO standards are not fully applicable for the building environment, such as large bridges, long tunnels and skyscrapers.

In the CDIO literature we find descriptions of courses featuring design-implement experiences, such as small-scale versions of houses, or material courses using bars or cubes, exists as good examples within civil engineering (Li, Yang, & Xiong, 2009; Millard & Jones, 2009; Rode, Christensen, & Simonsen, 2011). However, the enormous complexity of full-scale railways, nuclear waste power plants, water infrastructure and large infrastructure projects such as moving a whole town will not be reflected in small-scale versions. Other useful contributions address the issue of traditionally “pure” basic courses, and lacking examples related to the civil engineering area. This is a common situation also for many other engineering programmes, regarding e.g. mathematics, physics and mechanics. There are well-described experiences in courses those have been transferred into CDIO courses for civil engineers (Loyer, 2013; Ulfkjaer & Bundgaard Nielsen, 2012).

Hence, single courses and their content have been successfully developed drawing on the CDIO methodology, but there is little documentation of how a whole MSc program in Civil Engineering has considered its particular context more deeply, especially of implementing and operating products.

THE FUNCTIONS OF THE C-D-I-O EXPRESSION

It symbolises what engineers do

The expression “*conceiving, designing, implementing and operating products, processes and systems*” was formulated to capture *what engineers do*. The verbs were deliberately chosen to be generic terms that could appear inclusive to all branches of engineering. For instance, instead of *manufacturing*, which was first considered, the more general term *implementing* was chosen (Crawley, 2015). The object of engineering was also described in inclusive terms. Crawley, Malmqvist, Östlund, and Brodeur (2007) explain that “*to simplify and standardize the terminology, the terms product, process and system are consistently used for the object the engineer designs and implements, which depending on the sector, is called a product, process, system, device, network, code, plant, facility, or project*” (p.9).

It is represented in the CDIO Syllabus

The CDIO Syllabus is a list of topics that can be used to formulate the intended learning outcomes of an engineering program, addressing the fundamental question: “*What is the full set of knowledge, skills and attitudes that engineering students should possess as they leave the university, and at what level of proficiency?*” (Crawley, Malmqvist, Östlund, Brodeur, &

Edström, 2014, p. 34). The Syllabus is not prescriptive, but intended to serve as inspiration for a broad understanding of the competences needed for engineering practice. Section 4 of the CDIO Syllabus, relates to *conceiving* (4.3), *designing* (4.4), *implementing* (4.5) and *operating* (4.6).

It is present in the CDIO Standards

The phrase "*conceiving, designing, implementing and operating products, processes and systems*" is used throughout the CDIO Standards. It is at the core of the first portal standard expressing the main idea, i.e. that we educate students to become engineers who can actually engineer. Standard 1 reads: "*The Context: Adoption of the principle that product, process, and system lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education*."

To achieve this aim, Standards 2, 3, 7, 9, and 11 use the expression "*personal and interpersonal skills, and product, process, and system building skills*" to denote all the intended learning outcomes that relate to skills, abilities, approaches and judgement. We like to think of it as *engineering skills* in a very wide sense, i.e. everything that graduates need from their program in addition to the disciplinary fundamentals, to be prepared for life and working life.

Standards 4, 5 and 6 refer to particular forms of learning activities for "*product, process, and system building*". Standard 4 concerns an introductory course where students should first be exposed to engineering practice, and Standard 5 refers to a sequence of more advanced learning activities, called "*design-implement experiences*". Standard 6 is about environments to support such learning activities.

It gave the CDIO Initiative its acronym

The acronym formed from the expression "*conceiving, designing, implementing and operating*", the working definition of engineering practice, came to name the whole CDIO Initiative. It serves as a reminder that the aim of the endeavour is to strengthen the professional side of engineering programs. On the positive side, it has achieved some symbolic status and become something of a brand. At the same time, the acronym can also be a burden, if some engineering programs feel excluded.

WHAT ENGINEERS DO IN CIVIL ENGINEERING

The civil engineering process

A typical construction project can be divided into the stages of investigation, planning, design, construction, and operation and maintenance. The division of the construction process is not typical for all cases but gives an understanding and outline of the stages leading to, for instance, a building.

Just like in the conceive-design-implement-operate, we do not imply that there is only a straight linear process, but it is rather to be seen as the holistic background to any specific activity. For many situations the investigation and planning stages go back and forth due to for instance risk assessment and social development in infrastructure underground projects.

The process can also look differently depending how the project is organised. The typical construction phases can be seen in Figure 1.

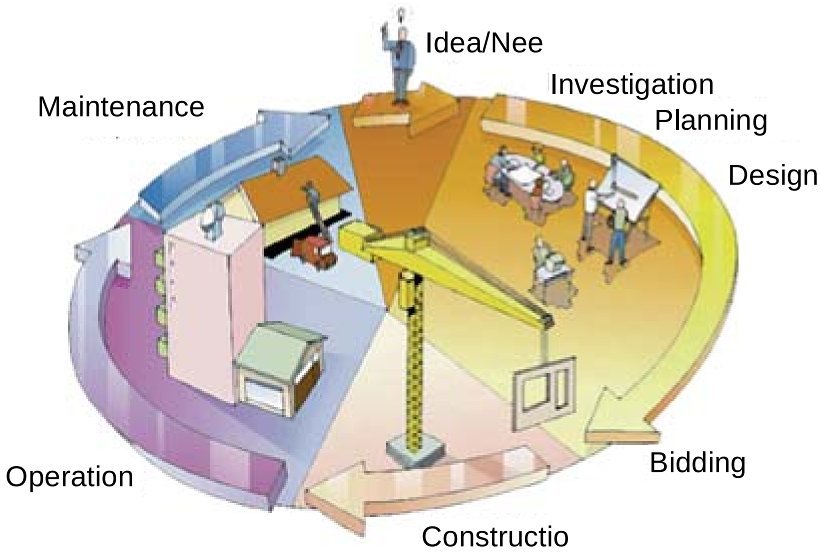

Figure 1. The construction phase that follows after an idea: investigation and planning – design – construction – operation and maintenance. The bidding is when contractors bid for the construction part of the project. Modified from Byggfakta (2016).

In each stage of the process, it is important to simultaneously be aware of all the other stages, and understand how the whole construction process is linked together and how the stages depend on one another. This is one of the most important learning outcomes for civil engineering students, to be able to work in this complex situation, simultaneously seeing the whole and the details. The interdependencies throughout the process add a considerable complexity, which can take much time and effort to learn. For instance, a civil engineer designing the reinforcement in a concrete beam must know in what type of structure the beam should be used in – which determines the loads, environment and other requirements – and must simultaneously also think about the construction workers who shall build the beam – it must be practically possible to place the reinforcement in the formwork and to cast the concrete. When issues such as aesthetic possibilities, cost, environmental impact and risk assessments are added, the task is even more complex.

Investigation

A construction project starts when someone has a need of a building, bridge, tunnel, airfield etc. To start the process aiming for the need, clients who have the need do (or commission) investigations and establish feasibilities on what type of construction they aim for and how big or small the object should be. They also make schematics, preliminary budget and schedule, form a project team, arrange for financing, and identify risks. A first proposal is presented. This stage can also be referred to as the concept stage.
For underground and geotechnical constructions a pre-investigation takes place aiming at defining location for the construction based on environmental effects, function, purpose and economy.

Planning

Based on the result of the investigation a planning phase is settled. The planning includes location of the object, its basic measures, dimensions, type of construction regarding materials and general shape leading to sketches and outline drawings. It also means development of plans, selection of equipment, suggestions of technical solutions, reconfirming of the economics in terms of budget, cash flow, financing and schedule. The risks and alternatives are re-assessed. A more detailed proposal is presented.
For underground and geo constructions a detailed investigation takes place in the planning phase at the selected location. Compared to other engineering fields where the material often is selected in the planning or design stage, the soil or rock mass that will be used as construction material cannot be replaced for underground constructions. Hence, for geo constructions, there is a comprehensive investigation and evaluation of different alternatives performed.

Design

After the planning, and in the design phase, all details are determined and digital drawings are made, (i.e. architectural, construction, electrical, ventilation, water and waste water) and specification documents are written. All calculations for the construction are done and details about ventilation, fire safety, climate etc. are solved. The drawings and specifications should meet all requirements from the client, environment and the society (building regulations, laws etc.). Still at this stage, some specific detailed investigations might be performed for underground constructions.

Construction

With help of the drawings and specification documents contractors are set to construct the object. The finalization of the projects needs many contractors including building, electricity, plumbing, ventilation, fire proofing etc. The final product is inspected in order to see if it fulfills the construction and specification documents. The construction phase often needs planning and design in further detail in order to finalize the construction. Most civil engineers work in the design and construction stages. However, they are involved in different roles also in the other stages.

Operation and maintenance

When the project is finished it goes into the operation and maintenance phase. The built construction should be used during its intended life, which for buildings could mean 20, 50 or 100 years and for bridges 60 or 120 years while for underground tunnels it is often more than 100 years (and some all eternity, such as nuclear power plants). This of course implies that the object must be maintained and kept in good condition. A new building process might take place if the construction needs to be repaired or changed.

Comparing the civil engineering process with C-D-I-O

Side-by-side with conceiving – designing – implementing – operating, the stages of the civil engineering process do not cover exactly the same conceptual phases. A tentative mapping is seen in Table 1.

Table 1. Comparing C-D-I-O and the civil engineering process.

C, D, I and O	The Civil Engineering Process
Conceive	Investigation
Design	Planning Design
Implement	Construction
Operate	Operation and maintenance

Widening "products, processes and systems"

When it comes to civil engineering, "*products, processes and systems*" do not sufficiently describe the object of engineering. In addition to these, civil or built environment engineers also create residential areas, highways, power plants, industries, landscapes, harbours, dams, airfields etc. To some extent these objects could also be referred to as products or systems, but we propose the addition of *environments* to better capture their quality as human-built spaces (Hughes, 2004).

To summarise, for civil and built environment engineering the phrase corresponding to "*conceiving, designing, implementing and operating products, processes and systems*" would read in full: "*investigating, planning, designing, constructing, operating and maintaining products, processes, systems and environments*".

FURTHER DEVELOPMENT

Sustainable development

Nowhere in our proposed description of the process, nor in the original C-D-I-O phrasing, is there any explicit mention of end-of-life considerations. This is peculiar, as the intention is precisely to describe a *cycle*. In our field, structures are traditionally demolished after they reach their intended life. In the past, materials and parts were mostly crushed and just dumped, but now society, and thereby the construction industry, is developing a more circular view on materials and land usage. For instance, sometimes parts and materials can be re-used, i.e. steel is melted to produce new steel, and crushed concrete can be used as ballast in new concrete or as road fill. To enable sustainability we may now need to plan for several cycles of use. This implies a possible new stage in the construction phase after the end of the operation and maintenance stage, a stage that might be called re-usage. However, we do not propose adding it to the expression as a separate stage. We find it more important to *keep end-of-life considerations in mind during the whole process*. Sustainability can be purposefully *designed in*, if it is taken into careful consideration during every stage of the process. This is an area where more work is needed, including how it is implemented in the learning experiences throughout the education.

CONCLUSIONS

This proposal for an alternative expression does not in any way alter the underlying ideas and arguments of the CDIO approach to engineering education reform. When developing the Civil engineering program at LTU, we still call ourselves a CDIO program. But internally, we needed to deeply consider the fit between the fundamental ideas of CDIO and our subject area. By translating some key phrases into our own language, the same ideas are expressed for the civil engineering and built environment field. We have merely taken the essential conception of engineering in CDIO and dressed them in our own clothes.

Finally, we recommend other programs to make the same exercise of adaptation. Because we could, without too much trouble, translate the key phrases in a way that makes full sense to us, it is an indication that the fundamental concepts of CDIO are valid also in our field.

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A PRELIMINARY CASE STUDY FOR COLLABORATIVE QUALITY ENHANCEMENT

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ABSTRACT

Eight universities have collaborated in an Erasmus+ funded project to create a lean process to enhance self-evaluation and accreditation through peer alliance and cooperation. Central to this process is the partnering of two institutions as critical friends, based on prior self-evaluations of specific programmes to identify particular criteria for improvement. A pairing algorithm matches two institutions based on their respective self-evaluation scores. It ensures there are significant differences in key criteria that are mutually beneficial for future programme development and enhancement. The ensuing meetings between critical friends have been designated as 'cross-sparring'. This paper focuses on a case-study of the cross-sparring and resulting enhancement outcomes between Umeå University and Queen's University Belfast, and their respective Masters programmes in Software Engineering and Mechanical Engineering. The collaborative experiences of the process are evaluated, reported, discussed and conclusions provided on the efficacy of this particular application of cross-sparring.

KEYWORDS

Quality Assurance, International Collaboration, Faculty Development, Standards: 1, 10, 12

INTRODUCTION

The European Commission (2011) has set a strategy to become a smart, sustainable and inclusive economy by 2020. A key target is to improve European education and training and specifically this refers to the quality and relevance of higher education. External evaluation and self-assessment are defined as key roles. In September 2014 eight European universities began a collaborative Erasmus+ project to create a lean process to enhance self-evaluation and accreditation through peer alliance and cooperation. To date the project, which is designated QAEMP (Quality Assurance and Enhancement Marketplace - www.cross-sparring.eu), and its progress have been disseminated at several engineering education conferences, including the 11th International CDIO Conference (Kontio et al., 2015) and the 43rd SEFI Conference (Clark et al., 2015)

This paper describes the latest phase of the project, which involves the application of the devised new lean process to enhance the quality of higher education. The overall process is described in detail by Bennedsen et al. (2015) and can be defined in four steps, which are also illustrated in Figure 1:

1. Self-evaluation. Each institution evaluates one of their programmes against 28 criteria, which were produced based on the exemplary practices of many self-evaluation frameworks, including institutional standards and processes, national standards and processes, regional and global accreditation schemes and the CDIO standards (Clark et al., 2015). This culminates in the identification of several criteria that each institution wants to improve on their chosen programmes.
2. Pairing. A pairing algorithm matches two institutions based on their respective self-evaluation scores. It ensures there are significant differences in criteria that matter to them and hence they will be able to help each other in these areas.
3. Cross-sparring. Each institution visits the other with the goal of learning from and inspiring each other.
4. Enhancement. Each institution prepares a development plan for their respective programmes and institutions based on their cross-sparring experiences.

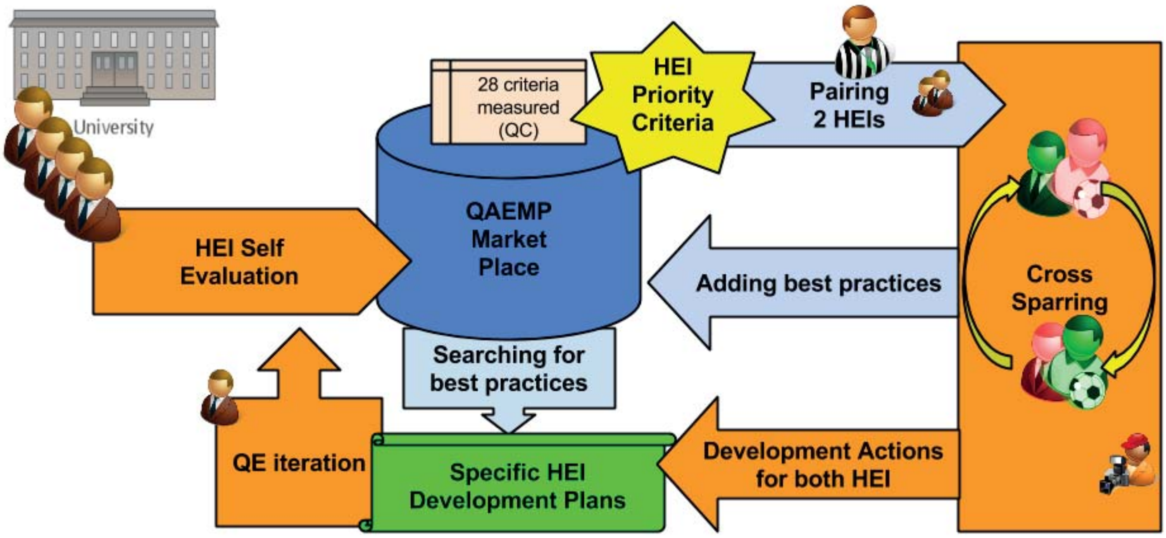

Figure 1. The Overall QAEMP Process (Bennedsen et al., 2015)

Central to the process is the partnering of two institutions as critical friends, based on prior self-evaluations of specific programmes to identify particular priority criteria they want to improve. The ensuing meetings between critical friends have been designated as ‘cross-sparring’.

The paper focuses on a case-study of the self-evaluation and cross-sparring steps in the process between Umeå University and Queen’s University Belfast (QUB), and their respective Masters programmes in Software Engineering and Mechanical Engineering. The cross-sparring concluded with respective documents from each institution reporting on the findings from their collaborative experiences, including the impressive practices, strengths, challenges and open questions raised during this process, which are described, evaluated and discussed in the ensuing sections of the paper. These findings will be used to evaluate the QAEMP process and make it more robust and applicable.

The paper is arranged into sections based on the following themes:

- Generic description of the self-evaluation and cross-sparring steps;
- Criteria to critique these steps;
- Umeå visit to QUB – experiences and findings;
- QUB visit to Umeå – experiences and findings;
- Joint discussion;
- Joint conclusions.

THE SELF-EVALUATION & CROSS-SPARRING PROCESSES (STEPS 1 & 3)

The basis for the QAEMP project matured from the partner institutions' involvement in CDIO and specifically, through self-evaluation and development of their programmes against the CDIO standards to complement their quality assurance processes. This project background is detailed by Kontio et al. (2015).

Self-Evaluation

The self-evaluation, or first step in the QAEMP project, generates data that initiates the whole enhancement process. A programme of study is chosen to conduct the self-evaluation, which should ideally be completed by the programme director(s) within a day. This data feeds into a 'marketplace' where participating institutions can be paired together to engage in peer-evaluation and opportunities to share best-practice regarding their implementation of teaching and learning. A robust self-evaluation framework has been developed, based on the following resources (Clark et al., 2015):

- Institutional standards and processes from the partner institutions;
- National standards and processes e.g. QAA in the UK;
- Documents relating to regional and global accreditation schemes e.g. ABET;
- Requirements and guidelines relating to particular learning and teaching frameworks e.g. CDIO.

This self-evaluation framework is based on 28 criteria, which are grouped under 10 themes as shown in Table 1.

Table 1. Final Criteria Classification

Theme	Number of Criteria
Programme Philosophy	1
Programme Foundation	4
Learning and Teaching	5
Assessment and Feedback	2
Skills Development	4
Employment	2
Research	1
Student Focus	4
Faculty Development	2
Evaluation	3

A measurement rubric has been developed for each criterion, using a maturity model rubric similar to the CDIO evaluation. This approach comprises six levels, with general expressions adapted to suit each criterion as shown in Table 2.

Table 2. Generic Measurement Rubric

Level	Description
5	Continuous improvement and development are evident
4	Evidence of implementation and evaluation are available
3	Implementation is underway
2	A plan to implement change has been produced
1	There is an awareness of the need to implement change
0	No intention to change

Cross-Sparring

In the QAEMP project the third step or procedure for collaboration between two institutions is symmetric – one institution studies the other and vice-versa. This procedure can be likened to sparring (in boxing) where sparring partners do not compete, but help each other develop through supporting, complimenting and sharing their skills and strengths. An overview of the whole QAEMP process is shown in Figure 1, which illustrates the steps involved: self-evaluation, pairing, cross-sparring and enhancement.

The cross-sparring model was developed to compliment the accreditation system and facilitate the dissemination of best practices in quality assurance and education among HEIs. The identification of best practices takes place when the actual cross-sparring is conducted. Institutions collaborate/spar to learn from each other as partners for a short period rather than competitors. They can identify their sparring-partner's strengths and challenges free from bias and provide more immediate feedback for development actions. An effective external collaborator (cross-sparrer) can help a partner institution (cross-sparree) reflect with greater impartiality and obtain a more objective view of its strengths and potential improvements, and at the same time identify best practices that can be useful for their own institution.

The cross-sparring process (CS) has been designed to be flexible, reactive, targeted, simple and compact. Once a pair of HEI's has been selected, two instances of CS take place, with the institutions visiting each other in turn. This gives each institution the opportunity to take on the role of both the 'sparrer' and the 'sparree'. For each pairing, the sparring partners are responsible for preparing, planning and leading the cross-sparring in turn to ensure it conforms to the guidelines. Together, they manage the delivery of the outputs, which include an internal report for the pairing institutions, output for the QAEMP Market Place and, if necessary, feedback on the process for the sponsor. Note that sponsor and observer roles can be added to evaluate or inspect the process. Sparring requires honesty from both partners to be mutually beneficial.

The sparring-partners must be familiar with the self-evaluation documents prior to the CS and agree on the number of criteria to be analysed. This enables the cross-sparrer to produce a short executive report at the end of their site visit and also to learn from the institution visited. The cross-sparree can then analyse this feedback to develop their enhancement plan and upload a description of any best practice to the web-based marketplace. The enhancement plan should address six areas regarding the scrutinised priority criteria: (i) impressive experiences from the visit; (ii) strengths; (iii) challenges; (iv) development plan (define the precise actions for improving the quality of education); (v) best practices; (vi) any open questions.

The CS is composed of four main activities:

- Initialisation - Participants from each partner institution agree on their own priority criteria (for enhancement) from the self-evaluations and the focus, boundaries, roles, responsibilities and composition of the CS team. This activity is conducted in advance of either of the two visits and should require a workload of no more than sixteen hours per institution;
- Organisation and Preparation - the teams, the self-evaluation consultations, the visit agendas and production and validation of the CS plan. This activity is conducted in advance of the visits and should require a workload of no more than sixteen hours per institution;
- Sparring – at the cross-sparree institution identify evidence related to the priority criteria, best practices, challenges and potential improvement actions. Two days should be scheduled for this activity;
- Feedback and Development Plan - reporting actions, market place updates, sponsor notification, follow-ups and good practices. A workload of sixteen hours per institution should suffice.

A CS kit of instructions and document templates has been produced to facilitate the process for the partners.

CRITERIA TO CRITIQUE THE SELF-EVALUATION & CROSS-SPARRING PROCESSES

The participating institutions were tasked with critiquing both of the steps in the QAEMP process which they had actively participated in: the self-evaluation and the cross-sparring.

Quality of Self-Evaluation Process

To evaluate the self-evaluation content the following questions were applied to each criterion:

- Is the rationale understandable?
- Is the rubric understandable, and in accordance with the general maturity model?
- What indicators were used corroborate the measurement rubric level chosen?

To evaluate the self-evaluation framework the following questions were applied:

- Are all criteria relevant?
- Are some of the criteria overlapping?
- Are there missing criteria?
- Does the order of the criteria work or is there a grouping that would be more logical?

The partners were also free to feed back any other items they deemed important for this part of the process.

Quality of Cross-Sparring Process

To evaluate the cross-sparring comments were sought on:

- The pairing algorithm regarding the choice of partner.

- The site visits.
- The benefits accrued.
- The added value gained.
- The CS documentation.

QUB REFLECTIONS ON CROSS-SPARRING WITH UMEÅ

Initialisation, Organisation and Preparation

The CS began with the Initialisation activity. The compositions of the teams were decided, including the respective roles and responsibilities. It was fundamental that the members included those involved in the previous self-evaluations of their respective programmes. The key part of the initialisation activity was to identify and agree on the priority criteria for each institution. In theory, the pairing step of the QAEMP process should have partnered two institutions with suitable differences in their self-evaluations to easily facilitate and validate this activity.

Figure 2 shows a graph of the respective self-evaluations produced by QUB and Umeå (for their masters programmes in mechanical engineering and software engineering), with clear differences in criteria levels between the two institutions. Specific criteria where QUB scored themselves significantly lower than Umeå have been highlighted (encircled in green) and hence these were criteria were QUB could potentially learn and gain inspiration from Umeå. Five priority criteria were identified by QUB based on their institution's current priorities and to maximise the potential gains illustrated. They were ranked as:

1. Criteria 9 – Learner assessment.
2. Criteria 1 – A holistic view of learning.
3. Criteria 2 – Appropriate Learning Outcomes.
4. Criteria 18 – Wider stakeholder input.
5. Criteria 7 – Personal and interpersonal skills development.

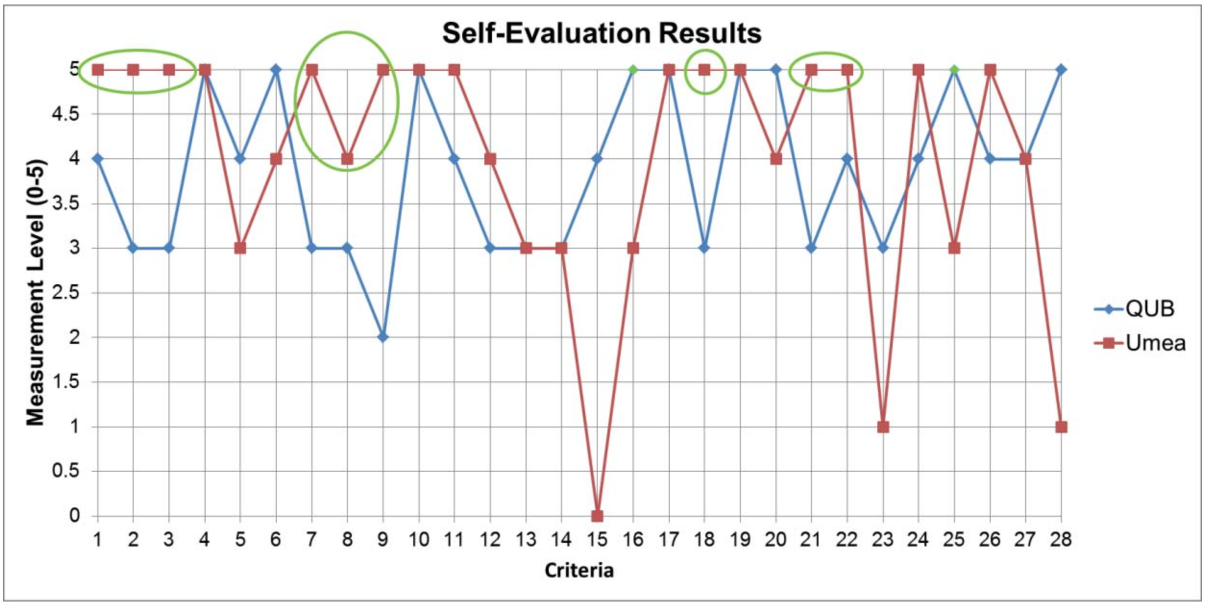

Figure 2. Graph of the Self-Evaluation Results for QUB and Umeå

Table 3 provides an explanation of these five priority criteria. It is worth noting that the original priority criteria specified by QUB during the self-evaluation step, which were used in the pairing step, were subsequently reevaluated during this initialisation activity in the CS process. Originally the priority criteria were 8, 12, 18, 23 and 25, the latter two not being supported by the pairing algorithm as seen in figure 2.

During the initialisation activity Umeå also identified five priority criteria for enhancement: 5 - Active learning; 8 - Faculty development; 16 - Research is used in teaching; 23 - Equality, diversity and equal opportunity considerations; 25 - Evidence of educational scholarship by faculty. It can be seen from figure 2 that these criteria all scored lower than the respective QUB criteria, except for criteria 8. Interestingly, they too had reevaluated from their original priority criteria, which were 6, 14, 16, 20 and 23.

Table 3. QUB Priority Criteria Descriptions from Self-Evaluation Rubric

Priority	Criteria
1	*Criteria 9 – Learner assessment* Assessment of student learning is aligned with the learning outcomes and the learning experiences and consideration is given to the type, level and amount of assessment employed. This ensures that there is no over-assessment of students and that the assessment used promotes learning. Using a variety of assessment methods accommodates a broader range of learning styles, and increases the reliability and validity of the assessment data.
2	*Criteria 1 – A holistic view of learning* For an effective learning experience it is important that the different components of the programme are linked together in a meaningful way. That way the student has the potential to gain a complete understanding of a discipline and consider potential career options. To achieve this, the programme team need to reflect on the programme structure and content to ensure coherency in the meeting of programme goals.
3	*Criteria 2 – Appropriate Learning Outcomes* Setting appropriate learning outcomes helps to ensure that students develop a foundation for their future careers. Specific and detailed learning outcomes for personal and interpersonal skills, and professional skills, as well as disciplinary knowledge need to be identified such that they are consistent with programme goals and can be validated by programme stakeholders.
4	*Criteria 18 – Wider stakeholder input* With a focus on preparing students for life beyond higher education, it is important that programme development takes place in a way that engages a range of internal and external stakeholders e.g. Industry Advisory Board and Benchmark Statements. This ensures that the programme is ‘fit-for-purpose’ and has the potential to produce the best possible graduates.
5	*Criteria 7 – Personal and interpersonal skills development* Personal and interpersonal skills development is embedded in the learning experiences to demonstrate that it is a combination of knowledge and competencies that is required to be effective in the discipline beyond higher education.

Before any sparring could take place, it was necessary to organise and prepare the agendas and logistics for each visit. As the first meeting scheduled was Umeå’s visit to QUB, the first agenda was prepared by QUB. This was developed after carefully examining Umeå’s self-evaluation along with their stipulated priority criteria.

Cross-Sparring Visit to Umeå

Each visit was scheduled for two days. The agenda for the visit of Umeå to QUB addressed Umeå's five priority criteria; two on the first day and three on the second day. QUB presented evidence of their indicators and practice in each of these criteria to inspire Umeå and enable them to experience an approach that they could potentially implement or tailor to their own programme. The agenda also included an introduction to QUB's school and programmes, a tour of the school's facilities, discussions on QUB's priority criteria and ended with collaborative reflections on the process thus far.

Umeå prepared the agenda for the visit of QUB to Umeå one week later. This agenda followed a similar format to the previous, but started with a broader university overview to better explain and set in context the higher education system in Sweden compared to the UK. Umeå addressed the QUB priority criteria by presenting their indicators and relevant specific practice to inspire QUB and provide relevant examples and experiences for QUB to consider for implementation to enhance their programme.

As already explained, the CS kit includes several documents that must be completed as the CS progresses. These documents prompted the partners to comment on specific topics, which are described from QUB's perspective in the following sections.

Observations of Priority Criteria at Umeå

<u>Criteria 9 - Learner assessment</u>: Umeå implement a project assessment and management system called SCRUM, specifically for iterative software development cycles, which merits investigation regarding its suitability for the iterative CAE design optimisation phase of a mechanical engineering design project.

<u>Criteria 1 - Holistic View of Learning</u>: Umeå apply a comprehensive matrix of all programme learning outcomes mapped against assessment strategies that gives an effective holistic view of learning. Programme Directors at Umea are allocated a significant percentage of their time (typically 6%) to complete an Annual Programme Review (APR) document as part of a very structured process, which is comprehensive in its consideration and stakeholder inputs.

<u>Criteria 18 - Wider stakeholder input</u>: Local company engagement in curriculum development at Umeå and student employability was efficiently and effectively managed to the benefit of all. A key part of this was the careers day, where external companies interact with different cohorts at various stages in their studies, in a full day of career focused events.

<u>Criteria 8 - Faculty Development</u>: The 1-year Catalyst programme, which piloted a methodology to engage staff in pedagogical development, was a valuable and stimulating example of how the common problem of staff development in this area might be effectively improved by stimulating cultural change within a Department / School.

Findings at Umea

The Faculty structure at Umea and the provision of mathematics teaching across degree programmes without context by the mathematics department appears to have contributed to attainment and retention issues. QUB's School of Mechanical and Aerospace Engineering

(SMAE) faced very similar problems in the past and have been able to resolve these by bringing the delivery of mathematics teaching within the School.

Despite the different programme themes there were many areas of similarity between the two institutions' approaches to teaching. One example of this would be the learning outcomes, design methodology and assessment methods in the first year introductory modules, although the period of delivery and opportunity to embed the course as part of an integrated curriculum at Umea seem more restricted by their programme structure.
I*mpressive Experiences and Strengths at Umeå*

There were many positive experiences witnessed at Umeå, but these stood out:

- The quality assurance loop implemented at both Faculty and programme level in Umeå: observe-analyse-propose-implement. It is an inspirational system, which allocates an impressive amount of resource to complete the loop
- The industry engagement at various levels of programme development and delivery.
- The growing demand for their Software Engineering degree and the associated positive impact of alumni on the local economy.

Challenges at Umea

Due to their Faculty structure and also the nature of provision of tertiary education in Sweden, there were two key challenges identified and discussed:

- The inability of programme directors to contextualise the delivery of modules facilitated by other departments/schools, specifically mathetmatics.
- The retention of students stemming from the inability to specify the level of mathematics ability of incoming students.

Evaluation of the CS Process

From a QUB perspective:

- The self-evaluation and pairing steps of the QAEMP process worked well to identify priority criteria.
- The CS visits benefit from agendas which provide introductions to each institution, providing a broad university context, rather than focused at the school/department level.
- The CS kit was pack was too complicated and even confusing, so needs simplification.
- The CS visit duration of two days was appropriate to cover the five priority criteria of each institution.
- The distance between Belfast and Umeå added two further days for travelling to each of the visits, which makes them almost week-long events.
- The mismatch in disciplines between QUB and Umeå (mechanical engineering and software engineering) proved to be beneficial and not a shortcoming.
- The fact that the CS teams had not previously met was not a problem as the process structure facilitated effective communication.
- The CS process provided useful feedback to both institutions, enabling them to formulate development plans for their respective programmes.

UMEÅ REFLECTIONS ON CROSS-SPARRING WITH QUB

Focus criteria for improvement in Umeå:
Criteria 5 – Active learning.
Criteria 8 – Faculty development.
Criteria 25 – Evidence of educational scholarship by faculty.
Criteria 16 – Research is used in teaching.
Criteria 23 – Equality, diversity and equal opportunity considerations.

Synthesis of elements of the visit to QUB transferable to Umeå:

The QUB partner has done a lot of work on active learning, faculty development, and educational scholarship that is an inspiration for the Umeå partner. There is also work on equality and equal opportunity implemented in QUB that can be transferred to Umeå.
Criteria 5 - Active learning: The curriculum in QUB ensures that active learning is emphasised in more or less every module the students take.

Criteria 8 - Faculty development: A course in university pedagogics is mandatory for all teachers, which ensures a minimum level of pedagogic knowledge. The teaching track for some of the faculty ensures that at least some of the teachers have time for pedagogical development.

Criteria 25 - Evidence of educational scholarship by faculty: The teaching track ensures that at least some faculty members engage in educational scholarship. Close ties to the CDIO community as well as other networks facilitate cooperation projects with other institutes.

Criteria 16 - Research is used in teaching: The design of the QUB curriculum is permeated by the results of educational scholarship. In the later parts of the studies, the students choose between “tracks” of modules that have been designed by research groups at the school.

Criteria 23 - Equality, diversity and equal opportunity considerations: Steps have been taken that have resulted in a certification for gender equality. Every person serving on an appointment board is required to have taken a course about the ethical and legal aspects of hiring new staff. All decision bodies must have female representation.

Impressive experiences and strengths:

The work that has been done by the QUB partner in creating an integrated curriculum and integrating active and interactive learning in many courses, as well as basing much of the teaching on design-build-test projects is very impressive.

Following research that shows that engineering students learn mathematics better when taught in context and by engineers, and noticing that the mathematics teaching was not working for the students, the QUB team decided to teach their students mathematics themselves, rather than outsourcing to another School within their institution. This shows great initiative and dedication.

The Umeå team was also impressed by the amount of educational scholarship the QUB team engages in. In particular, the way they use scholarship as a means to identify causes of problems they see in their teaching is impressive.

The programmes at QUB have a 95% retention rate, which is truly inspiring.

Challenges:

In Umeå, the programme team for the Masters program in Computing Science Engineering does not have the same amount of control over the curriculum or the way courses are taught as in QUB. The programme is owned by the Faculty of Science and Technology, but the courses are given by departments (primarily the Department of Computing Science, but also the Math and Physics departments as well as the Department of Applied Physics and Electronics). This makes it more difficult to create a truly integrated curriculum and to ensure that active and interactive learning is encouraged.

Transferable success factors:

- Teaching track lecturer positions with dedicated time for educational scholarship, development as a teacher and dissemination of best practices, but also academic standards that the lecturers are required to fulfill.
- Stress active and interactive learning in all courses.
- Teach everything, including mathematics, in context.
- Require female representation in all decision bodies.
- Require training for every person participating in a recruitment/interview board.
- Student diagnostics at the beginning of studies.
- Base the pedagogical development of the study programme on a structured and well developed approach such as CDIO.
- Analyse the learning styles of the students and try to help them to develop new learning strategies, geared towards life-long learning.

Potential improvement actions for Umeå:

Form a group of teachers interested in pedagogical improvement and scholarship.

Form partnerships with other institutions that are interested in pedagogical improvement and scholarship.

Investigate the possibility of design-build-test courses that stretch the whole academic year. In particular, the introductory course could be considered.

Design a diagnostic test for new students. Possibly also use a learning styles test. Use results to better understand the students' strengths and weaknesses. If possible, involve other programmes as well.

Use peer rating (but not assessment) on courses that involve group work. QUB has consistently used peer rating and have documented the improvements in self-assessment shown by the students.

Investigate the possibility of changing the content of the mathematics courses the students take, as well as the way in which mathematics is taught (aiming for context and active/interactive learning).

Investigate the possibility of having teaching track lecturers similar to the ones in QUB. This is not something that can be achieved in the short term, but perhaps in a number of years.

Focus on the things that can actually be influenced and changed. Wasting time by trying to change things in areas where there is no or limited control is counterproductive.

CONCLUSIONS

The self-evaluation and the cross-sparring steps in the QAEMP process have been described, discussed and evaluated by two institutions involved in a pilot of these initial steps in the process. It was a very positive experience for both parties and identified specific areas for enhancement in their programmes under scrutiny. In addition, the cross-sparring proved stimulating as an activity, which allowed the partners to learn from each other and be inspired by each other in a very friendly and conducive environment.

The programme self-evaluations from each institution proved very beneficial in identifying the key criteria for the cross-sparring visits and associated agendas. The arguments and indicators provided in the self-evaluations to justify the marking rubrics for each criterion were very valuable in this regard.

The pairing algorithm used to partner QUB and Umeå seemed to work well, based on the self-evaluations, but both institutions found it useful to revisit their priority criteria to maximize the gains from the ensuing cross-sparring visits and this proved worthwhile. Five priority criteria were identified by each partner and the two-day visits were an appropriate amount of time to cover them. The fact that the two partners were evaluating different programmes from different disciplines did not hinder the process, but benefited it by ensuring the focus was on the criteria and not the respective content. Both teams concluded that the CS kit produced by the QAEMP team requires simplification.

Participants from both institutions found that the practical implementation of this process works and when rigorously applied can facilitate the mutual enhancement of the programmes under scrutiny.

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PAIRWISE COLLABORATIVE QUALITY ENHANCEMENT: EXPERIENCE OF TWO ENGINEERING PROGRAMMES IN ICELAND AND FRANCE

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ABSTRACT

Quality in higher educational programmes is acquired over a long period. Depending on their location, history, tradition, management style or culture, institutions have their own strengths, but also constraints and priorities for quality enhancement. Analysing or even just seeing how programme leaders and developers are managing educational quality in partner countries may provide an opportunity to learn from them and transfer some of their good practices to one´s own context. As a constructivist complement to accreditation to foster quality, a 2015 pilot study showed the strong potential of a large self-evaluation model including maturity scale to shed light on priorities.

The focus of this paper is to critically examine the self-evaluation model and a cross-sparring process, and to assess which parts of the process proved beneficial. Even if very valuable, via short but prepared visits to learn from each other, it shows that (i) the number of criteria in focus should be limited to ensure a deep collaborative analysis and actionable plans, and that (ii) the forms used to report must remain simple and flexible so as to be delivered under time constraints. Thanks to the cross-sparring process, the study validated a flexible and non-competitive approach to stimulate thought and discussion about collaborative quality enhancement at international levels, even without dedicated quality referents in the institutions or a formal quality assurance framework in place. Given the large numbers and nature of higher educational institutions, this practical model reveals an excellent approach to institutions in need of continuous improvement.

KEYWORDS

QAEMP, Internationalization, Program Evaluation, Accreditation, Best Practices, Framework Implementation, Quality Enhancement, CDIO Standard 12.

INTRODUCTION

In order to learn from the experience of others, Telecom Bretagne (TB) in France and Reykjavik University (RU) in Iceland have chosen to engage in a pilot study for collaborative quality enhancement in engineering education by sharing institutional best practices. A collaborative quality enhancement experience took place in the fall of 2015 between two institutions, including a self-evaluation (SE) and cross-sparring model (CS). The pilot study was a part of a European Erasmus+ project. The QAEMP project (Quality Assurance and Enhancement Market-Place for HEIs) proposes a continuous enhancement model and processes for educational programmes in engineering. For their programmes to be enhanced, based on targeted self-evaluations, including criteria and a rubric reference model (Clark et al., 2015), institutions identify and prioritize the criteria they want to improve for a specific programme (Bennedsen et al, 2015). In the pilot study, each institution chose criteria on which it wanted to improve (from a pool of 28 criteria), and visited the other to learn best practices and seek advice from the other. RU wanted to learn and improve on integrated curricula including design projects, different learning styles, and technology to engage students. TB wanted to learn and improve on workspaces and equipment, learner assessment and formative feedback, student progression monitoring, and communication with students.

For each criterion, a clear final statement and rationale is set in order to ensure consistent understanding and a measurement rubric has been developed. The rubrics are based on a hierarchical maturity model as found in the ISO 33020 standard on Measurement Framework for assessment of process capability and organizational maturity (Rouvrais & Lassudrie, 2014), see Table 1.

Table 1. Maturity model for educational programmes in QAEMP.

Level	QAEMP Description
5	Continuous improvement and development is evident
4	Evidence of implementation and measurement of effectiveness are available
3	Implementation is underway
2	A plan to implement change has been produced
1	There is an awareness of the need to implement change
0	No intention to change

Educational program transformation plays a recurrent and key role in the future of an institution (Rouvrais and Landrac, 2012). For quality in engineering education, there is a need for a model that brings together assurance and enhancement and that can be used across institutions, across disciplines and across countries (Bennedsen et al., 2015). At the heart of the process proposed here is a cross-sparring collaborative model, whereby two institutions are matched as critical friends based on the criteria they have prioritized (PC) and their maturity levels for those specific criteria. A reciprocal visit model permits the two institutions to learn from each other. Both institutions engage in such a cross-sparring process over a semester, with the aim of enhancing the quality of their educational programmes in engineering.

Cross-sparring Process in QAEMP

In QAEMP, cross-sparring is to be understood as a process to make analysis and feedback more collaborative, thanks to reflective sessions where strategies but also difficulties can be informally discussed and a critical but supportive external view obtained. This approach is beneficial both for the institution analysed, which will get a more objective view on its strengths and potential improvements, and for the sparring partner which may identify best practices that can be useful for his own institution. In the QAEMP project, the collaborative model is symmetric, i.e. one institution helps to analyse the other, and vice-versa. The approach is not about competing but about supporting, sharing and complementing. In its actual form, the CS process is composed of four macro activities (once two institutions have been paired):

1. **MA1: Initialization** (e.g. to agree on the selected PC, focus, perimeter, roles and responsibilities and composition of the CS team). This activity is conducted only once in coordination, for the two visits;
2. **MA2: Organization** (e.g. team preparation, SE consultation, agenda, production and validation of the CS plan). This activity is conducted twice, i.e. one instance in each institution, it includes however a coordination between the two institutions;
3. **MA3: Sparring** (e.g. identify evidence related to the PC, enable identification of good practices, challenges and potential improvement actions at the cross-sparring institution). This activity is conducted twice (i.e. two visits, one in each institution);
4. **MA4: Capitalisation** (memo reporting, updates or uploads in a so-called Marketplace of good practices, sponsor notification, follow-ups). This activity is conducted only once, in coordination.

At the end of the CS process, documents are to be delivered, focusing on (i) findings, impressive experiences and strengths, challenges, open questions, and (ii) action plans for quality enhancement. Based on what was observed and collaboratively analysed, actions to develop one's own programme/institution are defined (and hopefully executed).

To meet the main goals of the cross-sparring model, the specific criteria that an institution would like to enhance are chosen from a pool of 28 criteria. Eight institutions participated in this pilot project and each identified 3 – 5 criteria which they wanted to enhance in their chosen programme. The institutions were then paired for cross-sparring i.e. RU and TB were one of four pairs. Ideally, a chosen sparring partner should have a higher maturity level for the criteria on which an institution wants to improve and thus be able to show best practices which the other can learn from. In this experience, RU, with a BSc programme in Biomedical engineering, wanted to learn more on integrated curricula including design projects, different learning styles, and technology to engage students. TB, with a MSc programme in ICT, wanted to learn more on workspaces and equipment, learner assessment and formative feedback, student progression monitoring, and communication with students.

Scope of the Paper

This paper describes a case study of the QAEMP CS process at RU and TB. It focuses on the activities in the above described CS process and reports on the outcomes. This analysis of experience of the QAEMP model and process, and the lessons learned, will give advice to programme leaders interested in a more constructive and collaborative continuous improvement approach, based on an agile iterative cycle to complement cyclic accreditation requirements or broaden the scope of quality assurance standards.

REYKJAVIK UNIVESITY AND TELECOM BRETAGNE AT A GLANCE

Facts and Figure

Reykjavík University is the second largest university in Iceland with about 3,200 students and 250 employees. It is owned by the Chamber of Commerce, the Federation of Icelandic Industries, and the Confederation of Icelandic Employers. The university is “semi-private” in the sense that approx. 75% of the funding comes from the state. RU consists of four academic schools: School of Law, School of Business, School of Computer Science and the School of Science and Engineering.

Telecom Bretagne is one of the flagships of European institutes of higher education in Telecommunications and Computer Science. Affiliated with many networks of alliances in France and abroad, it is also a pole for high-level research activities. In 1878, the high School of Telegraphy was created in Paris, France. It becames *Ecole Nationale Supérieure des Telecommunications* in 1942 (now called Telecom ParisTech). Then the National School of Telecommunications of Brittany was created in 1977, now called Telecom Bretagne. A summary of the two institutions is given in Table 2.

Table 2. Facts and Figures on RU and TB.

	RU	TB
Year founded	1998	1977
Status	Semi-private, under the aegis of the Ministry of Education	Public, under the aegis of Ministry of Industry
Latest buildings	2009	1977 (including some extensions)
Schools	School of Science and Engineering, School of Computer Science, School of Business, School of Law	School of ICT Engineering
Eng. Accreditations and Labels	Authorized by the Quality Board for Icelandic Higher Education, under the Ministry of Education, and validated by the Association of Chartered Engineers in Iceland (VFI).	French CTI (*Commission des Titres d’Ingénieur*,) and HCERES, European EUR-Ace and QuesteSI
Type of curriculum for Eng. degrees after K12 studies	3+2 (Bologna LMD, ECTS)	(2)+3 2 years of preparatory schools with a national selective *concours* (Bologna MD, ECTS)
Nb of BSc Eng. Programmes	9	0
Nb of MSc Eng. Programmes	7	2
Programme under study for QAEMP	BSc in Biomedical Eng	MSc in ICT Eng
Nb of engineering students in 1st year for the programme analysed	40	160
Nb of engineering students overall	800	750
Nb of full time faculty in School of Engineering	50	147
CDIO membership	Since 2012	Since 2008

Both institutions are or have been engaged in mergers with other institutions. Reykjavík University merged with the Technical University of Iceland (THI) in 2005. Following the merger, the School of Science and Engineering was established, partly built upon the foundation of a 40 year old institution (THI) but with the addition of new engineering programmes. TB and Ecole des Mines de Nantes made the decision to merge in 2015. The merger will lead to the creation of a new Mines Telecom Atlantic School in France, positioned at the heart of digital transformations, energy, environment and societal impacts. The full administrative merger will be finalized in January 2017 and the first students will be enrolled in September 2018, with a single integrated educational programme between three physical sites in Brittany.

THE CROSS-SPARRING VISITS

Two faculty members from RU visited TB in November 2015, two faculty members from TB visited RU in December 2015, and the agenda for each visit was two full days. RU´s cross-sparring visit to TB Brest was both interesting and rewarding. The French system for higher education is very different from Icelandic universities. The institutions were so different that the orientation process and programme architectures, i.e. getting to know each others system, took more time than had been anticipated in the agenda. Table 3 shows the improvement criteria chosen by the paired institutions, including the maturity levels as graded by their programme leaders in the self-evaluations.

Table 3. Priority criteria for improvement (PC), chosen by RU and TB in 2015, including declared maturity level (bolded values are for enhancement purposes).

QUALITY ASSURANCE AND ENHANCEMENT MARKETPLACE FOR HIGHER EDUCATION INSTITUTIONS	RU	TB
The 4 items chosen by RU		
QAEMP criteria 3, An integrated curriculum: “The teaching of personal, interpersonal, and professional skills should not be considered an addition to an already full curriculum, but an integral part of it. Faculty play an active role in designing the integrated curriculum by suggesting appropriate disciplinary linkages, as well as opportunities to address specific skills in their respective teaching areas”.	**2**	*3*
QAEMP criteria 22, Integrated design projects: “The ability to design is valued in graduate employment; hence, projects where students design and create artefacts of the profession are integrated into the programme”.	**1**	*5*
QAEMP criteria 27, Different learning styles: “It is well understood that students prefer to learn in different ways. In order to encourage effective student learning, different student learning styles need to be taken account of in the development and delivery of learning opportunities.”	**1**	*3*
QAEMP criteria 14, Technology to engage students: “Technology is a valuable resource when considering the design of engaging learning experiences. It is important that technology is used throughout a programme in a thoughtful way that adds value to learning. The modern world is technology rich and today’s students are often very tech-savvy. Incorporating technology into learning and teaching”.	**1**	*5*
The 5 items chosen by TB		
QAEMP criteria 6, Appropriate workspaces and equipment: “Learning environments, artefacts and resources that support and encourage engaging professional learning are needed to bring the discipline alive and ensure meaning is being made. The building of disciplinary knowledge and skills is best achieved in workspaces that are student-centred, user-friendly, accessible, and interactive”.	*3*	**3**
QAEMP criteria 9, Learner assessment: “Assessment of student learning is aligned with the learning outcomes and the learning experiences and consideration is given to the type, level and amount of assessment employed. This ensures that there is no over-assessment of students and that the assessment used promotes learning. Using a variety of assessment methods accommodates a broader range of learning styles, and increases the reliability and validity of the assessment data”.	*1*	**2**
QAEMP criteria 15, Feedback to students: “An important feature of the assessment process is the provision of feedback to students on their work. If the feedback is timely, appropriate and formative it allows students the opportunity to learn more deeply and develop effective skills in addressing the assessment tasks they are set”.	*4*	**2**

QAEMP criteria 19, Student retention and progression: “The retention and progression of students is continuously monitored and acted upon to ensure the health of the programme”.	*3*	**2**
QAEMP criteria 26, Effective communication with students: “In order to create a positive learning environment, effective communication with students is essential. To achieve this dialogue with students concerning their experiences as students needs to take place formally and informally (Student newsletters, social media, focus groups, drop ins etc.)”.	*2*	**3**

RU had, in its self-evaluation, chosen four criteria for improvement but focused in the end on three of these criteria; An integrated curriculum, Integrated design projects, and Technology to engage students. The fourth, Different learning styles, was more or less put aside. This was simply because TB had so many inspiring examples to show regarding integrated curriculum, including integrated design projects, and technology in teaching and learning, that the time did not allow for more.

TB had, in its self-evaluation, chosen five criteria for improvement but focused in the end on feedback to students and effective communication criteria due to a change of priority in the context of its merger. TB is an interesting educational institution, it is highly selective in the intake of students and extremely prestigious. TB students are on the average younger and in some ways not as mature as the average RU students, mainly regarding their future professional identity (Rouvrais & Chelin, 2010). RU has fewer problems to manage on professional identity and misconceptions or stereotypes about engineers. TB aims to make each student aware of his/her competences upon graduation, by personally monitoring each student’s progression. The two visitors from France finally learned a lot on success factors and student motivation and retention after their exchanges with stakeholders at RU, including open discussions with students. This provided an opportunity for extensive reflection on Project-based Learning, Work-based Learning, Active and Experiential Pedagogies (Rouvrais & Landrac 2012, Rouvrais et al. 2004). RU offers, in most respects, a more comfortable student working environment and, and teachers at RU have much more flexibility to manage their pedagogical style and learning outcomes. This environment is perfect for pedagogical innovators.

QAEMP PROCESS – LESSONS LEARNED FROM THE TWO PILOT VISITS

“A key objective of the QAEMP project is to ensure that the approach to quality assurance and enhancement has impact but is not overly demanding in terms of time or paperwork. In other words that it is focused on action and value added to staff, students and the programmes being considered” (Bennedsen et al. 2015). Even if such flexibility and reactive properties were anticipated, the experience showed that both organizers and visitors have to be more pro-active in order to meet all the process outcomes.

The Grasp All - Lose All - Effect

Nine criteria, which the institutions had prioritized for improvements, were investigated during the two cross-sparring visits. These had been identified by the institutions through self-evaluations conducted in the spring of 2015, six months earlier. A strong effort was made by each institution to show their good to best practices, as reflected in the agendas of both visits. At TB, there was a total of 15 items on the agenda and a total of 14 people made presentations or had discussions with the visitors from RU. At RU, the corresponding numbers were 11 items on the agenda and 22 persons that interacted with the visitors from TB. On both sides, it was forgotten to address the maturity levels on the criteria, the focus was more on the results than the processes in place for monitoring continuous improvement.

With only two days, a hectic learn and inspire agenda, and nine criteria to focus on, it clearly emerged that the scope was too broad. The mass of information received was hard to follow and align with, and thus generated disperse reporting. Each time you meet someone, you forget the focus of analysis. But many constructive exchanges took place during the two visits, including first discussions about exchange agreements with international services. Research in engineering and technical science was also under the scope. Many topics that were outside the focus of the visit were discussed, e.g. gender and intercultural issues, students living facilities, faculty training and academic career paths, research labs, economic issues such as tuition, national budget, incomes, etc. During the visit to RU, other programmes than the one under consideration were also discussed, i.e. a large part of the discussion was at an institutional level rather than at programme level.

Visitors were, mostly due to their curiosity, rapidly submerged by many ideas, even though the agendas were concise and well prepared. The visitors were becoming acquainted with an institution and becoming friends, discovering possibilities for potential future collaboration. This was fruitful but left less time for focusing on QAEMP enhancement plans based on sound validated good practices, to be transferred and activated formally. Thus, there were too many criteria prioritized. Both institutions found it quite easy to capitalize on the others good practices for their own context, but much harder to report or give good advice on their obstacles or difficulties. Even if all partners were open-minded, visitors were not expert counsellors and cultural dimensions are to be taken into account. Finally, right after the two visits, memos were not really filled out and no actionable and written action plan for each institution was developed.

Ideas for adjusting the Visit Agenda

A timespan of 2 days for a visit in each institution seems to be perfect. The distance between the countries involved is over 2000 km, so 2 days were required for travel, a total of 4 workdays for each visit. It is thus possible to prepare a visit on the incoming plane and/or and work on a visit report on the way back. The four days for a visit should be used as effectively as possible such that the reporting is more or less completed during the visit. Therefore, having 1 hour to reflect and 1 hour to report, each day of the visit, is a must in the agenda, with already prepared templates. The templates should also accommodate some flexibility that may be spurred by the agenda of the visit. In this CS instance, both participants suffered from not reporting immediately after the visits. As a pilot study, quality enhancement based on the chosen criteria was of interest but did not turn out to have a great strategic importance.

The pairing of unlike institutions and unlike programs proved interesting and we are definitely of the opinion that it should be seen as a benefit, not a shortcoming. But in the case of such a “mismatch“ in pairing, it will take time for each visitor to familiarize themselves with the educational system of the other institution and therefore there will not be as much time for focused analysis of things that are part of the defined improvement criteria. If the paired institutions/programs are very unlike then it would make sense to focus on fewer criteria for improvement and thus have more time to go deeper into each of them. Also, one should have some leverage in the agenda to be able to incorporate unexpected interest or curiosity on a specific topic that is not on the initial agenda.

Recognized by both participants, having the opportunity to meet students during the visits was more than instructive. Such meetings without the presence of local faculty, allowed the visitors to know much more and get insight into the student perception and implications regarding feedback and course evaluation. The students comments were more than valuable for transfer to the partner institution, due to a more open and reflective discussion with external visitors.

CONCLUSIONS

In this paper, the authors have analyzed the strengths and weaknesses of the cross-sparring model and process, but not the strengths and weaknesses of each institution, which remains more internal for quality enhancement development plans. Thanks to prior self-evaluation of one of their educational programme, it was clear that reflective self-evaluation is a powerful and objective tool. The overall cross-sparring principles of the QAEMP project were met: to get to know each other, to learn and inspire each other, to be “critical friends”, to openly evaluate and analyse rather than audit. Learning from others, and sharing good to best practices, showed that it is also a medium to improve educational quality, and thus performance, considerably. Given the large number and nature of higher educational institutions, this practical model reveals an excellent approach to institutions in need of continuous improvement. But even if the collaborative model and expected outcomes are attractive, the cross-sparring experience was also a pilot study in order to calibrate models, tools, and kits for future public dissemination of the European project results. The visit process, including initialization, organization and capitalization phases, shows some complexity and limits on its practicability for busy programme leaders. Only two criteria per institution or two per visit day may be more realistic to provide clear and beneficial capitalization.

Finally, as a complement to accreditation to foster quality, this pilot study shows the strong potential of a large self-evaluation model, including maturity scale. This pilot study of the cross-sparring process validated a flexible and non-competitive approach to stimulate thought and discussion in the domain of collaborative quality enhancement at international level. As an example, now with more than one hundred collaborating institutions worldwide, the CDIO network can help programme leaders to learn from practice elsewhere, exchange ideas and experiences, review developments, and inspire others (Kontio, 2016).

Although this cross sparring is less formal than audit visits for accreditation or ranking for accountability (Gray et al. 2009, van Vught and Ziegele, 2012), both participants have clearly identified the needs for (i) clearly focused criteria and (ii) a well-defined agenda prior to the visits. In fact, in order to focus on targeted criteria, limit waiting time for visitors and presenters, and allocate enough time to reflect and organize notes, a well-organized agenda is necessary. Although some just in time planning adjustments were necessary during the two visits, e.g. due to more details required or workspace curiosity, it is to be noticed that outside risks were to be taken into account. For the visit to France, worker strikes (e.g. traffic controllers, buses) were monitored, but the 2015 terrorist attack in Paris 10 days before the visit was a surprise. For the visit to Iceland, volcano eruptions were taken into consideration (e.g. several air traffic constraints in 2010), but the snowstorm the day before the trip was of an unexpected severity. Such events perhaps recall the importance of some societal criteria for higher education and future engineers, e.g. thinking in a global context and in the long term, fostering sustainability, social responsibility and resilience related skills. Some student project learning activities place more and more emphasis on such skills in both institutional programmes (e.g. Saemundsdottir et al, 2012) and are part of the national or regional culture and heritage of both TB (Brittany Asterix blend) and RU (Iceland’s geography and isolation).

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2 CDIO Implementation

2

CDIO-BASED TEACHING CONTENT AND METHOD REFORM OF ENVIRONMENTAL IMPACT ASSESSMENT COURSE

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ABSTRACT

Environmental Impact Assessment(EIA) has the characteristics of comprehensiveness, timeliness, practicality and applicability, etc., the current EIA courses mainly focus on the teaching of relevant theories and methods, but lack practical teaching, especially the cultivation of students' engineering practice ability. Based on CDIO engineering education idea, we try to reform the teaching content and method, and provide a real engineering environment which associates with theoretical study and engineering practice for students, improve their professional skills, team cooperation ability, critical thinking ability, comprehensive ability to solve engineering problems, and cultivation of innovation ability along with learning professional basic knowledge. The teaching reform includes some highlights, such as optimization and adjustment of course content and method, writing specialized teaching textbook and establishing teaching website, exercising and cultivating student's engineering practice ability, self-study and presentation skill, construction of curriculum evaluation system. And the reforms are applied to the EIA teaching process in two grades. Accordingly, the evaluation index system and evaluation method are explored and constructed. During 2 years of teaching reform practice in two grades, the reform effect is significant, students can master the requirements and skills of compiling EIA report, and the engineering practice ability is improved obviously.

KEYWORDS

environmental impact assessment, CDIO, engineering education, engineering practice ability, evaluation index, CDIO Standards: 3, 6, 8, 11

INTRODUCTION

Due to the active exploration and development in the past 30 years, the Environmental Impact Assessment (EIA) system was constantly improved in China, the “Environmental Impact Assessment Law of the People's Republic of China” was issued in 2002, which showed a new stage of EIA development in China. At the end of 2015, the number of EIA technical guidelines issued by Chinese Ministry of Environmental Protection was more than 20, which involved general principle, each environmental factor, planning environmental impact assessment, ecological environment, environmental risk assessment, major industries, etc. EIA plays an important role in decision-making of environmental protection, there is a great demand for technical professional in EIA market, meanwhile, students need to obtain more professional skills and knowledge in university.

Excellence engineer's education program of China has been put into practice in 2010, deep participation of industrial enterprises in the training process, cultivating students according to the general standard and industrial standard, strengthening cultivation of students' engineering ability and innovation ability are the basic characteristics. (Li Shu-wei et al., 2011). Based on "Excellence Initiative" (Han Yao-xia et al., 2014), (Han Xiang-yun et al., 2014) and "CDIO Engineering Educational Idea" (Wang Shuai-jie et al., 2015), Chinese scholars introduced guidance-case teaching method, and made a preliminary probe in the EIA course reform from teaching philosophy, content and method, which aimed to improve students' ability to analyse and solve practical problems. However, influenced by traditional teaching mode, there are many constraints or problems along with curriculum reform, for example, most of existing EIA books are lack of case analysis, and the contents are lagging far behind the EIA development, therefore, it's urgent to make reform and innovation on the existing teaching system in order to cultivate professional students who can quickly adapt themselves to the requirement of EIA market.

EIA course is a core curriculum for the environmental engineering and science majors in college of resources and environment, Chengdu University of Information Technology (CUIT), the basic goal of this curriculum is to cultivate student who can master the basic knowledge of EIA, analyse and solve practical problems, meanwhile, apply the relative knowledge to compile EIA report, and get continuous improvement in many aspects, such as self-learning ability, thinking ability and life value. In order to meet the demand of new development, we make reforms on the teaching content and method of EIA course, and apply to the environmental science majors in 2014 and 2015. From the final results, we can see that students' professional skills have been improved greatly, and the effect is significant.

MAJOR PROBLEMS OF THE COURSE

According to the retrospective analysis, major problems of EIA course before the reform are included as follows.

1. EIA textbook can't catch up with the EIA development in China, and it's difficult to find a suitable textbook at present.

Due to rapid development of EIA in recent years, the new policy, standards, technical guidelines and other normative documents have been issued or updated, so the course content need to be updated timely. In addition, most textbooks don't focus on the key point of EIA practice. Therefore, it's urgent to write a textbook which has timeliness and practicality.

2. Teaching method is too simple, and it's not enough to cultivate students' engineering practice ability.

The teaching process is dominated by classroom teaching, lecture-oriented teaching time accounts for about 90% of the total course hours, course teaching is still bound in spoon-feeding teaching and students' passive learning. In addition, it is difficult to carry out practice teaching in that there is lack of practice base. Consequently, it's so hard to effectively connect course contents with engineering practice in the teaching process, and students can't make good use of knowledge to practice. Hence, it's important to improve students' engineering practice ability by strengthening engineering practice training.

3. Students have only a flimsy grasp of EIA knowledge.

Most students' learning goal is to cope with examination, rather than take active learning to master professional knowledge. During their spare time, students are busy with student organization's work or online games, rather than learn and improve their professional knowledge or skill, consequently, they are not familiar with basic specialized knowledge and common soft wares. Therefore, it's urgent to reform the examination method, cultivate and improve students' self-learning ability.

FRAMEWORK OF THE COURSE REFORM

Framework of EIA Course Reform Based on CDIO Idea

Through teaching process of "basic content + EIA case analysis + discussion + project practice", basic knowledge, reasoning, problem-solving ability and systems thinking required by CDIO are implemented to the course teaching, theoretical knowledge and techniques of EIA, engineering practice ability, teamwork skill, report presentation and communication skill are embodied in the teaching process. Framework of curriculum reform is showed in figure 1, major reforms of course teaching and practice teaching are included as following.

1. Adjustment and optimization of teaching content and method.

Writing special teaching textbook according to the latest EIA laws and regulations, technical guidelines, which highlights EIA case analysis and report compiling. Seriously preparing the teaching plan, adjusting and optimizing the teaching content and method, difficulty and key points are stressed, such as EIA technical methods, case analysis, engineering practice ability training, etc., then striving to achieve the goal of "new, less and essence". In addition, we build teaching website which contains the latest news about EIA development, courseware, assignments, and various EIA reports, etc., and online interaction is available.

2. Cultivation of student's engineering practice ability.

EIA case analysis is strengthened in classroom teaching, and the basic professional knowledge should be mastered by each student. Then students can get to know real engineering project through practice base on campus or off-campus, and design the EIA report plan according to the knowledge in classroom, meanwhile, EIA report can be compiled and finished through team collaboration. In this way, students are trained to achieve mastery, meet practical requirement, and their engineering practice ability can be improved greatly.

3. Training of student's self-learning ability, presentation skill.

Extracurricular projects or tasks are arranged in the classroom at first, such as introduction of one aspect in EIA development, or application of one method or model, which are additional assignments of this course. Then students prepare the report by reading relevant materials in their spare time, finally students will be selected randomly to introduce the report, and everyone in the class is expected to participate in discussion. Additionally, we simulate real EIA report review, students will introduce their EIA reports when the EIA reports are finished, and teachers will review the reports and put forward existing problems and suggestions. Finally, the review comments will be provided after teacher's discussion.

4. Construction of course evaluation system.

After finishing the course, the evaluation index and method are established to evaluate the effect of course teaching, timely finding problems and continuously making improvements.

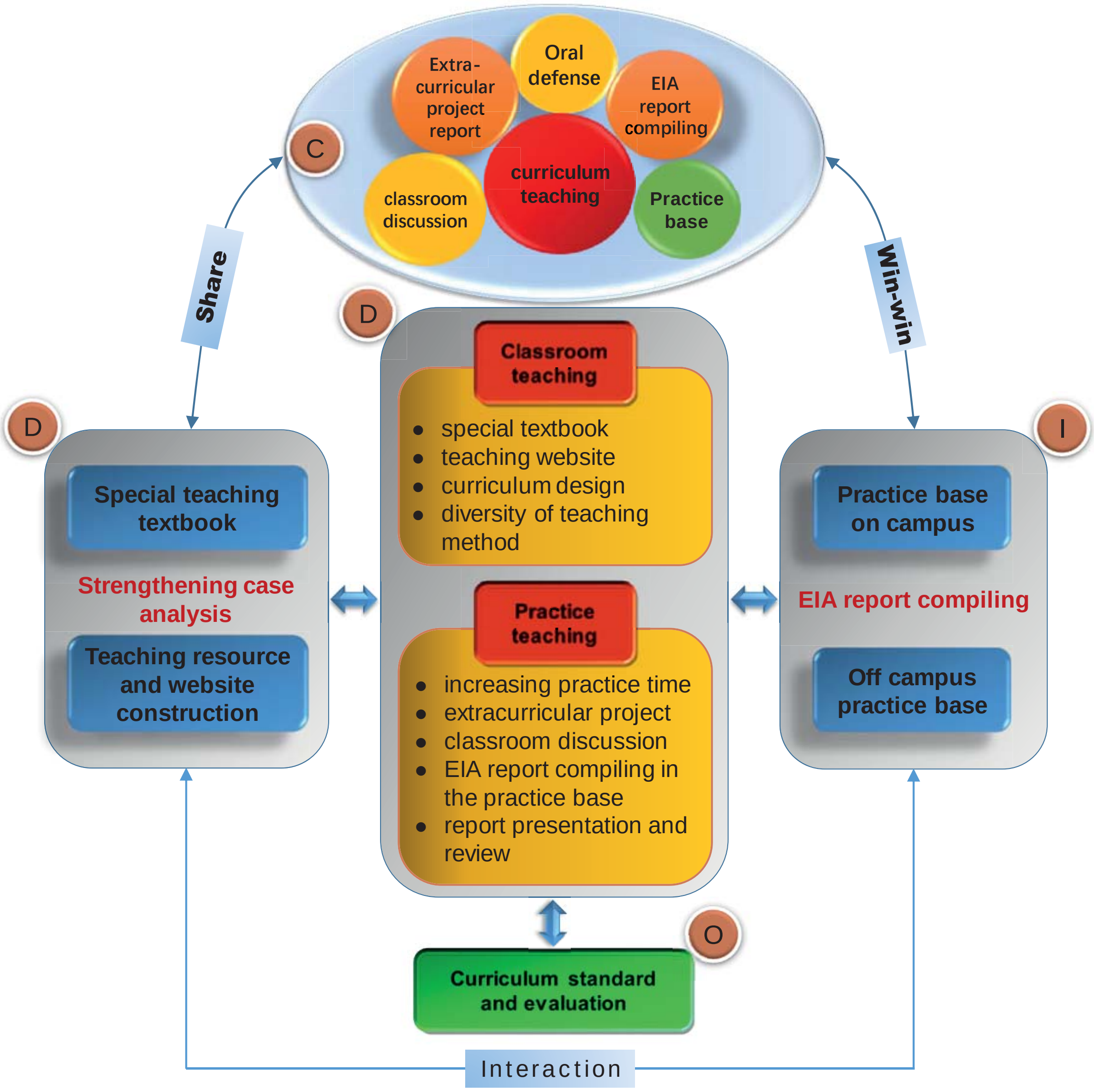

Figure 1. Framework of EIA course reform

Design of Course Teaching Mode

Refer to CDIO teaching mode, the teaching mode of EIA course includes four process, which is conceive, design, implement and operate.

1. Conceive process (clear course task and task preparation, namely let students know what should they do, and how to do).

Main task of this course is to let students master relevant knowledge and basic skills, and own the ability of compiling EIA report independently on the basis of EIA case study and project engineering practice.

2. Design process (design of project implementation plan, that is, students design project implementation plan by themselves).

Reducing teaching hours and increasing practice hours accordingly. Students try to know the real project through practice base on campus or off-campus, then learn and master the detailed implementation process or plan of on-site survey, project contract, monitoring program, outline of EIA report, EIA report compiling, report review, etc.

3. Implement process (project implementation, that is, let students complete the project by themselves).

According to preliminary study of EIA basic knowledge, and project implementation plan and related basic data, students are divided into several groups to compile EIA report by teamwork, and they can ask teachers once problems or difficulties are emerged in this process. Additionally, EIA report must be finished within the given time.

4. Operate process (project evaluation, that is, according to task requirement, obtain the evaluation and feedback of project completion).

After the reports are compiled and finished, we organize teachers to review the EIA reports which are compiled by different groups, and randomly select one student to make presentation, then teachers or students ask questions, and team members can make an answer in time. Teachers will give each student a grade according to the quality of EIA report and answer. In addition, the proportion of regular grade will be increased in the final grade.

We make a comparison between before and after the curriculum reform, the results are showed in table 1.

Table 1. Comparing with key factors of EIA course before and after the curriculum reform

Key Factor	Before Reform	After Reform
Teaching material	• EIA handout • courseware	• special textbook of EIA, strengthening case analysis and practice ability training • courseware
Teaching method	• lecture • discussion • on-site survey • EIA report presentation	• lecture • autonomous learning • discussion • on-site survey • EIA and extracurricular project report presentation
Teaching period	• teacher's teaching time (90%) • student's presentation time (10%)	• teacher's teaching time (80%) • student's practice and presentation time (20%)
Student's engineering practice ability	• compiling EIA report in the practice base on campus (one time) • team defense	• extracurricular project (students collect material by themselves, then randomly selecting student to make presentation after they finish

		the reports) (one time) • compiling EIA report in the practice base on campus (one time) • team defense
Regular grade	• attendance record • homework grade • grade of EIA report quality and presentation	• attendance record • homework grade • grade of EIA report quality and presentation • grade of extracurricular project report quality and presentation
Final grade	• final exam grade (80%) • regular grade (20%)	• final exam grade (60%) • regular grade (40%)

IMPLEMENTATION AND ASSESSMENT

Implementation of Course Reform

EIA course reforms are explored based on CDIO idea, then reform plan has been applied to grade 2012 environmental science majors in 2014 (1 class, and 40 students) and grade 2013 environmental science majors in 2015 (1 class, and 43 students). The basic information of EIA course can be seen in Table 2.

Table 2. Basic information of EIA course in CUIT

Course Title	Environment Impact Assessment			
Credit	3			
Student	Environment Science			
Hour and Distribution	Total Hour 48			
	Teaching 38	Experiment 0	Practice 10	Computer Practice 0
Course Category	Core			
Assessment Method	Exam, regular assessment			

Assessment of Course Reform

Reference to the standards of CDIO and Excellence Engineer's Education Program in China, and combining the situation of EIA course, the evaluation index system has been explored and constructed from teaching condition, teaching content, teaching method and teaching effect, in order to test the effect of curriculum reform, which consists of 11 secondary indicators, it's showed in table 5.

The evaluation method is integrated with quantitative and qualitative evaluation in order to improve the reliability and comparability of evaluation result. Total score of evaluation index is 100, which is calculated by comprehensive evaluation. And calculation equation is,

$$M = \sum K_i M_i \tag{1}$$

M is total score of comprehensive evaluation, K_i is ranking coefficient, and coefficient of A, B, C, D is 1.0, 0.8, 0.6, 0.4 respectively (Han Xiang-yun et al., 2014), M_i is score of each secondary index.

Preliminary evaluation content and criterion are established on the basis of major factors involved in teaching condition, teaching content, teaching method and teaching effect. It is showed in table 3.

Table 3. Evaluation content and criterion of EIA course

Secondary index	Evaluation content	Evaluation criterion
Teaching material	Textbook, courseware, handout	• selection of excellent textbook or compiling high quality textbook. • providing good and valid documents to students' self-learning and research learning.
Practice teaching condition	Advanced and opened practice base	• space and equipment of practice teaching can meet requirements. • providing comprehensive practice, and the effect is obvious.
Network teaching	Website construction, rich teaching resources	• teaching website is running normally, good hardware and keeping update. • meeting the teaching requirement, and playing an important role.
Curriculum framework and content	Course plan and content design	• reasonable curriculum system, content is new and focused. • course notes and teaching plan are available. • practice teaching scheme is reasonable.
Content organization, teaching arrangement	Course schedule and content arrangement	• linking theory with practice, knowledge transference, ability training and quality oriented education as a whole. • reasonable arrangement of classroom teaching and practice teaching.
Engineering practice, teaching method	Practice teaching content and method	• engineering practice can meet the requirements of cultivating professional students. • practice teaching has obvious effect in training students to find, analyse and solve problems. • practical teaching method is flexible, effect is significant.
Teaching method, evaluation method	Advanced method and examination reform	• advanced teaching methods are adopted flexibly. • effectively arouse the enthusiasm of students, promote to think independently, stimulate their innovation ability.
Audio-visual teaching method	Audio-visual aids and application effect	• making full and proper use of modern education technology. • obtaining actual effect in inspiring students' learning interest, learning initiative, and improvement of the teaching effect.
Peer review	Feedback of peer review	• material is real and reliable, and good evaluation.
Teaching evaluation by	Feedback of student's	• student's evaluation material is real and reliable, and good evaluation.

student	evaluation	
Teaching results	Classroom teaching and practice teaching situation	• students' attendance rate is high, and lively discussion is often emerged in classroom. • quality of EIA report, project report is good. • presentation effect is good, more students can involve in discussion, and interaction effect is good. • the ability of students is improved greatly.

According to the evaluation content and criterion, teachers (3 teachers) and students (10 students in each grade, a total of 20 students) participate in the primary survey. Additionally, students don't need to determine the rank of teaching content and teaching effect because they are not familiar with these parts, so only 3 teachers make a survey. Then the data is collected (see table 4), we take teaching condition as an example. Probably, some ranks are controversial, such as network teaching (see table 4), teachers will discuss and determine the final rank. The final ranks are showed in table 5.

Table 4. The evaluation rank of teaching condition

Secondary index	2014			2015		
	by student	by teacher	final rank	by student	by teacher	final rank
Teaching materials	5A, 15B	1A, 2B	B	16A, 4B	3A	A
Practice teaching condition	20B	3B	B	2A, 18B	3B	B
Network teaching	6A, 14B	1A, 2B	B	15A, 5B	2A, 1B	A

Based on the evaluation index and relevant data, the reform effects in 2014 and 2015 are evaluated, and the results are also showed in table 5. The total score is 83.6 in 2014, and 88.8 in 2015, it shows that the result is significant through continuous improvement of the course. However, the evaluation results of some indexes are not good, such as practice teaching, teaching content and method, which need to be improved later.

Table 5. Evaluation index system of EIA course

Primary index (score)	Secondary index	Score (M_i)	Evaluation rank (K_i)				2014	2015
			A	B	C	D		
			1.0	0.8	0.6	0.4		
Teaching condition (22)	Teaching materials	8					B 6.4	A 8
	Practice teaching condition	8					B 6.4	B 6.4
	Network teaching	6					B 4.8	A 6
Teaching content (33)	curriculum framework and content	12					B 9.6	A 12
	content organization, teaching arrangement	6					B 4.8	B 4.8

	Engineering practice, teaching method	15					B 12	B 12
Teaching method (15)	Teaching method, evaluation method	10					B 8	B 8
	audio-visual teaching method	5					B 4	B 4
Teaching effect (30)	Peer review	8					A 8	A 8
	Teaching evaluation by student	10					A 10	A 10
	Teaching results	12					B 9.6	B 9.6
Total score (M)		100					83.6	88.8

CONCLUSION

Cultivation of students' engineering practice ability is an important task in EIA course, which need a good coordination of multi-level, multi-faceted factors. EIA course reforms are explored according to the principles of CDIO and excellence engineer's education program in China. The course materials, classroom teaching, practice base, EIA report compiling, report presentation and evaluation system are connected together, and engineering practice teaching is strengthened. During 2 years of reform practice in two grades of environmental science majors, the effect is significant on the basis of evaluation results.

Through the reform and practice of EIA course, some major problems also have been found, which need to be researched in the future.

1. In the case of fixed total course hour, how to allocate hour will be more reasonable? If teaching time is too little, some contents cannot be taught. Conversely, students' engineering practice training will be affected.

2. How to scientifically evaluate the teaching effect, and quickly find the problems? More evaluation index, more data, and some indexes data is difficult to obtain or quantify, it leads to a big deviation between final evaluation result and actual situation. In addition, determination of index value or weight also need further discussion in that the difference of different courses is very large.

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5

ON DESIGN-IMPLEMENT PROJECTS IN ELECTRONIC ENGINEERING

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ABSTRACT

In engineering education, the link between the theory and the design and manufacturing of practical applications is very important. At our university, project-oriented courses providing design-build experience and following CDIO guidelines, are organized starting from the first bachelor year in electronic engineering. During the second bachelor year, a more advanced CDIO project is organized where students design, build and test a device in a team of five to seven people. In this course a new topic is chosen each new academic year and creativity is stimulated by allowing many degrees of freedom to define the final product. In their team, every student has a different task, determined by specific job profiles, such as project manager, analog design engineer, digital design engineer, software engineer, mechanical engineer and CAD engineer. However, it is also a requirement for every student to keep an overview over the complete project. Progress and milestones are discussed in regular project meetings. A project schedule is presented by means of Gantt charts and adjusted if necessary. Intermediate and final peer assessments are performed, of which the first one is only intended to provide tentative feedback. At the end of the project, the students make an oral presentation, give a lab demonstration and hand in a written report. Grading of the project is performed by relying on individual permanent assessment during the semester, general and specific project output, quality of the report and presentation as well as the final peer assessment. Communication skills are considered very important throughout the engineering program. Presentation as well as writing skills play an important role in the final grading of the project work. During the project, the importance of the CDIO cycle is stressed. Students learn that product development is an iterative process on many levels, where constant feedback allows the design strategy to be adapted in order to obtain a high-quality product as a final result. Students confirm this in the included course assessment.

KEYWORDS

Design-Implement Experiences, Engineering Workspaces, Integrated Learning Experiences, Active Learning, Learning Assessment.
(Standards: 5, 6, 8, 11).

INTRODUCTION

In engineering education, the importance of the link between the theory and the design and manufacturing of practical applications cannot be stressed enough. In the previous decade, our university underwent a significant program reform, providing more space for project-oriented courses. A similar program reorganization, including motivation, is presented in Shen, Y. (2015). A first design-implement experience at a basic level is included in the first bachelor year in electronic engineering at Ghent University. In this first year project, teams of students conceive, design, implement and operate an electric motor from basic mechanical and electrical components. A second, advanced level design-implement project course is organized in the second bachelor year, on which the focus is in this paper. This course presents an extreme challenge to the students for the first time in their academic career. Further CDIO initiatives are organized in the curriculum, with the ‘bachelor’s dissertation’ in the third bachelor year and the final ‘master’s dissertation’, resulting in four large projects of increasing complexity, as is also the case in Kjærgaard C. et al.(2012). This is completely in accordance with CDIO Standard 5.

The focus of this paper is presenting the design-implement projects of the second bachelor year in electronic engineering, as described in the Course Specifications (2015). Students design, build and test a device in a team of five to seven people. Each year another topic is chosen. Projects of the past ten years included a mechanically rotating LED display, the ‘snake’ (a device for measuring movements of the spine), an ultrasound scanner, an intelligent solar charger with rotating solar panel, a MIDI controlled analog music synthesizer as well as a bat detector. Another project example is displayed in Figure 1, where a complete digital clock radio was developed, including an OLED display. The microcontroller, at the heart of the circuit is programmed in the C language, which is also the case in all projects mentioned above. The complexity of the project is always large enough for an advanced-level design implement experience.

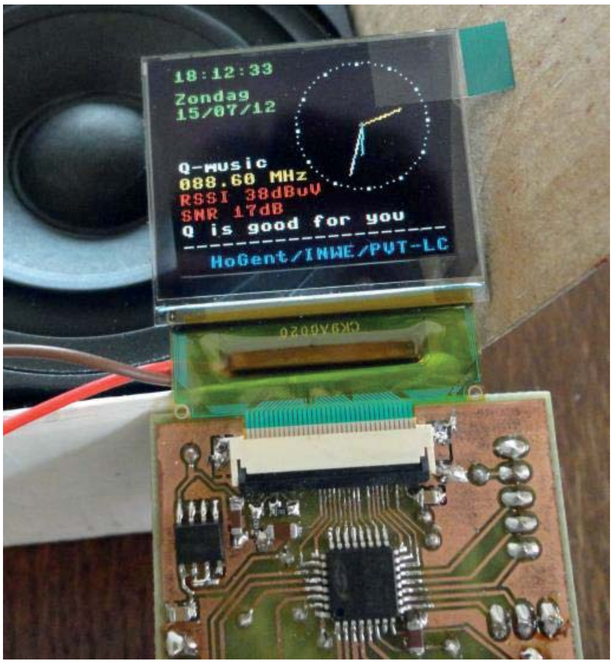

Figure 1. Clock radio with OLED display

The students are supposed to work on their projects one day per week during a full semester of 12 weeks. In their team, every student has different tasks to fulfill. We include the following job profiles: project manager, analog design engineer, digital design engineer, software engineer, mechanical engineer and CAD (computer aided design) engineer. However, it is important that every team member keeps an overview of the entire project.

The students meet regularly, where they discuss the progress and milestones of their project. Although the meetings are supervised, the students are always encouraged to take initiatives and be creative. At these meetings, a project schedule is discussed and adjusted where necessary. Gantt charts are employed to encourage better project management as well as to provide more overview.

Due to the limited technical background of second bachelor students, technical and scientific support is constantly provided by the two supervisors. Halfway the semester, an intermediate peer assessment is performed, which outcome does not count for the final grade. The supervisors clearly state to the students that this assessment is only intended to provide feedback on how the team members appreciate their work, and to inform the supervisors in time about potential problems in the team.

At the end of the semester, an oral presentation is performed with an active contribution of every team member. Additionally, a project report of about 30 pages is handed in. Furthermore, a final peer assessment is performed. The grading of the students is performed by the supervisors, relying on individual permanent assessment during the semester, general and specific project output, quality of the report and presentation as well as the final peer assessment. However, the final peer assessment is only employed as an additional instrument to support the permanent assessment.

The following sections of the paper describe the organization of the different projects, the project assessment, a SWOT analysis and the conclusions.

ORGANIZATION OF THE PROJECTS

Team Definition

From the first project session, teams of five to seven people are defined, including the following job profiles:

- Project leader (1, combined with another task in this list)
- Analog design engineer (1-2)
- Digital design engineer (1-2)
- Embedded software developer (1-2)
- CAD engineer (1)

Depending on the specific project content, two persons can have a similar job profile. The project leader combines his/her responsibility generally with a technical job shared with another student.

Job profiles are appointed to the students by letting them fill out their preferences on a list. They can rank the different job profiles by using numbers. Job profiles performed in other (earlier) projects are ranked at the bottom. The supervisors then search for team compositions in order to appoint the specific job positions to those students who have a high preference for it. Generally, students get a job which is their first or second choice.

Introductory Classes

A number of introductory classes are taught, on the following topics:

- Project history, methodology and assessment
- CDIO principles
- Technical details important for the current project
- Theoretical background of relevant technical issues
- CAD exercise, drawing a schematic and printed-circuit board
- Embedded software programming exercise

These introductory classes take two project sessions, after which the teams start planning and brainstorming about technical issues, a process illustrated very well in Khan R. et al. (2015).

Hands-on Project Work

Project work is performed in the lab at our university on a weekly basis. According to CDIO standards, the workspaces used are student-centered, user-friendly and always accessible.

The lab is available to the students most of the week, but extra hours are mostly spent in the last project weeks. For 2.5 hours per week, students are constantly supported by two supervisors, providing practical as well as theoretical advice, from design guidelines to ordering new components or providing them from the local stock.

According to CDIO standard 5, early success is an important motivating factor. Early success is stimulated by the constant support, helping the students to quickly achieve small goals in an early project stage. The project proposals are always written in order to include a large number of goals of increasing complexity.

All teams are encouraged to communicate their project experiences and design choices to the other teams, in order to make them learn from each other's design choices. Hands-on and social learning are included into CDIO standard 6. Iteration into a redesign, as a consequence of social learning, especially in an early project stage is a highly valuable experience.

Despite the interaction, the end result should be clearly different for each team because of their creative and independent design choices. Schematic and printed-circuit layouts as well as embedded software source code are compared and should be fundamentally different for each team.

PROJECT ASSESSMENT

Permanent Assessment

Permanent evaluation is the most important factor in grading the final project as well as in providing feedback. The supervisors are both continuously present during the project hours, inspecting the work of the students, and taking notes of the project status while providing feedback. The performance of individual students is constantly being observed. Figure 2 displays a student lab setup during project implementation in the first half of the semester. Such a measurement setup allows easy comparison of the project status between different teams.

After a few weeks trends become visible: some students tend to present more creative ideas or take initiative; others tend to go with the flow. This phenomenon corresponds very well to typical engineering teams in realistic and industrial settings. Regular project meetings are held every week, where each team discusses the project status and future schedule in the presence of the supervisors. They provide feedback to improve the teamwork and also give technical input if necessary.

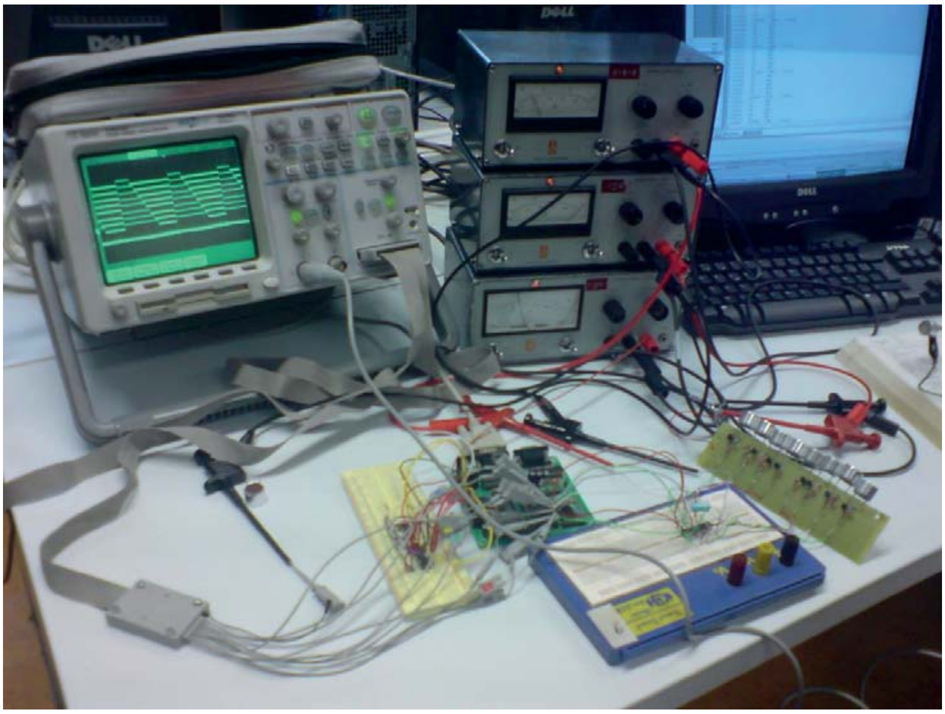

Figure 2. Project implementation during first half of semester

Intermediate Peer Assessment

In the first introductory class, the students are informed that peer assessment will be performed. They are already used to this system from their first year project course.

Halfway the semester, an intermediate peer assessment is performed, to allow the students to get feedback from their team members. It is stated explicitly that this intermediate peer assessment is not used for grading the project.

The intermediate peer assessment helps to spot large problems at an early stage, concerning individuals who do not fit well in the team. In case such a problem is apparent, extra meetings are held with the team as well as with the individual student and the supervisors. Practical experience learned that these problems are often caused by inefficient communication and can be solved most of the time.

Presentation

At the end of the semester, the students have to present their work in a written report of about 30 pages, a group presentation and a lab demonstration.

In this presentation, students will typically cover the topic, which they spent most of their time on. At the end of the presentation, questions are asked by the supervisors, concerning the jobs performed in the project as well as on project overview. Fellow students can also ask questions.

Demonstration

After the presentation, a demonstration is required in the lab. Here students generally show a working prototype as the end result of their project. Partially working or non-functional prototypes can also be presented.

In case a prototype does not work (partly or completely), a good grade can still be obtained if the project is clearly presented and documented and if the remaining problems are clearly identified.

Figures 3 and 4 display a working prototype of an ultrasound scanner, allowing visualization of objects in front of the scanner. This multidisciplinary project included all following skills:

- Project management
- Teamwork
- Analog circuit design
- Digital circuit design
- Mechanical design
- CAD
- Embedded software development
- MATLAB code development
- Test and measurement skills
- Writing and presentation skills

Therefore the project is also a valuable Integrated Learning Experience as explained in CDIO Standard 8, developing multidisciplinary knowledge simultaneously with personal and interpersonal skills.

Moreover, the supervisors use concepts from the students' theory courses to provoke a deeper understanding of practical issues encountered during this project, hence promoting active learning (CDIO Standard 8), comparable to Liqiao W. et al. (2015). Realizing the project requires background from multiple theory courses, such as analog electronics, digital electronics, embedded systems, physics and mathematics.

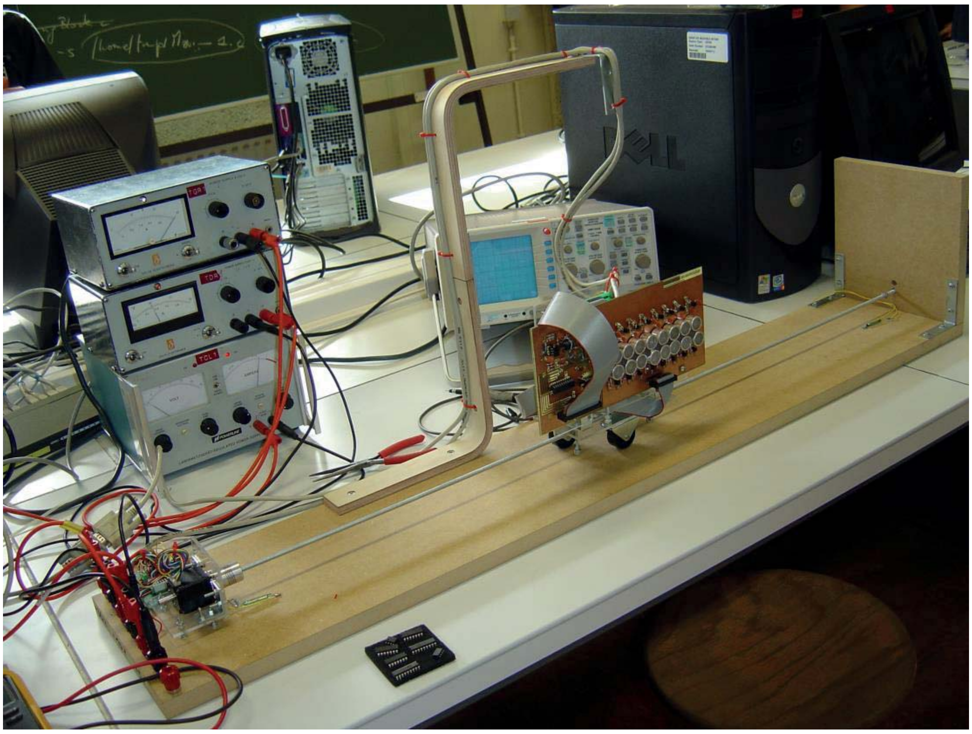

Figure 3. An ultrasound scanner as implemented by the end of the semester

Figure 4. A team demonstrating their ultrasound scanner

Final Peer Assessment

The final peer assessment is performed after the presentations, right at the end of the project. It is mandatory for each student to fill out the peer assessment in order to obtain an individual project score.

The students are informed that the peer assessment will only be used as a guideline in grading the students. Permanent assessment by the coaches is much more important, but the peer assessment shows if the opinion of the supervisors is supported by their team.

Well-known methods, such as calculating a peer assessment factor and multiplying global project marks by this factor to obtain individual results are not employed, as we have the experience that this system allows the students to have too much impact on the grading. Care should be taken at all times that some students do not fail the course solely because of group dynamics.

Grading

After the presentation, demonstration and final peer assessment, both supervisors exchange views to determine the results. Generally this happens within two weeks after the end of the course, when all project reports have been.

A meeting is then held where first, for each team, the performance of different students is compared. Then the overall performance of different teams is compared, as well as the individual performance of students in similar jobs in different teams.

The following factors are taken into consideration:

- Motivation
- Attitude
- Creativity
- Taking initiative
- Problem solving
- Communication skills
- Teamwork
- Perseverance
- Presentation skills
- Writing skills
- Peer assessment

After the final marks are calculated, a ranking of the students is performed. The list is checked for anomalies and slight corrections are possible according to comparison based on the constant monitoring of the students during the entire semester.

Feedback

Students receive via the electronic learning environment Minerva. They are allowed to ask feedback on these results, but they rarely make use of that. Generally, students accept their grade without discussion as they trust the supervisors in judging in an objective and honest way. By filling out the peer assessment, each student has already reflected about his/her own results and his/her place in the team. Additionally some feedback had already been provided after the presentation, hence students know what to expect approximately.

Learning assessment

According to CDIO Standard 11, it is highly important to have an effective assessment process for measuring the different learning outcomes. Fixed weights are employed to calculate the average grade based on specific assessment types for the different learning objectives that need to be achieved. Writing and presentation skills are even assessed by a language professor. Determination of students' achievements is hence performed accurately for each specific learning objective.

ASSESSMENT AND SWOT ANALYSIS OF THE COURSE

Assessment

At Ghent University, all courses are assessed by the students on a regular basis. Students fill out a number of questions, assigning scores from one to five to different course aspects. Figure 5 displays the results of such a student assessment for this second bachelor year CDIO project. Although the number of students who responded was rather limited (i.e. 17 %), the course is clearly appreciated, as the score is higher than the faculty reference (the average for all courses) in all aspects, with 'Learning effect' and 'Project coaching' even very near the maximum score (5/5).

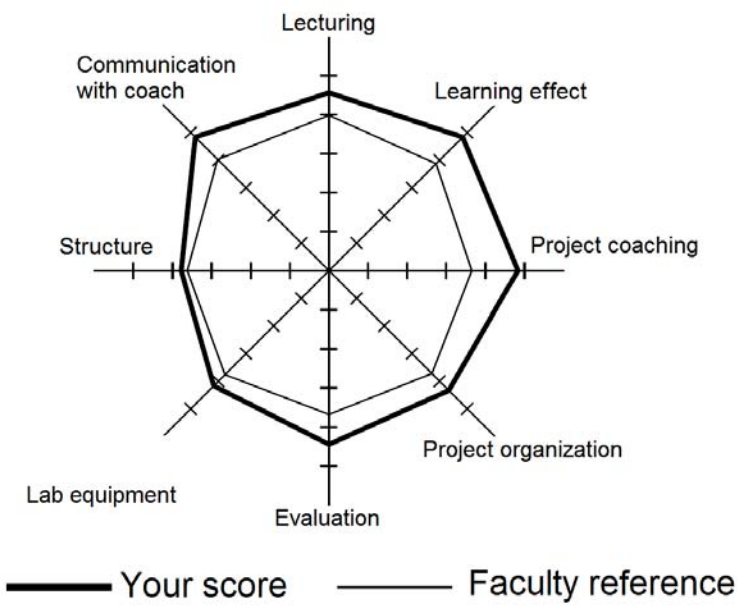

Figure 5. Graphical presentation of course assessment

Strengths

The project sessions are extremely motivating. Students regularly cite this as the course where they learned the most at this point in their education. They regularly work more hours than requested, stay in the lab much longer, or perform work outside the scheduled project hours, especially during the final phase of the project.

The project provides a unique hands-on experience and the degrees of freedom given for the design help to boost creativity. Students experience the whole design cycle, starting with only some vague ideas and finishing with a documented and functional prototype.

Weaknesses

Replacing classic courses with project-oriented lab sessions of this type causes people to acquire specific knowledge around their function in the group, leaving voids in their knowledge with respect to other fields. Year after year students could for example avoid drawing a printed-circuit board, finally graduating as an electronic engineer without having obtained this skill. Care has to be taken when composing the educational program in order to avoid such knowledge gaps.

Opportunities

CDIO projects can also be performed as a proof of concept for third parties, who have an idea that needs to be tested, as a way of community service learning. This has been done once in the past for a Belgian health insurance organization, requesting the development of a system for measuring movements of the spine. Such a project needs to be at a suitable level of difficulty and allow enough creativity for the students to realize their own ideas. A careful selection of such requests is very important, as illustrated in Törnqvist E. (2015).

Threats

Manipulation of the peer assessment system by the students is a risk. Popular students are sometimes protected by their peers, whereas other students can be severely discriminated. This is the main reason why peer assessment is only used as a guideline.

CONCLUSIONS

This paper described ten years of experience with advanced CDIO project courses in the second bachelor year of a curriculum in electronic engineering at Ghent University. Organization, topic selection and grading were discussed.

The main features of the course were the variety of project topics, with a completely new topic presented each year, combined with selected job profiles for the students and allowing ample creativity in design choices. A SWOT analysis of the course provided more insight into some specific issues encountered over all those years.

The experience of the past decade of project courses is very valuable. Students are always highly motivated for the projects and obtain good results as a team in nearly all cases. At course assessments, students regularly state this project is the course where they have learned the most in their educational career so far. The hands-on approach as well as the concentric learning and teamwork experience are highly appreciated. It is impressive how result-driven the students are, with near the end of the semester more and more people choosing to work overtime to get things working as the deadline approaches, like professional engineers. The student assessment results confirm their appreciation of the course.

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BIOGRAPHICAL INFORMATION

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STUDENTS' ROLE IN GAMIFIED SOLUTIONS IN HEALTHCARE RDI PROJECT

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ABSTRACT

Turku University of Applied Sciences has focused on game development education since 2009. In Turku Game Lab facilities, students and engineers have worked in a close cooperation in Gamified Solutions in Healthcare RDI project (GSH in brief) funded by Tekes (the Finnish Funding Agency for Innovation). In this paper, we will report how our students have worked in various roles in this project. The main focus in the GSH project has been on new services and effective activity solutions to elderly people through gamification. That is to say our objective is to offer more options for the elderly's self-care and eases the healthcare professional's work load. Our ICT engineering students specializing on game development and health informatics have participated from planning and idea generation phase to game development and testing, according to CDIO standards. This project has had relatively large international research exchange program. So our students have been able to work closely with international experts both in our game lab and Japan.

KEYWORDS

CDIO, Rehabilitation games, Health informatics, Gamification, CDIO Standards 1, 5, 7 and 8

INTRODUCTION

Turku University of Applied Sciences has cooperated with its Japanese partners for over ten years. As a result, cooperation has progressed in a level which is covering also large international research exchange activities. In this paper, we will describe how this cooperation has influenced in our engineering education, following the CDIO standards. That is to say we will report how we as teachers and researchers have followed the CDIO standards and based on this how our students have participated in GSH project in various roles. In 2013, before our RDI project called Gamified Solutions in Healthcare (GSH) we conducted a usability evaluation for Serious Games Finland's Glider game. This game is a motion based rehabilitation game designed for stroke patients in a close cooperation with Finnish physical therapists and medical doctors. Our industrial partner requested us to evaluate this game with Japanese elderly people. As we all know Japan is aging rapidly and we were interested in learning more about this relatively new business field. One student from Sendai National College of Technology (SNCT) visited early 2013 in our game lab. During this stay we designed the plan and conducted the pilot test. Kansei Engineering was selected as a research method. This Japanese research philosophy was chosen to get better understanding how Japanese researchers are conducting feasibility (especially usability) evaluations for designed software artifacts. During spring 2012, totally 12 Japanese test subjects from SNCT participated in our evaluations and the results have been published in [1].

Thanks to this successful test phase in Japan, GSH project was accepted by Tekes. GSH project develops new services and effective activity solutions to elderly people through gamification. This RDI project combines the expertise of many different disciplines and is linked to company-driven projects that develop scalable international serious games solutions for healthcare utilization. As the result this research project offers more options for the elderly's self-care and eases the healthcare professional's work load. In addition, the project targets to provide support for the Finnish health-care service industry in an endeavour to become World's top provider of gamified healthcare solutions. During this project new rehabilitation game prototypes were developed in our game lab. One of the first game prototypes tested in the project was so called SportWall game. Originally this game was designed by Puuha Group (one of our industrial partner) for children and in this project SportWall was redesigned by our game developers for elderly people. Results reported in [2] were promising compared to commercial games and it encouraged us to continue game development process in GSH project. Next Skiing Game was developed using SportWall game mechanics as a starting point. In spring 2015, this game was tested in Sendai Finland Wellbeing Center (SFWC) with 24 elderly people and later in Finland. These results have now been analyzed and are under evaluation process. The latest game concept called Hiking Game has a bit different approach in aims of rehabilitation. Glider, SportWall and Skiing Game are all so called rehabilitation games with exercise effect. The Hiking Game has been designed to give experiences and entertainment elderly people who are not anymore able to attend outdoor activities nor have long walks in nature. This game has social aspect because it can be played in a group of people. This game together with Skiing Game along with several other games will be tested in spring 2016 also in Singapore.

Another gamified application focusing on social functioning is Old Photos on a Map. This one has been designed for elderly people to share their memories using photos placed on a city map. The concept design of the application has been published in [3]. This application has been developed in a cooperation with Waseda University from Tokyo and we have plans to start testing this application with Finnish elderly people in spring 2016. Another application developed in a close cooperation is CADo flower arrangement application which has been developed with Ochanomizu University from Tokyo as well. In addition, we have developed in GSH project a Clinical Layer which is a virtual physical therapy application. This application was presented in Singapore in World Federation for Physical Therapy 2015. Based on achieved promising feedback these results have now been sold to our industrial partner which has commercialization targets.

In the next chapters, we will report how our students have participated in GSH project in various roles. By presenting these activities we try to illustrate how serious RDI activities can be combined with CDIO principles. As a background information, we have experiences of using CDIO standards in our engineering education since 2007 [4]. In our previous papers we have also reported how important teaching methods namely industry driven projects, learning by doing, and certain case studies in which CDIO standards have been applied are in our engineering education [5-8.]

STUDENT'S ROLE IN GSH PROJECT

The following case studies will be used as examples how we are organizing RDI integrated education in Turku Game Lab facilities nowadays. In GSH project, our students have participated from the planning and idea generation phase until the game development and testing phase. As described above we have tested rehabilitation in various field experiments during the GSH project. Students have participated in preliminary tests and events in which elderly people have played motion detection games such as SportWall and Skiing Game. Students have also been in essential role in the game development itself. In addition, students have conducted and gathered relevant state of the art material for the utilization of game developers. Not only our students but also students from our international cooperation universities (Japan and Singapore) have been involved in the GSH project activities.

Case Glider Game

One student and his professor from Sendai National College of Technology participated in the Glider game testing. This student introduced himself in Kansei Engineering research philosophy. He was also responsible of designing, conducting, and analyzing the field experiments under supervision of professors from Sendai and Turku. In addition, totally 12 college students from Sendai were participating in the tests as test subjects. More information about the designing and conducting can be found from [1].

Students' role: one Japanese student from Sendai National College of Technology has designed and conducted the game testing, 12 Japanese students participated in as test subjects.

Figure 1. The Glider game tested in Sendai National College of Technology in spring 2013.

Case SportWall Game

As already mentioned, SportWall game was originally designed for children. To redesign the game for elderly, we initially studied the usability and usefulness of commercial games that have potential to be used for the elderly's physical rehabilitation such as Nintendo Wii games, Xbox Sport games, and PlayStation Sport games [2]. Moreover, we consulted with the physiotherapists to effectively design the game in terms of therapeutic movements, game design and customization, and assessment to meet individual needs in doing rehabilitative exercises. Basically, this game was designed and integrated with different therapeutic actions such as side-swaying, sit-to-stand, and jump actions based on the therapist' inputs to the physical rehabilitative exercises for the elderly. Along the SportWall, another game called PhysioWall, was developed with a slower pace with clean physiotherapy moves. The game graphics were developed with students, as well as the gamification concept and preliminary testing activities were done by students.

Students' role: Our students have participated in graphical and game design, game testing and demonstrating game in exhibitions and other events. In addition, one Myanmarian PhD student has conducted studies in feasibility evaluation, social functioning, and cultural difference comparison.

Figure 2. Two graduates from our university testing SportWall game with elderly people (left) and developing graphics for PhysioWall game (right).

Case Skiing Game

In GSH, project we have developed the Skiing Game which is designed for engaging elderly people in regular physical exercise that is required for their general wellbeing. We carefully planned and implemented the game based on the findings from the pre-studies [9]. Our main objective in the game design and development was to provide an elderly-friendly, simple, and intuitive game system for the elderly and their physical exercises. The objective was also to appeal to something familiar to Finnish elderly generation, in this case cross-country skiing, because the technology would be something new to them. Based on gathered feedback during the development by our test-volunteers, we have followed the desired landscapes of snowy mountains and forest as the game context and background. The game play is simply based on steering a pair of skiing poles (double pole skiing technique), which is relatively easy and familiar exercise technique to elderly people who have previous experiences about cross country skiing. We have used a traditional web-cam based controller-free interaction and simple game labels and instructions using English language.

Student's role: Our students have participated in graphical design, game development, and game testing. In addition, one Myanmarian PhD student has conducted studies in feasibility evaluation, social functioning, and cultural difference comparison.

Figure 3. Our students have participated in Skiing Game development.

Case Hiking Game

This game consists of three different scenes from Finnish summer, made into three levels. In the first level, we are walking through Finnish forest environment. While walking in the forest we are able to explore Finnish forest. We are able to meet pines and spruces, as well as elks, and birds. The second one is about following a beautiful river by paddling your canoe until we will go ashore a mountain in Lapland. We will see salmons jumping ahead of our canoe. In addition, we will be again meeting animals and cottage in the riverside. In the last level, we are climbing up in the mountain. Compared to the first level now we are moving more vertically through causeways and ladders. We can again meet animals such as hedgehogs. The game has been designed to be played in groups or alone. Kinect sensor will be recognizing player's movements so the idea is that elderly people are exercising together ahead of the sensor and based on this we are able to navigate through predefined path successfully. The players are able to see the progress in the user interface as a vertical progress bar. This progress bar will visualize for the players 3-4 task locations in which we are able to take pictures of animals and other interesting objects which can be later shared with each other.

Student's role: Our students have participated in graphical design, game development, and game testing.

Figure 4. One student based game company has participated in Hiking Game development.

Case Old Photos on Map

This gamified solution has been designed for elderly people to collect, share and memorize old photographs together. Elderly people are able to store their photos including some metadata such as the location and the date when it has been photographed. This system has features to filter photos by are the location or by the year. In addition, when these photos have been shared with other elderly people everyone has rights to comment or memorize these photos on map. TUAS Social sciences students have participated in the development of Old Photos on a Map by conducting a theory framework of elderly memory issues and brain health for the developers.

Old Photos on Map application has also an agent which has been designed in a close cooperation with Waseda University from Japan. The agent will help elderly people to use the application and try to raise conversation to help elderly people to memorize something while browsing photos on map.

Student's role: Our students have participated in the software development, pre-testing and in graphical design (two students have researched and designed Japanese graphics while working in Sendai). In addition, one PhD student from Waseda University has developed the agent as one of the advanced features in the application.

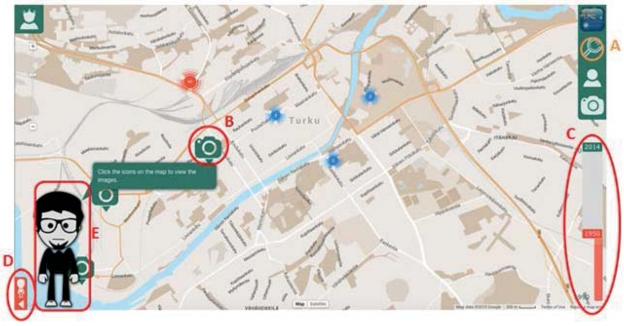

Figure 5. Our students have finalized the Old Photos on Map application for the upcoming tests.

Case CADo

CADo is a mobile application designed for recreating traditional Japanese flower arrangements in virtual reality [cf. 10]. Flower arrangements are fully following traditional Japanese techniques of ikebana. This application is designed for elderly people and necessary exercise in maintaining fine motor skills. In practice, user needs to handle uniquely designed controller that serves as an actual physical controller in an application (initiating start, cancel, confirm, delete functions) and a visual marker for system to use in triggering augmentative reality. The controller also serves as a model of a flower that needs to be virtually cut and arranged in chosen arrangement from given collection. Long with the rehabilitation goal, this application provides soothing setting in which time is no pressure and hint-system would give unlimited number of trials.

Visual language together with the core mechanics of this application provide a calming and yet necessary activity for the elderly people, who wish to improve or maintain the vital senses of coordination. Each session is providing a short entertainment with rich 2D and 3D graphics and interactive setting. This application uses augmentative reality as the main settings for users' interaction. The controller which would be designed as a stick with variety of sensors and markets, would additionally serve as a scanning market which holds information that user wishes to send to the virtual setting. In each stage of the project development, our students found a solution in challenging tasks of creating a virtual ikebana in own everyday surrounding. Additionally, programmers have created a possible use of sensors for more sufficient practice of the application, which is aimed for the users that have conditions with side-effects of trembling hands. In our next phase, we plan to conduct tests in Finland and Japan among elderly people and develop the application further according to the received feedback and test-results.

Student's role: Our students have participated in the software development, and in graphical design. In addition, one PhD student from Ochanomizu University has developed advanced features in the application.

Figure 6. User interface design and use of application in practice.

Case Clinical Layer

Clinical Layer is a solution which is able to interpret physical therapy movements utilizing motion detection sensor called Microsoft Kinect for Xbox One. This motion based sensor together with physical therapy exercise libraries enables innovation creation which is a combination of real time tracking and playful exercising. Clinical Layer as a tracking system is sufficient detecting variety of body-movements. This tracking system (including TV, PC, and Kinect sensor). It has been tested with a couple of game prototypes namely Chair Exercise and Swimming Game.

Student's role: Our students (including both our university and University of Turku) have participated in the software development in a close cooperation with our industrial partner GoodLife Technology.

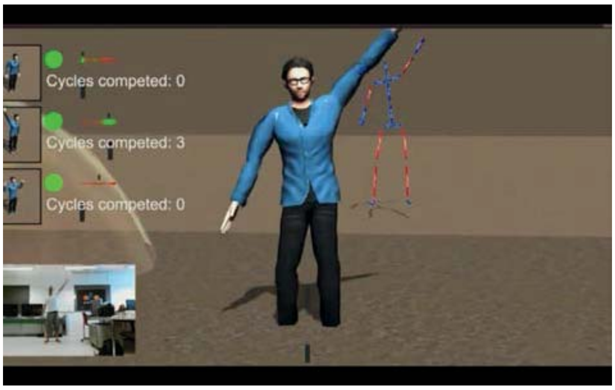

Figure 7. Our students have developed this solution in a close cooperation with GoodLife Technology.

STUDENT PROFILES IN GSH

As described above our students have worked widely in GSH project in various roles. Typically students can be classified in four categories. The first and second year students are mainly participating in our introduction courses. These students have not worked in GSH because they have not enough experiences in game development. The second category is our students studying in Game Development specialization area. These students are working in game development projects in which our game lab experts together with the GSH project manager have coached them in the game development activities. In this phase, students have earned credit points and our game lab experts have been responsible of the achieved results e.g. game testing.

In the third category, our advanced students have worked in GSH project as student assistants. Their role has been essential in the means of programming, visual designs and usability testing. Sometimes they have coached and supervised other students, integrating GSH activities widely in our curriculum. These student assistants have shown their expertise not only in programming or graphical design but also in the frequent communication with our industrial partners. Finally in the fourth category, we have students who have graduated and have continued working in our game lab as engineers (they have possibilities to continue their studies in scientific university or continue their working careers with industrial partners.

In addition, several game development and health informatics students have made their final thesis work for GSH project. These more extensive research works have turned out valuable to the project. They have been utilized for example in requirement analyses, background analyses, theory concepts, user interface designs, game development and programming.

Figure 8. Our students' roles in GSH project.

CONCLUSIONS

All in all, we can summarize that GSH project has opened various ways to utilize CDIO standards in our engineering education. This project has been a valuable platform (as visualized above in Fig. 8) that has joint multidisciplinary students working towards a common goal, each utilizing their own expertise. A multidisciplinary project needs many experts and GSH has succeeded in acquiring and combining these skills both from our university, University of Turku, industrial partners and international cooperation partners. The project has involved students over the course of several years and has both offered and demonstrated them more innovative viewpoints to apply their expertise. Some students have grown with the project, from second or third category onwards becoming project engineers and perhaps later being employed by TUAS industrial partner companies. The possibility to combine project work with studies offers a unique path for TUAS students to build their future.

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INNOVATION GENERATION MODEL – FROM INNOVATION PROJECTS TOWARS RDI PROJECT CONSOTIUMS AND BUSINESS ECOSYSTEMS

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ABSTRACT

The use of CDIO principles should have influence not only in learning outcomes but also in RDI and business driven activities. In this paper, we will report how these pedagogical methods have helped us in game development education and relatively vital RDI activities. In addition, some early phase influences have been identified also in business driven activities. As a result, we will present an Innovation Generation Model which will illustrate our strategy to utilize students' capabilities as an important factor in our RDI and business development. This Innovation Generation Model will be concretized with five case studies. The first one, called Pikkuli Case, will show how results achieved in innovation projects have been used as a seeds in an RDI project which has received significant external (both governmental and industrial) funding. The second case study namely Rockodile Games Case, in turn, will be used as an example of our Capstone innovation projects which have led to startup activities. In our third case called NeuroCar Case, we will focus on reporting how scientific research (namely cognitive neuro science) and our game development activities have led from innovation projects to a business driven RDI project with objectives to generate new business based on the achieved research results. In our fourth case called Bet-Ker Case, we show how integration of education and RDI project resulted into an innovative marketing and sales tool which was created by game programming for a refractory materials and components manufacturing company. Finally, in our fifth case, we will show how integration of education and RDI projects have led to startup activities, commercialized web-based 3D interior design product and an innovative educational tool for interior design education in a 3D virtual spaces.

KEYWORDS

Capstone, CDIO, Innovation project, RDI, Startups, Standards: 1, 3, 5

INTRODUCTION

The use of CDIO standards (CDIO, 2015) has impacted engineering education significantly during the last few years. In this paper, we are interested in which kind of a role CDIO has had in our Research, Development and Innovation (RDI) activities. In previous studies, we have reported how Finnish universities of applied sciences (UAS) have contributed to our innovation system including the utilization of multidisciplinary teams, RDI integrated engineering education, technology transfer to the local industry, and innovative trials (Pieskä, 2012). We have also emphasized the teacher's role in RDI integrated education. That is to say, RDI staff in our laboratories do not have enough knowhow and tools to transfer the knowhow of the latest technologies to students efficiently. We have also reported how important learning and teaching methods, such as learning by doing, have been applied in industry-driven projects (Pieskä et al., 2012; Luimula et al., 2013; Luimula & Skarli, 2014, Kulmala et al., 2014). In one of our latest studies (Pieskä et al., 2015), we have focused not only on technology oriented engineering education but also on business oriented perspectives. We have seen that RDI-integrated engineering education is not only serving students but also local industry.

According to Pieskä (2012) one of the key findings has been the mixing of expertise inside an organization including also foreign students and exchange researchers. This has been actually found to be one of the key drivers for successful results in our applied research teams. The results of the collaborative applied research projects have influenced our engineering education. The advanced equipment and software obtained in these projects have given the students a possibility to study with the newest equipment and tools. Typically, students participate in the projects during the final phases of their studies and, when they have moved to local SMEs after graduation, they transfer their knowledge about the possibilities of new technologies to the SMEs. Also direct feedback from SME personnel or engineering students has been valuable to further develop our education. In many cases, we have used technology demonstrations as innovation generation tools. The received feedback has been used to develop technology demonstrations more concise and comprehensible. The results of the technology demonstrations have been distributed by using different digital media including video clips and simulations for smart phones, websites and digital video libraries.

Pieskä et al. (2012) have visualized a model in which educational and project personnel are overlapping is the core element of successful integration of applied research and education. The interaction of project staff and faculty members brings real-life project topics for students and it can also be utilized in focused visits to companies. Sometimes students can be employed in projects as project assistants or they can find jobs in collaborating enterprises. In Pieskä et al. (2015) in turn, we have introduced a model in which applied research and education has been integrated. The model contains technology expertise and business knowledge with collaboration involving enterprises, the research staff and faculty members. The model emphasizes to proactively take into account the needs of current and future customers. The research approach has been found beneficial on the both sides: innovation capability has increased remarkably in both partners.

Based on our experiences, we have seen that pedagogy, especially the use of CDIO standards, is one of the key enablers in innovation generation. On the other hand, we have to emphasize the role of RDI activities in this innovation generation process. Without vital RDI activities we don’t have up-to-date facilities including the latest technologies and the knowhow how to utilize these innovatively. For example, Turku Game Lab facilities currently has around 0.5 million euros external funding annually. This facility is a working environment, shared by two higher education institutes namely Turku University of Applied Sciences and University of Turku. The original idea since 2009 has been that students from both the technical and artistic fields can meet and develop games together. Annually around 30-40 new game developers graduate from the lab. Our students are especially interested in entertainment game development. However, we have seen some difficulties to succeed in this business. Therefore, it seems to be important to widen their understanding of business potential in game development. This has been done by focusing on serious games and gamification not only in our engineering education but also in RDI.

Actually a new research group namely Futuristic Interactive Technologies was formed early 2016. This research group aims to utilize the interactive technologies (including game technologies) in various fields in a comprehensive manner. The main goal is to find new interactive user interface solutions for new areas of applications, with novelty and innovation value, employing the practices of user centric design and agile, rapid prototyping. This course of action aims to create visually rich and engaging user experiences packaged in innovative product and service concepts for both private sector businesses and public sector organizations. Applying new interactive technologies enables development of new business models and contributes to turning the widely recognized Finnish technology know-how brand into a more lucrative form.

RFMedia Laboratory is an ICT know-how center located in Ylivieska, Finland. The laboratory is a high-level applied research unit consisting of personnel from the Centria University of Applied Sciences and University of Oulu / Oulu Southern Institute. Centria has very vital RDI activities and has succeeded extremely well to get external funding when compared to other Universities of Applied Sciences. Therefore, RFMedia Laboratory has the latest technology to use both in RDI projects and in education. Its research focus is ICT enabling business activities meaning the integration of ICT and software know-how to various business sectors. Based on business needs, RFMedia Laboratory studies, develops, and makes pilot solutions utilizing ubiquitous computing, mobile software, wireless communications, game technologies and 3D imaging.

CASE STUDIES

The ICT Engineering education of Turku University of Applied Sciences has applied CDIO standards in program development since 2007 (Roslöf, 2008). In this paper, we will report how the use of these standards has not only influenced in our engineering education but also to our RDI and business-driven activities. In this chapter, we will report case studies as examples on how to generate innovations in engineering education. The first one, called Pikkuli Case, will show how results achieved in innovation projects have been used as seeds in an RDI project which has received significant external funding (including governmental and industrial funding). The second case study, namely Rockodile Games Case, will be used as an example of our capstone innovation projects which have led to startup activities. Our third case called NeuroCar Case will focus on reporting how scientific high quality research (cognitive neuro science) and our game development activities have led from innovation projects to a business driven RDI project aiming at generating new business based on research results. In our fourth case called Bet-Ker Case, the focus is an interactive product presentation for metal industry created with game programming software. Finally, in our fifth case, we will show how game programming and 3D virtual spaces can be used in Interior Design Cases to boost web sales and interior design education.

Case Pikkuli

The first versions of the Pikkuli game prototypes were developed in Capstone innovation course (cf. Kulmala et al., 2014) of Turku University of Applied Sciences in a close cooperation with our industrial partner Sun In Eye Productions. Five students from the Information Technology (IT) degree program studying Digital Media were selected to this project. The results were demonstrated in the annual student exhibition ICT Showroom 2014. This demonstration contained two mini games. The prototypes were tested by game test experts from the Turku Game Lab for quality assurance. At the end of this project, students were testing the game prototypes with ten children from a local kindergarten. The received feedback was quite promising and formed the basis for the further development of the game.

In the next phase, three IT students studying Game Development were selected based on their experience of the Unity's 3D game engine, especially coding their own plugins for 2D game development. Because the graphical assets came almost directly from the animation pipeline, also an Arts Academy animation student was needed to support the programmers so she worked as a bridge between the animation studio and the game development team. The only game concept included from the first prototype was the maze game but its gameplay, mechanics and some of the assets were redesigned. Our two main objectives in this second project were to commercialize the mini games and to study how to improve the workflow of animation processes so that the assets can be utilized efficiently in the game development. Moreover, the development team as well as the experts from the Turku Game Lab and Sun In Eye Productions tested the mini games frequently for quality assurance and to optimize the game. We tested them also with the target group to make adjustments in the gameplay and user experience. As a result, we designed and implemented two new mini games: music game and runner game (see Figure 1).

Figure 1. The three Pikkuli mini games developed in the second phase (from left to right): music game, runner game, and maze game.

Later, Sun In Eye Productions joined our Tekes (Finnish Funding Agency for Innovation) funded RDI project called Fast Wow Effects Boosting SME Business (total budget around 1.1M€) and these games have been tested in Finland and Middle East to get understanding of end user experiences in different cultural contexts. The first results seem quite promising and our partner has started their commercialization activities. The game development has continued intensively with our students during 2015. At the moment, totally seven mobile games are available in AppStore and GooglePlay. In Figure 2, innovation generation has been modelled based on Pikkuli case.

Figure 2. Innovation generation in the Pikkuli case.

Case Rockodile Games

A student group from our Game Development specialization area developed their first game prototype during their second year of studies. This game, called Elementale, was demonstrated in ICT Showroom 2014 and based on promising feedback (best game award) the group decided to join the Startup Journey program arranged by a local student-driven pre-incubator society BoostTurku. Their first game published in marketplaces was finished during the journey and the students decided to establish a company called Rockodile Games. The group has continued working and studying in parallel. Their personal study plans have been designed so that the group can work efficiently but still based on our engineering education principles. As a result, in early 2015 the next game called Lemming Dynasty was developed during a Project Course on Game Development. This game was presented in ICT Showroom 2015 in which the game was again nominated with the best game award (see Figure 3). At the moment, Rockodile is working in SparkUp (a local start-up community space) and the newest game Lowglow was published in Steam at the end of 2015.

Figure 3. Rockodile's Lemming Dynasty received the best game award in ICT Showroom 2015.

If we analyze how this case differs from the first one, we recognize that now our student group was entrepreneurially-driven from the first trials until the final success. In addition, this case shows the potential in entertainment industry. The student group has successfully published already many games in various marketplaces such as AppStore, GooglePlay and even Steam. We have found it useful to give such student groups some freedom in their study planning. On the other hand, we have underlined that the students have to pass through all the required curricular content. In Figure 4, innovation generation has been modelled based on the Rockodile case.

Figure 4. Innovation generation in the Rockodile case.

Case NeuroCar

At the end of 2014, a cognitive neuroscientist, a professor from University of Turku contacted the Game Lab. During early 2015, one of our student groups supported by our game development experts implemented the first prototype version of a virtual evaluation tool called NeuroCar which can be used for a simultaneous evaluation of driving acuity and spatial perceptual capacity. That is, this system has been developed in a multidisciplinary team consisting of systemic neuroscientists and computer scientists. Our approach has been to develop a portable system that is cost effective enough to be used in hospitals, driving schools or even police cars. In the first development phase, our main objective has been to present a prototype of a measurement device for driving skills and perceptual capacity. (Luimula et al., 2015)

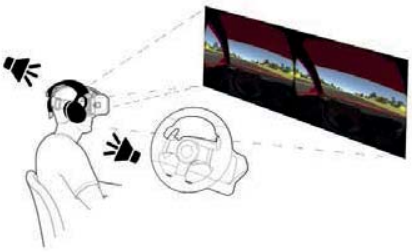

Figure 5. System illustration of the NeuroCar prototype.

Thanks to this prototype development, we received an RDI funding from Tekes for so called Virdi project (Virtual Reality in Driving Inspection). This time the funding was available for innovation generation based on the latest scientific results in neuroscience. Later, two other student groups have focused on prototype development in which we are illustrating how this system can also be utilized for training of driving skills and for various experimental purposes in cognitive neuroscience. We are starting the RDI project in which NeuroCar evaluation and training tool will be studied towards commercialization. So, the ultimate goal in this RDI project is to study different commercialization paths towards new business. Our students have been and will be in the center in this RDI project as well. In Figure 6, innovation generation has been modelled based on the NeuroCar case.

Figure 6. Innovation generation in the NeuroCar case.

Case Bet-Ker

In the Bet-Ker Case the metal industry company wanted to have a new kind of tool for marketing and product presentation purposes. A student group of our Pelipaja Game Lab took the task during their traineeship and implemented the first prototype version supported by our game development experts. The focus of the Pelipaja Game Lab and its projects is to increase game industry know-how and boost business incubator development towards start-up companies. In our RDI project the prototype was completed as an interactive product presentation and marketing tool by our game development expert.

Figure 7. Game programming applied for an interactive product guide for metal industry.

Figure 8. Innovation generation in Bet-Ker case.

Interior Design Cases

In Interior Design Cases we showed how game programming and 3D virtual spaces can be used to boost web sales and interior design education. In the web-based 3D interior design tool development, ideation, requirements definition and first demonstrations were made in the RDI project KKI, the commercialization was carried out with a start-up company (Mediaholvi cooperative association) where the members include Centria students and staff. In the Interior Design Educational case, student from the further education course carried out his job trainee in the Fast Wow project and created the first virtual model prototype of the holiday house. That virtual model was completed with the help of our game development experts as an interactive 3D tool for interior design education to a local vocational school.

Figure 9. An interior design view in the web-based 3D design tool *KokoTila* (left) and the virtual model of the holiday house for the Interior Design Educational case (right).

Figure 10. Innovation generation in the Interior Design cases.

INNOVATION GENERATION MODEL

In our previous studies (Luimula, 2010), a research as a combination of challenges related to ubiquitous systems and prototyping has been presented as our approach to IS research. We have compared our research activities including both academic field experiments and industrial pilots to Hevner's framework (Hevner et al., 2001). In this paper, our focus is in the left hand side of the framework as described below in Figure 11.

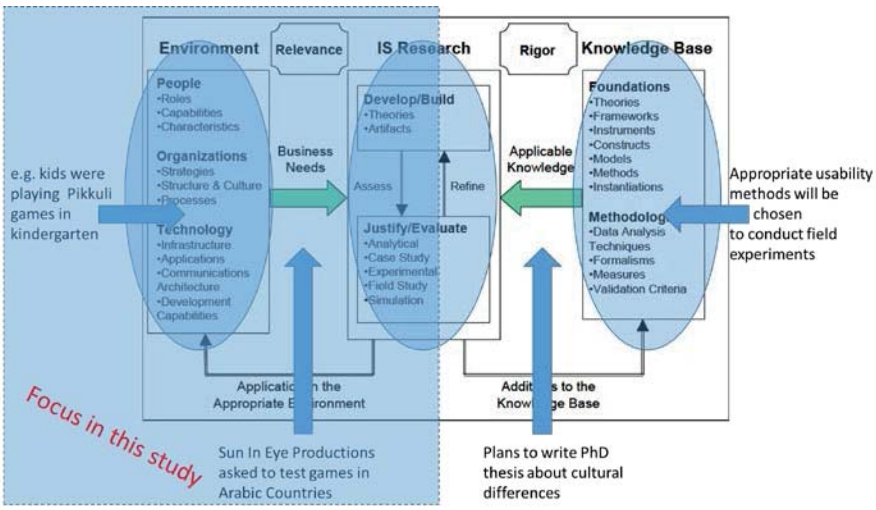

Figure 11. Our focus in this study related to Hevner's IS research framework.

In our previous studies, evaluations together with industrial pilots have been conducted in test generate cycles. That is to say both field experiments and industrial pilots have formed an iterative and incremental design process in which essential feedback has been gathered and analyzed for the next construction phases. Data gathered from the experiments has been analyzed with appropriate metrics. In this study, we have illustrated above how CDIO as a pedagogic tool can be used in business oriented RDI activities and in innovation generation. These case studies above can be seen as various test generate cycles. This time cycles are not covering rigorous academic field experiments but relevant business studies which are generating innovative solutions for Finnish society.

The innovation process which we introduced via our case studies can be presented by the Innovation Generation Model (IGM) showed in the Fig. 12. The iterative innovation process starts with open innovating and continues clockwise from conceiving to designing, implementing and operating. Rapid experimenting is an essential part of our model, it gives for the innovation process the speed which is needed in fast developing markets. Experimenting includes both technological and business experimenting. The results of the innovation process are innovative quality products and services. The students which have developed as true professionals can also be considered as resulting products of the innovation process. The potential spin-off or start-up companies are important outcomes of the innovation process. Figures 2, 4, 6, 8 and 10 show results and details of the intermediate phases in the five cases which were presented in this paper. With CDIO standards the quality of the innovation process can be monitored both from the RDI and educational view. CDIO can be seen as a basic strategy to utilize students' capabilities as an important factor in our RDI and business development.

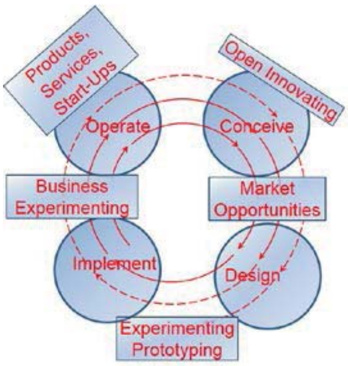

Figure 12. The Innovation Generation Model.

CONCLUSIONS

In this paper, we have presented five case studies which are used as examples of our innovation generation in two Finnish higher education institute namely Turku University of Applied Sciences and Centria University of Applied Sciences. Our RDI activities are quite similar because of our background in applied research. We believe that innovation generation as presented in this paper is at the moment needed widely in Western societies. For example Finnish society has been struggling already several years. In the same time our competitiveness has decreased and our demography is aging rapidly. On the other hand, we have in our economy also a lot of positive signals. Events like Slush annually organized by student association called Aalto Entrepreneurship Society underlines how our society is at the moment underlining entrepreneurship and innovation generation. Our IGM model has a lot of potential and we will encourage our colleagues and our partners to apply these methods in their RDI integrated education. As we have already seen these methods are generating innovative solutions and welfare for our society.

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10

IO (IMPLEMENT AND OPERATE) FIRST IN AN AUTOMATIC CONTROL CONTEXT

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ABSTRACT

A first course in Automatic control is presented. A main objective of the course is to put most of the emphasis on the Implement and Operate phases in the process of developing a control system for a process. The course is built around a large amount of student active learning based on three extensive laboratory exercises, where each laboratory exercise can have duration of up to two weeks. For each of the laboratory exercises there is a sequence of learning activities supporting the students' learning: Introductory lecture, problem solving session, preparation work, help-desk session, independent work in the laboratory, and a final demonstration of the control system. In addition there is a small project where the task is to write a manual for a process operator. The laboratory tasks involve implementation of a control system in an industrial PLC (Programmable Logic Controller) and development of an operator interface.

KEYWORDS

Active learning, laboratory exercise, PLC-programming, operator interface, Standards 7, 8, 11

INTRODUCTION

According to the CDIO framework, see Crawley et al (2014), the goal of engineering education is that every graduating engineer should be able to:

Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.

Assuming that this characterization is adopted, a logical consequence is to design engineering education with this goal in focus. Traditionally a course in an engineering discipline starts with the theoretical basis (including analysis tools), continues with design methods, where the result in many cases is an equation on paper, and sometimes ends with some type of implementation, while the operate phase seldom is covered. This paper presents a course in Automatic Control named Industriella Styrsystem, see Industriella styrsystem (2016), given at Linköping University. One aim of the course is to put emphasis on the Implement and Operate phases in the process of creating a product or a system. However, in order to make the implementation meaningful a minimum amount of theory is provided, and a pedagogical challenge is to do that with limited use of mathematics.

Designing a course where the aim is to emphasize the Implement and Operate phases implies a substantial amount of student active learning, and this is also the case in this course. The core of the execution and examination of the course consists of three big laboratory exercises and a small project. Since the execution of the different laboratory exercises overlap in time, and resources in terms of equipment are limited this puts strong requirements on the students' abilities to plan the work.

The paper is organized as follows. It starts by giving a brief introduction to the subject, and the following section gives an overview of the course and discusses the expected learning outcomes and the structure of the learning activities. The next section presents the equipment and the various software tools are presented. In the following sections the emphasis is on the contents and the execution of the course via the Conceive-Design-Implement-Operate phases. Finally the paper ends with some conclusions.

ABOUT THE SUBJECT

Automatic control is a key enabling technology in many engineering products, processes, and systems, and the task for an automatic control mechanism is to make a product, process, or system behave in a desired way. The field is sometimes called The Hidden Technology, Åström (1999), since its presence in the different applications is seldom visible. Instead the effects can be observed indirectly via the operation of the object under control. Automatic control can be found in a large number of applications, ranging from process industry, aerospace applications, passenger cars and trucks, power systems, consumer products like mobile phones and computers, biomedical engineering equipment, etc. The objectives for using automatic control mechanisms depend on the application, but they involve aspects like quality, productivity, safety, efficient use of energy and other resources, comfort, etc. One of the fascinating features of the subject is that the creation of a real world control systems includes several disciplines, including mathematical models and tools, process knowledge, hardware and software technology, sensor and measurement technology, etc. The mathematical models and tools in a basic course in automatic control normally involve calculus (differential equations and integrals), linear algebra, and transforms, and on a more advanced level probability and optimization are useful mathematical tools.

The subject is often seen as core engineering knowledge, and it is part of the curriculum in many engineering education programs around the world. Hence there are a lot of textbooks available in the subject, like e.g. Dorf and Bishop (2008) and Franklin et al (2010) in English and Glad and Ljung (2006) in Swedish. Many of the textbooks have similar structure, starting with some examples, continuing with the mathematical background, and then spend most of the presentation on various analysis and design methods. To less extent implementation aspects are given attention in these books. So in a sense, this represents the conventional way to present the subject in the engineering education. A pedagogical challenge in automatic control education is to connect the world of mathematical models, i.e. differential equations and Laplace transforms, with the real physical world. A first step is often to use simulation in order to support the understanding and intuition, and to help the students to connect e.g. time and frequency domain properties, and a second step is to carry out experiments using physical processes. Despite the fact that experiments using real hardware plays an important role there is a trend, for economic reasons, to use more and more of virtual and remote equipment. See e.g. Dominguez et al (2014) and de la Torre et al (2015).

ABOUT THE COURSE

Basic facts

The course is given for the Bachelor of Science program in Mechanical Engineering (Swe: Högskoleingenjörsprogrammet i Maskinteknik) during the second half of the spring semester of year one. The course comprises 6 ECTS credits, and there are normally around 65 participants in the course. The main part of the learning activities is based on three large laboratory exercises and one small project. The third laboratory exercise uses different hardware and software, and a somewhat different control problem is studied. This laboratory exercise will hence be left outside this paper. In addition there are four lectures and four exercise sessions supporting the preparations of the laboratory exercises. The project is tightly connected to the first two laboratory exercises, and the task is to write an operator manual for the control system. The laboratory exercises rely on a substantial amount of independent work by the students, and the duration for each laboratory exercise can be up to two weeks. More details about the organization will be given below.

The required knowledge and skills from previous courses in the curriculum include first order differential equations and integrals from the calculus course, basic skills in programming, basic knowledge about binary numbers, together with skills in writing reports. What is also of fundamental importance, even though not so visible in the curriculum, is the ability to work independently, take initiatives, and to use a systematic approach for trouble shooting.

Another consequence of the character of the course, with three large laboratory exercises, is that it also requires a substantial amount of planning by the students. Problems with completing the laboratory tasks or the project and finishing the course in time can often be connected to insufficient planning. It should also be noted that the students follow two other courses in parallel, where one of them also comprises laboratory exercises.

Learning outcomes – short summary

The learning outcomes of the first two laboratory exercises and the project can be summarized briefly as follows:

- Implement the relationships

$$\mathrm{I_k} = \mathrm{I_{k-1}} + \mathrm{K}\frac{\mathrm{T_I}}{\mathrm{T_S}}\mathrm{e_k}$$
$$\mathrm{u_k} = \mathrm{K\,e_k} + \mathrm{I_k}$$

(i.e. a discrete time version of a so called PI-controller) in an industrial PLC (Programmable Logic Controller). Implementing the relationships above may look deceptively simple, but, as will be described below, it includes numerous practical aspects related to the hardware and programming environment.

- Determine the coefficients K, $\mathrm{T_I}$ and $\mathrm{T_S}$ such that the algorithm is able to control the behavior of a laboratory scale process.
- Develop an operator interface that presents relevant information to a process operator and allows the operator to modify the operation of the plant.
- Write a manual for the operator describing the process, the control system, and a method to tune the coefficients of the control algorithm.

Remark: As mentioned above, the third laboratory exercise deals with sequential control, which is a particular class of control problems. The structure of the learning activities is similar to the other two laboratory exercises, but since the equipment (a model factory producing Lego cars) and software are different this exercise is left outside the presentation.

Learning outcomes with reference to the CDIO Syllabus

The CDIO Syllabus offers a structured way to specify expected learning outcomes, see The CDIO Syllabus (2016), and in this section we will discuss the expected learning outcomes of this course using the CDIO Syllabus as reference.

1. **Disciplinary knowledge and reasoning:** The learning outcomes of the course are clearly connected to section 1.2 Core engineering fundamental knowledge, with some basic understanding of system models and feedback control, but with emphasis on implementation aspects of control systems.
2. **Personal and professional skills and attributes**: Due to the nature of the subject and the organization of the learning activities with extensive independent work, the learning outcomes are mainly connected to sections 2.3 System thinking and 2.4 Attitudes, thought, and learning respectively. System thinking, in terms of subsystems and interaction between them, is fundamental within the subject. Among the several relevant subsections in 2.4 one can mention 2.4.2 Perseverance, urgency and will to deliver and 2.4.7 Time and resource management respectively.
3. **Interpersonal skills: Teamwork and communication:** The entire examination of the course is based on the laboratory exercises and the project. The learning activities are carried out in pairs, and this means that the course will give thorough practice in teamwork in a small team, connected to section 3.1 Teamwork. The purpose of the project is to write a short manual intended for an operator with limited knowledge in the automatic control subject. The report is supposed to give an overview of the process and the control system, a description of the user interface, and some guidelines for tuning of the control system. This task is hence related to section 3.2 Communications.
4. **Conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context – The innovation process**: As indicated already by the title of the paper the emphasis of the course is in the implement and operator phases, and hence the learning outcomes have closest connections to sections 4.5 Implementing and 4.6 Operating of the CDIO Syllabus.

Structure of learning activities

Given the desired learning outcomes as described above, it is natural that the course will have a big emphasis on student active learning. It would be very difficult to practice implementation in real hardware without a substantial amount of active learning.

For each laboratory exercise the overall structure of the learning activities is as follows:
- Introductory lecture presenting background material.
- Problem solving session dealing with problems related to the laboratory tasks.
- Independent work with preparation tasks. Access to a reasonable amount of assistance upon request.
- Helpdesk-sessions, where the students are expected to present their solutions to the preparation tasks.
- An initial, scheduled, and supervised session in the laboratory.

- Independent work in the laboratory. Since the number of workplaces is limited the student groups have to make reservations in advance to get access to the workplaces.
- During the laboratory work there is access to a reasonable amount of assistance upon request.
- Demonstration of the working solution to the supervisor.

The project is connected to the first two laboratory exercises, and the execution of the project task, i.e. tuning of the control system and writing of a manual for an operator can start as soon as the first laboratory exercise has been completed.

EQUIPMENT AND SOFTWARE TOOLS

Industrial process control systems typically involve a large and complex industrial process and a substantial amount of control equipment. Real industrial processes are very seldom available for education purposes, and instead one has to use affordable and safe laboratory scale equipment. Figure 1 shows the type of equipment that is used in this course, and it consists of the following hardware and software components:

- A process consisting of two water tanks on top of each other, a pump, and sensors measuring the water levels in the tanks.
- An industrial PLC of the type Siemens SLC5/03.
- A standard PC to be used as operator station.
- The software tool RSLogix in which the program to be executed in the PLC is developed.
- The software package InTouch and, in particular, the tool WindowMaker, which is used to develop the operator interface.

Figure 1: Laboratory scale plant and operator workplace.

Both for the PLC program and the operator interface the student groups are given a program skeleton to start from in the development process.

CONCEIVE PHASE

The Conceive phase in a development project deals with the problem of identifying needs of e.g. economic, environmental, or quality character, and where the introduction of a new product or system can contribute to fulfilling the needs. For the automatic control subject there are many examples both in industrial processes and in consumer products where the automatic control functionality is crucial for the operation. In e.g. a paper mill there are hundreds of control systems contributing to the task of maintaining the quality of the product, efficient use of energy and raw material, and keeping the emission of waste products at a minimum. In practice this means controlling physical quantities like level, temperature, pressure, flow, concentration, etc.

DESIGN PHASE

The aim in this phase is that the students should be able to carry out a simple model based design of a control algorithm, via the use of so called lambda-tuning. A main pedagogical challenge is to present a sufficient but minimal amount of "theory" in order to make the laboratory experiments meaningful. This includes:

- Introducing the *process* concept.
- Introducing *inputs*, *outputs* and *disturbances*.
- Motivating that a constant input value eventually results in a constant output value, (i.e. the *static* behavior), and that another constant input value results in another constant output value.
- Motivating that a sudden change of the input value, from one constant value to another, will lead to a gradual change of the output from a constant value until it reaches the constant value corresponding to the new input value (i.e. the *dynamic* behavior).

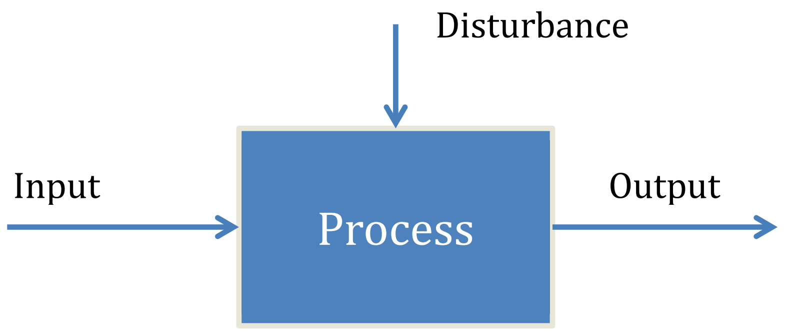

Figure 2: Block diagram description of the process to be controlled.

In e.g. an indoor climate control application the output represents the indoor temperature in a building, the input is the applied heating power, and the disturbance is the outdoor temperature.

- Introduction of the two parameters, *time constant* and *static gain* respectively, which describe the properties of the change of the output value relative to the change of the input value. The parameters are illustrated in Figure 2.

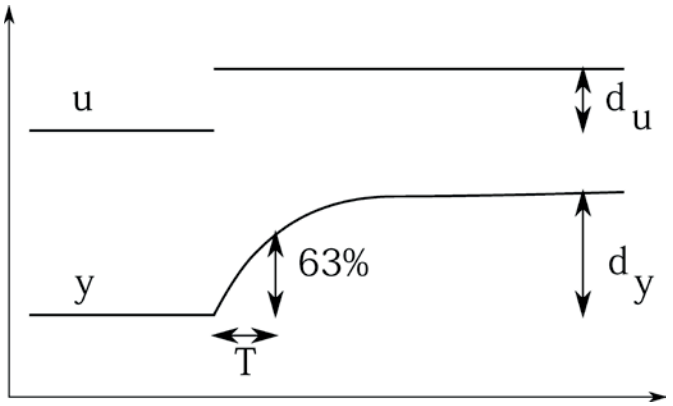

Figure 3: Change of output value y as result of change in the input u. The input change is denoted d_u, and the resulting change of the output is denoted d_y. The static gain is obtained as the ratio $k = d_y/d_u$, and the time constant T is obtained as the elapsed time from the change of the input until the output has reached 63 % of the final value.

For the climate control example Figure 3 says that a constant level of input power gives (after some time) a constant indoor temperature and that, after a sudden increase of the power level the temperature will gradually change and finally settle on a higher constant temperature.

- Introduction of the *feedback principle* where the input is determined as a function of the observed output.
- The properties of *proportional* and *integrating feedback*.
- A simple *design rule,* so called lambda tuning, to determine the gains of the proportional and integrating feedback as functions of the time constant and static gain.

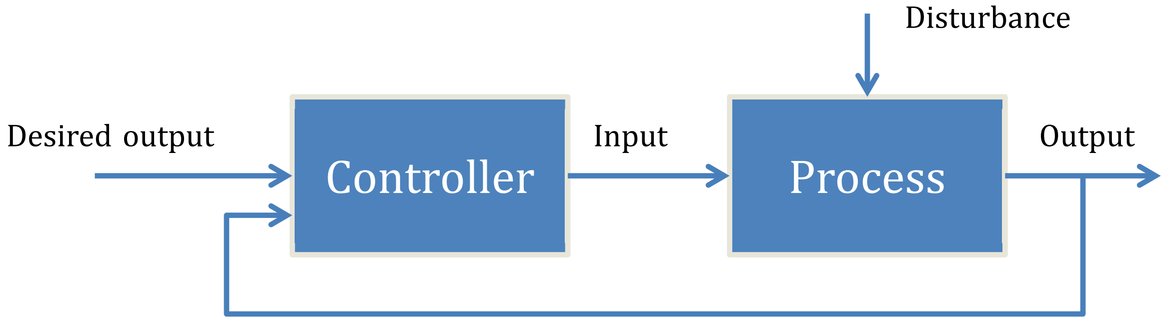

Figure 4: Block diagram description of the feedback control system.

In the climate control example Figure 4 means that the controller, typically a computer program, at every time instant compares the present temperature to the desired temperature and, depending on the outcome of this comparison determines a suitable input power. The outcome of the design phase is hence a mathematical description of how to determine the input power as function of the desired and present temperature.

IMPLEMENT PHASE

Recall the equations above, i.e.

$$I_k = I_{k-1} + K\frac{T_I}{T_S}e_k \quad (1)$$
$$u_k = K\,e_k + I_k \quad (2)$$

The task is to implement equations (1) and (2) in an industrial PLC in order to control a laboratory process. At the first sight it may seem very simple, but since it is will be done using real industrial hardware and is meant to cover relevant practical aspects the task involves a number of issues:

- The program is developed on a PC using a development tool called RSLogix, and then downloaded and executed on the PLC.
- The programming is done using so called ladder diagrams where conditions, e.g. comparisons and logical checks, and actions, e.g. multiplications and logical operations, are represented by graphical blocks.

In the first laboratory exercises the students start from a given program skeleton with a built-in PI-controller, and add the following extra functionalities to the control system:

- Ability of the program to change between manual and automatic control of the tank level.
- Ability to choose which tank level to control.
- A supervision function that detects if there is risk for overflow in any of the tanks and then automatically switches to manual control and sets the input signal to zero.

In the second laboratory exercise the task for the students is to implement the PI-controller from scratch, i.e. to replace the PI-controller used in the first exercise. This implies several new practical aspects to take care of:

- The PLC uses integer arithmetic, and parameters and values are represented using 16 bits, including one bit for the sign. This implies that the programming has to be done with care in order not to cause numerical overflow in e.g. multiplications. One remedy is to use suitable scaling of all variables and parameters in order to find a trade-off between accuracy and risk of numerical overflow. The scaling makes it necessary to keep the scaling of each individual variable in mind, so that various operations are done using the correct scaling. Another remedy is to utilize the built-in check that detects if an overflow has occurred in a multiplication. In such a case one of the factors is rescaled and the multiplication is carried out again.
- The execution of (1) and (2) can under some circumstances result in a value of the input signal that exceeds the physical limits. Hence, the equations have to be complemented with a check and truncation of the input signal in order to avoid this.
- A straightforward implementation of (2) in combination with truncation of the input signal can deteriorate the performance of the control system via a phenomenon called integrator windup. In order to handle this problem (2) has to be modified using some suitable method.
- For accuracy reasons the integrating feedback has to be updated using a lower frequency compared to the proportional feedback. This is achieved by using a timer block in the PLC program.
- The performance of the PI-controller implemented from scratch should also be compared with the built-in controller.

OPERATE PHASE

The parts of the course that can be connected to the Operate phase involve the development of an operator interface and the creation of an operator's manual. The design of operator interfaces is an entire discipline in itself, and the aim is to provide initial insight into some of the aspects that need to be considered when designing an operator interface. The development of the operator interface is also done in steps distributed over the two laboratory exercises.

The interface is required to comprise the following features:

- Display of the levels of both tanks, both graphically and via numerical values.
- An alarm that turns on a red light when any of the two levels exceeds 80 % of the maximum level.
- A mechanism that turns off the pump, and hence the flow into the tanks, when either of the levels exceeds 90 % of the maximum level.
- Switches that enable change between manual and automatic control, and between the built-in controller and the controller developed by the students.
- Sliders, buttons and text fields that enable tuning of the coefficients of the PI-controller.
- Graphs showing the current value and time history of actual and reference tank levels and pump speed.

An important part of the course, related to the Operate phase, is the project where the task is to write a manual for an operator. The manual is expected to present the following aspects:

- A brief description of the entire system, including the tank process, the PLC, the PC, and an explanation of which information that is exchanged between the different units.
- A thorough presentation of the interface.
- A brief description of the parts of a PI-controller and the features of the different components.
- A description of one tuning method for selecting the coefficients in the PI-controller.
- In addition, the manual should meet the general requirements for a report of sufficient quality.

The project has to be completed and the manual has to be handed in within two weeks after the completion of the first laboratory exercise.

ASSESSMENT

In a previous session the intended learning outcomes of the course were listed with reference to the CDIO Syllabus, and the aim in this section is to summarize how the learning outcomes are assessed. The assessment is based on two main components:

- Demonstrations of working solutions that fulfill the list of requirements on functionality and user interface
- The operator manual.

Below it will be discussed how these two activities are connected to the assessment of the learning outcomes.

1. **Disciplinary knowledge and reasoning:** The disciplinary knowledge is shown by first being able to implement and tune a PI-regulator, and second by describing for a user, in the operator manual, the function of the different parts of the regulator and how to tune them

2. **Personal and professional skills and attributes**: The learning outcomes concerning System thinking, section 2.3, are assessed via the creation and operation of the control system, where the hardware and software component are integrated. The overall system and the interactions between the components are also explained in the operator manual. The various learning outcomes connected to 2.4, Attitudes, are assessed by showing the ability to finish the tasks given the different deadlines. As mentioned, the execution of the different laboratory exercises, and at the same time managing two other courses in parallel, put strong requirements on the ability to plan the activities. This includes e.g. attending the helpdesk sessions before the first scheduled laboratory session, getting the solution of the first laboratory exercise approved before the second laboratory exercise can be started. The writing of the manual can start after the first laboratory session has been completed, and the first version should be delivered within a specified time limit. A limited time for revision is allowed before the final deadline for the manual.

3. **Interpersonal skills: Teamwork and communication:** The teamwork is assessed indirectly via the ability of the two group members to solve the task together within the given time limits. Furthermore, it is required that both students in the group are able to explain how the solution works. The learning outcomes connected to 3.2, Communication, are assessed via the operator manual. This year a new component will be introduced, where the students are supposed to go through and sign a checklist which will be handed in together with the first version of the report. By signing the checklist the students certify that they have checked the most basic requirements concerning a report, like figure and table captions, reference handling, spell checking, etc. Normally only one revision of the operator manual is allowed.

4. **Conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context – The innovation process**: The key point of the paper is the emphasis on the implement, section 2.5, and operate, section 2.6, phases of the engineering process. Being able to develop a control system, including the operator interface, that fulfills the requirements concerning functionalities using real industrial hardware is seen as the evidence that the learning outcomes have been reached.

DISCUSSION

The course has been given for approximately five years and seems to have found a suitable form concerning learning objectives, organization and execution. The following observations can be made:

- The organization and execution of a course of this kind require that the involved teaching staff pays sufficient attention on the planning and timing of the various learning activities.
- Similarly, the course requires careful planning by the students in order to fit the various learning activities into the schedule together with other courses.
- The helpdesk sessions are very important in order to ensure that the students are sufficiently prepared before the laboratory exercises.
- The students find it positive that the main part of the learning activities is based on practical work in the laboratory.
- The writing of the operator manual gives good training in written communication.
- The instructions, e.g. in terms of a check-list, concerning the writing process can be improved.

CONCLUSIONS

A first course in Automatic Control has been presented, where one of the aims of the course is to put emphasis on the Implement and Operate phases in the creation of a new product or system. Another aim is that the students should work with real industrial hardware and get insight into the practical aspects of the implementation. The learning activities are based on three large laboratory exercises and one project. In addition to giving disciplinary knowledge in the subject, the course gives opportunities to develop several engineering skills, e.g. teamwork, communication, system thinking, planning of time and resources, etc.

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11

IMPLEMENTATION OF CDIO STANDARDS WITHIN A MODULAR CURRICULUM OF "METALLURGY" PROGRAM

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ABSRACT

The paper shares the experience of Siberian Federal University (SibFU) in designing and implementation of the modular curriculum for Metallurgy. Based on the backward design concept, which allows planning of the education starting from learning outcomes through learning techniques to the content of education, particular curriculum modules are defined. The modules cover broad educational fields in order to achieve integrated learning outcomes. The proposed model allows clear structuring of the learning content and various learning methods integration. The paper emphasizes the structure of the modular curriculum and specific learning outcomes that in total facilitates students' engineering thinking and professional skills. The learning outcomes of the modules are formed in in compliance with Russian Federal Educational Standards, CDIO Syllabus, and the requirements of the University industrial partners. The paper exemplifies the implementation of "Introduction to Engineering" Module which is innovative for "Metallurgy" programme: focused on soft-skills training. The results of the implementation of CDIO-based "Metallurgy" programme during the first year of CDIO initiative at SibFU are described. The analysis shows the improvement of learning process and outcome control due to the flexibility of modular curriculum design. Moreover, the proposed educational approach enables comprehensive learning and human resources administration such as modules arrangement and teaching staff mobility.

KEYWORDS

Module, Curriculum, Metallurgy, Introduction to Engineering, Standards: 2, 3, 4

INTRODUCTION

Siberian Federal University has been implementing worldwide CDIO initiative since 2013 in the framework of two undergraduate programs: metallurgy and heat engineering. The fields of mentioned engineering activity are highly demanded by the industries of the Siberian Region of Russia. The paper discusses the design and implementation features of the undergraduate curriculum of the metallurgy program based on CDIO principles.

TARGETS OF THE MODERNIZATION OF VOCATIONAL EDUCATION

Vocational education modernization on metallurgy program is focused on:

1) New socio-cultural and economic reality, the determining factors of which are:
   - high rate in knowledge updating in engineering and technology;
   - rapid updating of the production sector;
   - digitalization of society and appearing of new smart technologies;

- the necessity of implementing competence-based approach to enhance the vocational focus of the educational process.

2) Standard documents, national experience and international initiatives:

- Federal law “Education Act of the Russian Federation” №273-FL 29.12.2012
- The concept of long-term socio-economic development of the Russian Federation for the period till 2020 (The development of education);
- Framework standards for accreditation of engineering programs EUR-ACE (European Accredited Engineer);
- Worldwide CDIO initiative (Conceive-Design-Implement-Operate).

The vocational educational system responding to modern trends of economic development and social needs and also turning to the implementation of federal state educational standards which determine new educational result as the formed competence cluster has been increasing “practical orientation of education and its investment attractiveness”. As a result it is characterized as:

- “highly-intensive education”;
- personalized educational needs;
- developing wiki-education;
- mass character based on education through IT;
- based on the network project education;
- supporting a synergetic alliances and combinations in networking with universities, institutions and business (Gafurova et al., 2014).

MODULAR CURRICULUM OF “METALLURGY” PROGRAM

Competence-based approach sets the learning outcomes, achievement of which implemented on the multiparadigmatic character basis at solving different pedagogical tasks of organization and realization of the educational process. Particularly, the modular approach is used at determination of the content of program according to the Federal State Educational Standards. Module – is a relatively independent, logically completed, structured unit of the educational program which provides the formation and assessment of the learning outcomes. It is focused on such a result as the competence model of the postgraduate with the definite amount of credits and relevant educational and methodological support.

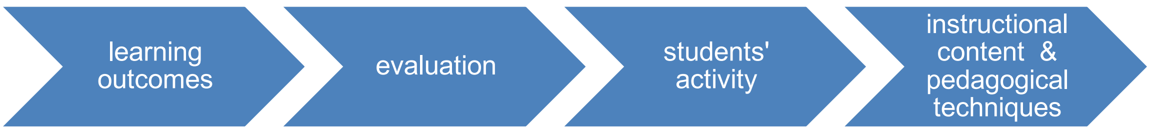
Modular curriculum raises the problem of module selection. Considering various results of the different sections of the curriculum we have identified 4 modules (Table 1).

Table 1. Modular Curriculum of “Metallurgy” Program

Modules	Disciplines	Credits
Humanities	History; Philosophy; General English; Business English; Professional English; English for specific purposes; English for Academic Purposes; Russian Language and Culture; Personal and Career Development; Team Building; Business Ethics	43
Natural Sciences	Mathematics; Chemistry; Physics; Physical Chemistry; Thermal Physics	32
Engineering	Engineering Graphics; Mechanics; Material Science; Electrical Engineering and Electronics; Information Services; Fundamentals of Metrology, Standardization, Certification; Health and Safety; Quality Management; Legal	49

	Aspects of Professional Activity	
Metallurgical Production	Metallurgy Fundamentals; Metallurgical Heat Engineering; Metallurgical Theories and Technologies; Automation, Control and Measuring Equipment; Primary Aluminum Production; Precious Metals Refinery; Alloys Production; Recycling	73
Project	Introduction to Engineering; Theory of Inventive Problem Solving; Project Work; Technical cases; Enterprise Economy	28
Industrial Training	Foundry Equipment; Fundamentals of technology of obtaining metals from ore and secondary raw materials; Metallurgical Heat Engineering	15
Total		240

In the process of module design, we relied on the concept of backward design defining the logic of the educational process from the learning outcomes to the content and pedagogical technologies (picture 1).



Picture 1. The Process of Module Design

The learning outcomes of modules are formed according to the requirements of the Federal State Educational Standard, CDIO Syllabus and the Corporation of the sector.

As an example, Natural Sciences Module (discipline – Mathematics) is considered. One of the learning outcomes of the discipline “Mathematics” is the formation of the ability to analyze and synthesize which corresponds to the professional competence 1 in Federal State Educational Standard and Syllabus 2.1, 2.4. The content of the process of the formation of the mentioned competence is described in the table 2.

Table 2. The content of the process of the formation of the competence: the ability to analyze and synthesize

Learning outcomes	Evaluation	Students’ activity	Content
Professional competence 1 – the ability to analyze and synthesize Syllabus 2.1, 2.4 (beginner level)	▪ Presentation of products of intellectual activity (scheme-maps, mental maps, solving problems algorithms, terms reference); ▪ Written survey of students on theoretical issues with elements of self-control and mutual	▪ Organize and summarize the theoretical material in the form of mental maps, supporting schemes; ▪ Develop the algorithms for solving problems; ▪ Represent	All the units of Mathematics, active methods

	control.	concepts according to the characteristics of the defined object.	

The process of the formation of the described competence in the other subject areas of the Module is represented similarly. As a result, we have a generalized picture on the formation of the described competence in the whole Module; the level of the competence has been increasing by means of repeated students' activities in different subject areas of the Module.

Another illustration that can demonstrate the advantages of the Modular approach implementation is the elimination of the educational material duplication. For example, such theme as "Field theory" was usually taught at Math Course and as it appeared it was almost repeated at Physics Course in such themes as "Magnetic field theory" and "Electrical field theory". The fact that teachers have started working together in the Module and considering the learning outcomes of the students after completing the Module not a particular discipline made it possible to see that kind of educational material duplication. Now the theme "Field theory" is taught only at Physics Course.

The experience of the Modular approach implementation in the idea of the content of the curriculum of "Metallurgy" program let underline the advantages of this approach:
- clear and systematic structuring of the content of education is provided;
- duplication of educational material is eliminated by means of co-ordination with all the disciplines of the Module;
- intra- and extra-Module integration focused on the learning outcomes is carried out;
- rational planning of the educational process on mastering the Module is defined in the sequence, and the succession of the units, themes, subject areas;
- students' systems thinking is formed by means of elimination of the subjects' separation and mosaic content of the material in subject areas;
- the team of teachers who are responsible for the Module is created and teachers' cooperation is being enhanced.

Introduction to Engineering Module is a fundamentally new idea for the engineering educational program. It is focused not only on the development of engineering mentality but also on training soft skills of the future engineer. Further we are substantiating the importance of emphasizing this module.

One of the goals of engineering education defined by CDIO Standards 1, 4 is the formation of the design-implement competence. Mastering of the design-implement competence will be supported and facilitated by means of, firstly, "Introduction to Engineering" discipline (CDIO Standard 4), secondly, receiving project work experience by learning the disciplines of engineering, humanities and natural sciences modules. Considering engineering as a set of intellectual activities, focused on the receiving the best results connected with the implementation of the full technological circle of product and system creation, design work and production operation we define the important role of the discipline "Introduction to Engineering" in the process of the formation of the design-implement competence. Substantiating the structure and content of the discipline "Introduction to Engineering" we proceed from, firstly, the necessity of the components formation of the design-implement competence; secondly, sufficient credits amount of every unit; and thirdly, purposeful sequence of the units and their places in the curriculum.

In the curriculum of bachelors' training (the Institute of non-ferrous metals and materials) on innovative educational program according to CDIO concept the discipline "Introduction to Engineering" is represented in the composition and sequence of the following units (table 3).

Table 3. The composition and sequence of the discipline “Introduction to Engineering” (the Institute of non-ferrous metals and materials, SFU)

Terms	Units
1	Introduction to Engineering (The History of Metallurgy, Engineering, Scientific Foundations of Intellectual Activity)
2	Information Resources (The Strategy of Resource Exploring, Information Structuring, Citation, Written Communication)
3	Business Ethics (Psychology, Business language)
4	Engineering design methods
5	Theory of Inventive Problem Solving
6	Strategic management of technologies (general principles of engineering)

The following design of the discipline “Introduction to Engineering” allows, firstly, to perform value-sense bearing function by means of formation the understanding of sense and significance of the engineering activity, the role and responsibility of the future engineers, influence of the engineering activity on society and environment, modern relations in the world of technology; secondly, to perform system-function by means of providing methodological support of the process of the design-implement competence formation through synthesizing the experience of project work of the students.

In practice we have the following results. Each term our students implement projects and the teachers, students and experts evaluate their competences in performing project work by specially developed measuring technique. The criteria for evaluation are:

1. Conceive (the ability: to state the problem; to find analogues of the problem and their solutions in various fields; to set the goal; to split the goal into tasks).
2. Design (the ability: to choose methods and means of solving the problem; to make the necessary calculations; to perform the graphic work according to calculations; to use automated design environment);
3. Implement (the ability: to make a model of the final product; to test the final product models; to select the type of the final product; to produce the final product).
4. Operate (the ability: to plan the project work, to manage the group; to choose the form and make the final product presentation; to take into account the commercial, social, ecological effect of the product).

And we add two more criteria, which are:

5. Interaction (the ability: to select tasks for themselves and other participants in the project; to participate in project activities at group meetings; to solve the complexity of the project individually and in team, to use telecommunications in performing the project).
6. Reflection (the ability: to carry out an intellectual assessment of the product; to understand the advantages and disadvantages of the final product and the work performed; to perceive personal development and results) (Ryabov, 2014).

In the issue at the end of the first academic year, according to the described measuring technique we have the following results (diagram 1).

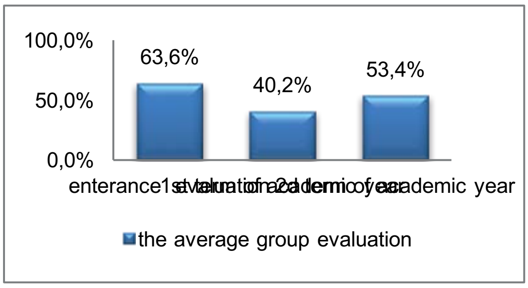


Diagram 1. The evaluation of the students’ learning outcomes in project work

The entrance evaluation was performed by students themselves and as it is easily seen in a diagram it was highly overestimated. Students were sure that they were ready to implement project work and the experience they had was enough. The results of the project work implementation at the end of the first term have decreased compared to the entrance test. But at the end of the second term the situation started to improve and we have 13,2% increasing. Experts particularly note the fact that the students started to work like a real team and their communication skills have become better. The evaluation of students' interaction, communication and team work skills are presented in diagram 2.

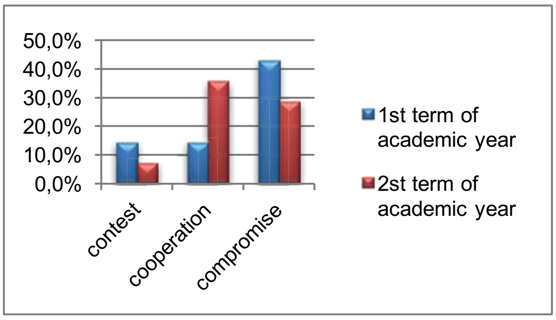


Diagram 2. The evaluation of the students' learning outcomes in interaction

Modular approach in the organization of the curriculum allows to improve the manageability of the educational process by changing the hierarchy. In terms of modular approach the head of the educational program controls module managers to whom some teachers of the module are subordinated. The duties of the module managers include the responsibility for the quality of the educational process in accordance with CDIO concept (training of the engineering graduates who should be able to: Conceive – Design – Implement – Operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products by means of activity approach, active methods, integration of subject areas, implementation of project work, the development of personal and interpersonal competences), HR and methodological support of the educational process.

CONCLUSIONS

In this paper we have shared our first experience in modular curriculum of the educational program. The feasibility of modular approach implementation in curriculum design is confirmed by qualitative indicators of the students' academic success, their involvement and active position in project work as well as other extracurricular activities. Moreover, the proposed educational approach enables comprehensive learning and human resources administration such as modules arrangement and teaching staff mobility.

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NEW ROLE OF EMPLOYER IN THE EDUCATIONAL PROCESS OF METALLURGY PROGRAMME

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ABSTRACT

This paper describes new ways in cooperation between higher education and an employer in terms of CDIO-based Metallurgy programme. A new role of industrial enterprises in higher education is substantiated, including the expansion of cooperation under key positions within the confines of Industry Training module of the SibFU's Metallurgy programme. In terms of collaboration between SibFU and UC RUSAL and JSC "Krasnoyarsk Plant of Non-Ferrous Metals" recent successful employer-university cooperation practice is exemplified. The paper discusses the content of Industry Training module and the changes it made to the role of the employer. The supplementary agreement between educational stakeholders for target training programs is discussed. Proposed collaboration model between stakeholders of higher education gives a broad range of possibilities for universities to enrich engineering education, and for industries to educate anticipated highly specialized engineers with deeper understanding of professional issues and actual working experience.

KEYWORDS

Metallurgy, Employer, Students Internship, Curriculum Design, Standards: 3, 6, 12

INTRODUCTION

Siberian Federal University (SibFU) has been implementing worldwide CDIO Initiative since 2014 in the framework of two undergraduate programs: Metallurgy and Heat Engineering, both are highly demanded by the industries of Siberian Region of Russia. The industrial enterprises interested in training of future engineers should take an active and key role in the practical side of the educational process. However, there is a trending passiveness among the industries of Russia resulting in the estrangement from the learning process. Commonly, the industries declare the list of demanded engineering skills leaving universities on their own in the educational process and skills formation.

The quality of engineering education is a keystone of CDIO Initiative with a multitude of ways to approach to the problem. In order to improve the quality of education, the system tends to address its inner capabilities rather than search for external ones. Thus, the CDIO Initiative is a framework for modernization of engineering education, which allows to develop a full-cycle programme for engineers training: from prognosis of specific industry branch up to the learning process implementation. This basis is successfully exemplified across numerous papers of CDIO Community.

However, since the problem is defined as a systemic gap between labor market requirements and learning outcomes, the solution is to be found outside the learning process, namely in the collaboration between educational institution and employer.

The transition to competence-based learning, which targets specific skills of graduates for professional activity, emphasizes the significance of dual education. It allows to integrate the efforts of social partners (university and employer) in the educational process by means of providing profession trials for students, thus introducing them to the range of professional problems. The depth of such collaboration of stakeholders defines the efficiency of dual education (Gafurova et al., 2013).

The dual education assumes that companies overcome their historical estrangement from engineers training in higher education. The establishment of public-private partnership between university and companies defines their broad involvement in all stages of higher education.

UNIVERSITIES AND INDUSTRY COOPERATION

The involvement of industrial companies in higher education in Russia is mostly limited to the roles of customer, evaluator and consumer, in fact being estranged from the learning process up to graduates' certification stage. However, there is a certain expediency of collaboration between industry and university (Table 1).

Table 1. The results of industry and university collaboration

	Company	University	Student
1	Training of engineers able to meet requirements	Company's funds attraction for university development	Employment after graduation
2	Staff development	Joint educational and scientific publications	Learning special disciplines for industry
3	Corporate culture development starting from undergraduate period	Involvement of industry experts in learning process	Corporate culture skills acquirement
4	Impact to the content of education	Joint efforts in science and engineering	In-depth professional skills acquirement
5	Reduce newbie employees' adaptation time	Teachers' professional skills development	Participation in scientific and engineering projects
6	Employees' academic skills development	Additional financial support for participating staff	Additional financial support from company
7	Company's competitiveness	Graduates competitiveness	Reduce adaptation time at new work

The shown practice of collaboration is yet to be established, however the idea of cooperation is in the very concept of CDIO Initiative (Crawley et al., 2007). Moreover, the concept of complete production cycle could be extrapolated to the concept of educational cycle, which can be described as follows:

1. Targeting (Conceive) the specific competencies of graduates which include employer's needs and worldwide professional challenges could be achieved as shown in Table 2.

Table 2. Partners' cooperation at Targeting stage

	Company	University
1	Expertise of the current state of sustainable staff development program	
2	Determine the demand for new specialists, developing their cluster of competencies for the nearest and further perspectives	Counsel and coordination
3	Particularization of graduates' cluster of competencies for each educational programme	
4	Counsel and coordination	Determine the changes in the content and technology of education aimed for education quality improvement
5	Counsel and coordination	Determine the programme requirements in the means of learning process organization and technology

2. During the stage of targeted development (Design) of educational programme, the involvement of employer is continued in terms of determining the workload of curriculum courses, and their integrative linking (Standard 3). At this stage the employer also provides the content and themes for Intro to Engineering course projects, including ones under joint supervision of university teachers and companies' representatives.

3. At the stage of programme implementation students are learning new content from employer in order to develop professional and interdisciplinary skills and abilities such as problems solving, solution finding and decision making in the situations of uncertainty and ambiguity in the rapidly changing world and technology (Jeschke, Hamers, 2016). A part of the learning process takes place in the real industrial environment. The important feature of CDIO-based curriculum in Metallurgy at SibFU is an Industry Training module, which extends learning environment (Standard 6) and which is described further in this paper.

4. The operate stage of joint collaboration between academic community and companies allows partners to foster the educational innovations, to share and distribute productive educational experience.

All in all, only full-scaled integration of efforts of both universities and industrial companies could produce next generation of engineers demanded by the world of work and able to answer current and future challenges (Kamp, 2014).

INDUSTRY TRAINING MODULE DESIGN

SibFU is implementing CDIO principles in the framework of Metallurgy and Heat Engineering undergraduate programs. Based on the backwards design concept, which allows planning of the education starting from learning outcomes through learning techniques to the content of education, particular curriculum modules were defined. The modules are unbounded from specific disciplines. Each module covers a broad educational field in order to achieve integrated learning outcomes (Standard 3). This paper shares the Industry Training module design, including the experience of university-industry collaboration and perspectives for future development.

In the scope of Industry Training module (ITM) SibFU and industrial companies completed an agreement defining key positions for employer's integration in the learning process. Despite the traditional practice of university-employer relationship in Russia, the proposed approach defines companies' full-scaled involvement into the development and facilitation of the educational process starting from the first year.

ITM includes continuous students' internship at metallurgical facility and a modular course for "Metals Production and Treatment" as shown in Figure 1.

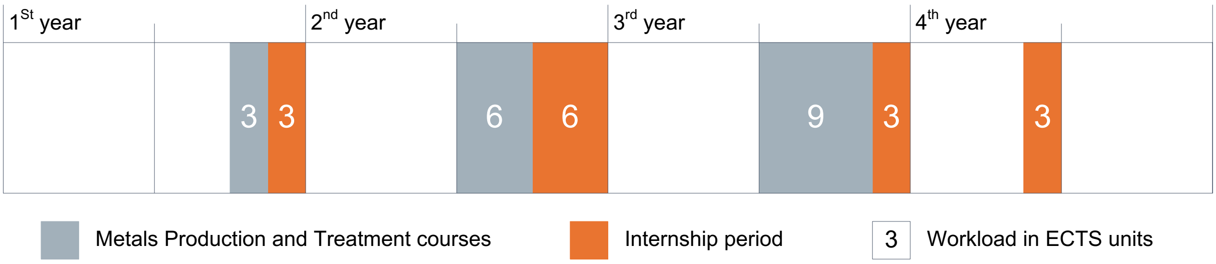

Figure 1. The structure of Industry Training module of undergraduate Metallurgy programme

After each year of studies, students undertake the internship at industrial company, each time deepening their knowledge and experience in future profession. Before the internship period there is a module of "Metals Production and Treatment" course, which is held by both university teachers and company experts. Thus, the theoretical knowledge is reinforced with an actual working experience within a real working environment, which facilitates interdisciplinary skills providing practice-oriented learning context.

The overall aims of ITM within undergraduate programme in Metallurgy are as follows:
- To introduce students to metallurgical enterprise;
- To acquire working experience;
- For students to learn their future professions;
- To make students aware of corporate culture and engineering ethics;
- To develop students' ability to integrate previous knowledge into learning ITM content;
- To develop students' ability to apply knowledge according to their professional and career interests.

The proposed aims of ITM could be achieved by specifying CDIO-based goals:
- Teach students to control variety of production processes at metallurgical facilities;
- Build the system of knowledge and understanding of metallurgical production cycle, specialized high-profile technologies, which allows to analyze and improve these processes;
- Facilitate students' intrinsic motivation for continuous expanding of professional skills, self-development and sustaining company's competitiveness along with career building;
- Develop individual and team skills;
- Develop environment-saving, health-care and resources-thrift thinking;
- Teach students to produce and present their results using various communication techniques and professional technical vocabulary.

ITM IMPLEMENTATION PRACTICE

Since the launch of CDIO-based Metallurgy programme in 2014, two metallurgical companies of Siberian region have become SibFU collaborators in the development and implementation of the programme: Krasnoyarsk Division of UC RUSAL and JSC "Krasnoyarsk Plant of Non-Ferrous Metals". According to the agreement between institutions, the involvement of the companies in the learning process is planned within the scope of the following activities:
- joint teaching of special metallurgy courses based at university;
- students' internship programme development;
- students' project themes proposal;
- Target Training Programs development;
- organization and participation in various public events.

Joint Teaching

SubFU invites companies' engineers for joint development and teaching courses within the framework of ITM and other modules of the curriculum. The invited professionals provide expertise in different areas of metallurgy and share unique practical knowledge with students, enriching their vision of future profession. SibFU teachers and UC RUSAL engineers are developing such courses as "Ecology and Industrial Safety", "Metals Production and Treatment", "Enterprise economy" etc.

Collaboration with industrial engineers is an important source of new practical knowledge for university teachers. To improve teachers' expertise even further, companies organize short training courses at industrial facilities, introducing current production process, management policy and staff development.

Students Internship

After each academic year students undertake internship period at partner companies' facilities. The programs of internship are developed by partners according to the required skills and competencies of engineering graduates.

The internship at UC RUSAL includes short teaching sessions and lectures on the history of aluminum industry, history of Russian metallurgy, company's production system and many others. Additionally, students attend various soft-skills trainings which are included into company's staff development programme. During these courses students are introduced to company's culture and they also improve their personal and interpersonal skills, such as communication, teamwork, leadership and time management (Standard 3).

JSC "Krasnoyarsk Plant of Non-Ferrous Metals" provides courses on advanced inorganic chemistry, pyro- and hydrometallurgy (company's basic production types) and about company structure. On site students get to know main and auxiliary chemistry laboratory equipment and participate in practical courses for chemical analysis methods.

Students Projects

Partner enterprises become the customers of students projects, that is relatively new practice for Russian higher education institutions. Instead of concluding long-term research contract, which is a common practice for university staff involvement into research projects where students are often left with minor utility functions; companies provide students with short-term project themes based on current and future metallurgy problems. Starting from the second year, students are involved into research of scientific and technical problems supervised by company specialists. Most projects require students to visit company during the studies and to work in a lab.

UC RUSAL provides students with project themes mainly concerned with aluminum production, electrolysis technology improvement and process control. JSC "Krasnoyarsk Plant of Non-Ferrous Metals" offers projects on technology of rare and precious metals production. Making projects under professionals' supervision allows partners to evaluate learning outcomes and teaching methods, providing feedback on the educational process (Standard 12).

Target Training Programs

In addition to Metallurgy undergraduate programme, partner companies provide Targeted Training Programme for students willing to qualify for working profession and being employed by the company after graduation. The Programme participants undertake additional courses held by the company. The courses include Corporate Ethics, Labor Safety and special training for chosen profession. During the internship period students attend staff training courses as a part of regular personnel training policy, and after that they can practice their profession with instructor in order to pass the qualification exam.

UC RUSAL offers the Target Training Programs for specialist of electrolysis, or calcination, or metal forming. Each year of internship students are able to improve their knowledge, master their working skills and have the opportunity to pass next qualification exam for a higher grade. Students' highest advances are rewarded with personal scholarships sponsored by partner companies. In fact, students of Target Training Programs along with undergraduate diploma could get working qualification for which several years of continuous practice are required. The Programme provides a head start for career of young engineer and helps to find the right place in the world of work.

Public Events Participation

University-industry partnership is also aimed at increasing the prestige of engineering professions, attracting potential students to technical specialties, and for other companies to collaborate with.

Each year SibFU organizes a public meeting of students, teachers, senior management and companies' representatives. This meeting is created for open-minded people to share their ideas, discuss the matters of cooperation and communicate freely with each other. Students projects presentations are also organized as a public conference. In this way, there is continuous feedback from all the stakeholders of the learning process.

KNOWN ISSUES AND CURRENT PROBLEMS

The diversity of collaboration forms between university and employer meets certain requirements for organization and legal support of both institutions' activities. Networking agreement offers flexible connection between large companies with heavily branched administrative structure. Despite that, we've encountered some specific difficulties while we were trying to implement the partnership and organize the process of searching new partners.

Firstly, many companies were not ready to deploy significant time, finance and human resources for full-scaled participation in the educational process. This problem roots to historical model of industry behavior, as it has been discussed before. Another side of this problem is that company has been busy with its main production process and has its own staff training system, which often cannot be successfully adopted for students' internship.

Secondly, there is a pedagogical problem. Developing companies are ready to invest resources and personnel in the collaborative projects of universities, however they can hardly achieve significant teaching effectiveness due to the lack of pedagogical skills of even most qualified engineers. SibFU organize continuous staff training for their pedagogical qualification, which is obligatory for CDIO programs teachers, and is ready to involve companies' engineers for training.

Thus, in the nearest future SibFU is planning to make collaboration forms more flexible and efficient, to invite not only local industries to contribute to education, but cooperate with a colleagues and companies from abroad.

CONCLUSION

This paper shares the vision of SibFU of cooperation between higher education and employer in terms of CDIO-based Metallurgy programme. The proposed model of partnership includes broad range of joint activities starting from programme and learning outcomes planned through internship programs and special courses development up to evaluation of education results and continuous feedback. The industries provide project themes and expert engineers to work with students, introducing them to the company's activity. Students are able to undertake Targeted Training Program in order to qualify for working profession and being employed after the graduation at university.

The paper presents the actual experience of SibFU for collaboration with local industry companies: Krasnoyarsk Division of UC RUSAL and JSC "Krasnoyarsk Plant of Non-Ferrous Metals" in the framework of Industry Training module of Metallurgy programme. Since SibFU has become CDIO collaborator in 2013, we currently have the first and second year undergraduate programs running. Thus, this paper shares the most recent partnership practice and its perspective vision.

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WHAT SHOULD WE TEACH? A STUDY OF STAKEHOLDERS' PRECEPTIONS ON CURRICULUM CONTENT

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ABSTRACT

The Bachelor of Engineering is a complex form of education; it has to meet the requirements of higher education in terms of academic stringency and scientific approaches, and at the same time fulfil the requirements of the companies and other takers on employability and professionalism. The aim of the CDIO initiative is to help educational institutions to fulfil the latter without losing the academic basis. Several studies have been made asking different actors to give their view on education and needed competencies, but these are often delimited to one or a couple of actors. One possible reason is the complexity of conducting such studies. This paper reports on a survey including program students, alumni and industry representatives and covers their perceptions of what is important to include in a Bachelor of Engineering program, and what is not. The methodological issues and choices as well as the main results are accounted for. The program in focus is a three-year Bachelor of Engineering in Forest and Wood Engineering taught at Linnaeus University, and the questions regarding content were based on the CDIO syllabus.

Results show that there are some contents all three groups of actors regard as important; all found knowledge in forestry, material sciences and technology related to wood industry as important. Also, analytic and communication skills, and the ability to work in groups were seen as important. Understanding social and environmental conditions and enterprise and business terms was also necessary. Least important was the ability to communicate in foreign languages and knowledge regarding construction technology and deepened knowledge of forestry.

KEYWORDS

Educational content, CDIO syllabus, mixed study research, stakeholder demands, actors perception, Standards: 2, 11

INTRODUCTION

How can we prepare our students for the first work? Is it possible to combine academic stringency with practical understanding? How do we give opportunities for students to experience that the ideal theories described in books differs from the reality and give them possibilities to practice real problem solving for instance in a situation where insufficient information is provided? How can we train the students in critical thinking? These questions teachers and academics in various technological and engineering subjects struggle with: see for instance Huang et al. (2008), Ferlin et al. (2005) and Jakobsen and Bucciarelli (2007). Knowledge and skills connected to the future area of work are important for reaching high employability of students, but not enough. In addition, the future engineer should also possess abilities and skills such as independence, time management, analytic stringency, critical and reflective thinking, team working capabilities and problem solving skills, Yorke and Knight (2007) and CDIO (http://www.cdio.org/se/index.html). Continuing, understanding for research activities and the ability to apply a scientific approach as well as the ability to discuss and argue for ones solutions and standpoints is required.

The learning environment must, according Illeris (2004), be considered both from its context and from a social perspective, that is, the expectations on the results achieved for learning. The curriculum design affects in other words both those who actively participate in the learning situation and those who benefit from it from a social perspective. All these actors, together with actors that regulate and support learning (such as administrators at a university) are the education stakeholders, Kettunen (2015). Especially teachers and other academic staff who have direct influence in the education define training content and format, Roberts (2015). Understanding different stakeholders and their demands on education and curriculum content is an important input for curriculum decisions. This paper addresses the curriculum content from the viewpoint of students, alumni and industrial representatives. By using the CDIO syllabus as a basis, a common set of question is developed that could be used for all types of stakeholders in different setups. In this paper, three different data gathering techniques are use: a traditional paper-based questionnaire, a web-based questionnaire, and focus group discussions.

DIFFERENT STAKEHOLDERS AND THEIR DEMANDS ON HIGHER EDUCATION

Any business, whether a company selling goods or an institution providing education, has several actors with direct or indirect interest in the business. These actors are called stakeholders, and stakeholders are either affected by the business or influence the business. General business-oriented stakeholder models typically include stakeholders such as employees, customers, competitors, suppliers, owners, creditors and authorities. In the educational context, the stakeholders are slightly different. We identify six main stakeholder groups: competitors, partners, takers, customers, employees and authorities. Competitors are primarily other educational bodies, but these can also be partners. A single institution could even be both a competitor and partner.

An important stakeholder group is the takers, that is, someone who takes advantage of students undergoing training. For an engineering education the future employers could be seen as direct takers, but in a larger perspective also the government could be seen as such. The takers put demand on employability, which is a mix of disciplinary knowledge, personal and interpersonal skills and the ability to transfer knowledge and skills from one disciplinary area to another, Yorke and Night (2007). According to a survey of competence requirements in Swedish industry, the most important competences, apart from basic skills in reading, writing and mathematics, are social and intercultural competence, analytical competence, and entrepreneurial and leadership competence, Schwieler (2007). The alumni, i.e. students who finished their education, form a subgroup of takers. Alumni form a bridge between education and working life and could give insights on the usefulness of educational contents, contribute with industry relevance in the education and help students with the introduction to the working life, and even for fundraising purposes, Ebert et al (2015).

The traditional customer concept is also a bit difficult to apply in higher education. In this case we see the student as the direct customer. There are also a possible future customers; the potential students. In a recent study of Swedish high school students' future decisions, 66% of the students were interested in higher studies, whereof 24% could consider a degree within engineering or technology, Teknikföretagen (2015). Among the group of employees we include those that are directly affected by education, mainly teachers and administrators, but also indirect ones such as communicators. The employees are often the active part in deciding on curriculum content and in curriculum design. According to Roberts (2015) graduate employability, teaching-research relationships, changed understanding of teaching and learning as well as new technologies and flexible delivery options are drivers for curriculum change. The authorities include both local and national governing bodies. In Sweden, the Swedish National Agency for Higher Education determines the goals of general degrees, such as Bachelor of Science and Bachelor of Engineering, Swedish national Agency for Higher Education (1992). The agency also conducts quality assurance and legal supervision of higher education. On European level, the Bologna framework, aiming at creating a comparable system of academic standards, has been a trigger for curriculum design, Gavin (2010).

A SURVEY OF DIFFERENT STAKEHOLDERS' PERCEPTION ON EDUCATIONAL CONTENT

The department of Forestry and Wood Technology at Linnaeus University offers courses and programs that cover the entire value chain from forest to finished wood-based product, and the material wood is a common theme in the education. Currently, the department gives two undergraduate programs (a bachelor's program and a bachelor of engineering program) and one on advanced level (master's program). Moreover, courses in sustainable small-scale forestry equivalent to more than 90 credits are offered. The bachelor's program and the sustainable small-scaled forestry are given only in distance form, while the bachelor of engineering program and the master are offered both as a campus and distance option. The application rate of the bachelor program and to courses in sustainable small-scale forestry is high, while the engineering program and the master program are having trouble in recruiting.

A year-long project funded by the Kamprad Foundation started in 2015 to review these programs with a special focus on entrepreneurship. As a part of this project, surveys of stakeholder expectations and demands were made in spring 2015, with a focus on the engineering program. A stakeholder map for the engineering program was developed for capturing the most important stakeholders, see Figure 1. Interviews, questionnaire surveys and focus group discussions regarding different aspects of the engineering program were thereafter conducted with representatives from industry, potential and current students, teachers and educational administrators. The results were used as a basis for program design enhancements. In this paper, the results from a sub-part of the full study are described. The purpose of this sub-study was to map stakeholders' views on educational content, including current students, alumni and other industrial representatives.

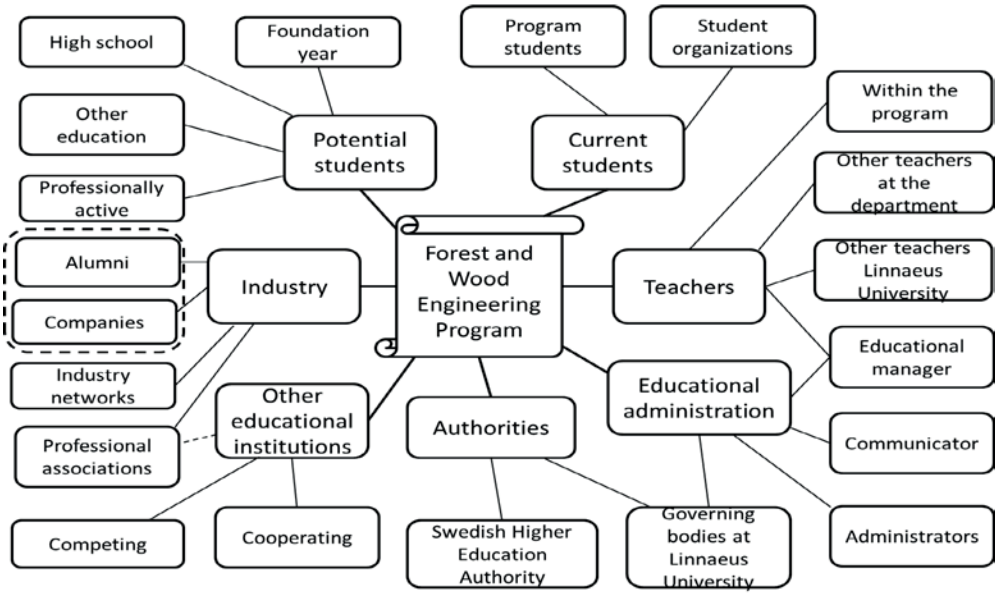

Figure 1. Stakeholder map for the engineering program

Study description

The main data gathering was conducted using a questionnaire survey including 29 questions, whereof two were free text and the rest four-point Likert scale questions. The Likert scale questions were divided into three subgroups (Knowledge, Skills, and Professional and societal understanding). The questions were developed using the CDIO syllabus as a basis. The questionnaire includes all skills and competence groups on the second level of the CDIO syllabus, see Table 1. The personal and professional skills and interpersonal skills were combined in the questionnaire under subgroup "Skills". The current program syllabus for the engineering program was used for formulating the questions included under the "Knowledge" subgroup, see Table 2. The questionnaire is found in Appendix 1.

Table 1. The CDIO syllabus v. 2.0 at the second level of detail (Crawley et al., 2011)

Skill group	Detailed skills
1. Disciplinary knowledge and reasoning	1.1 Knowledge of underlying mathematics and science 1.2 Core fundamental knowledge of engineering 1.3 Advanced engineering fundamental knowledge, methods and tools
2. Personal and professional skills and attributes	2.1 Analytical reasoning and problem solving 2.2 Experimentation, investigation and knowledge discovery 2.3 System thinking 2.4 Attitudes, though and learning 2.5 Ethics, equity and other responsibilities
3. Interpersonal skills: teamwork and communication	3.1 Teamwork 3.2 Communication 3.3 Communications in foreign languages
4. Conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context	4.1 External, societal and environmental context 4.2 Enterprise and business context 4.3 Conceiving, systems engineering and management 4.4 Designing 4.5 Implementing 4.6 Operating 4.7 Leading engineering endeavors 4.8 Engineering entrepreneurship

The questionnaires were mainly distributed in paper form for the alumni and in web-based form for the current students, see description below. In addition, a focus group discussion regarding educational contents was held with industry representatives together with representatives from academia. The results from this discussion are used as additional input in this study, and for giving depth and better understanding to some of the aspects. Mixing qualitative and quantitative data in this way can add insights and understanding that might be missed when only a single method is used, Johnson and Onwuegbuzie (2004).

Table 2. Bachelor of Engineering in Forest and Wood Engineering syllabus

Area	**Courses**
Mathematics and science	Basic Mathematics for engineers, Calculus for engineers, Linear algebra for engineers, Mechanics, Applied statistics (optional)
Technology, people, society	Engineering Economics, Quality management (optional), Industrial organisation (optional), Environmental technology and sustainable development (optional)
Other engineering sciences	Computer Aided Engineering, Thermodynamics, Fluid Mechanics and Heat Transfer (optional)
Forestry	Forestry basic course, Forest yield and wood utility (optional)
Forestry planning	Forest Management Planning (optional), GIS in forestry (optional)
Forest fuel knowledge	Forest Fuel Science
Material science	Forest products, Wood as an Engineering Material
Wood-related industrial engineering	Machinery in wood processing, Wood manufacturing
Wood-related industrial manufacturing	Manufacturing in the wood industry
Construction engineering	Building Technology (optional), Structural Mechanics (optional)
Wood-related business administration	Business Logistics, Forest Industry Markets
Other	Methodology course forestry and wood technology, Trainee on Company Placement, Degree project

Data gathering

A web-based survey was sent out to all who were enrolled in the program in the spring of 2015, a total of 38 students. The distribution form was email with a link to the actual survey. Reminding emails were sent twice to those who had not completed the survey. 15 students responded to the survey, representing a response rate of 39%.11 of these were men and three were women, while one respondent chose not to submit gender. The median age of the respondents was 22.5 years. Minimum and maximum age was 20 and 45 respectively. Four of the respondents studied in their first year, seven in year two and four were on their third year. The paper-based questionnaire for alumni was sent by mail to the respondents. A letter was sent approximately two weeks after the original survey was sent in which the respondent was reminded to complete the survey either on paper or via an anonymous web-based survey (link attached in the letter along with a unique code). A total of 148 questionnaires were sent out and of these 22 were answered through the paper version and six via the web. This gives a response rate of 19%. Of the respondents six were women and 22 men. The median age of the alumni respondents was 35.5 years. Minimum and maximum age was 26 and 70 respectively.

A focus group discussion was held on April 14 during a reference group meeting where representatives of academia and industry join to discuss education related issues. Reference group meetings normally take place once per semester. The activity was introduced via presentation material, and the discussion was led by the project manager (the author of this paper), which also took notes and compiled the material. Participants were first asked to note their preferences regarding the 27 questions on a separate form which was distributed at the meeting, and then a discussion in the group followed. Unlike the questionnaires, where a four-point Likert scale was used, the question was formulated more openly as “please note the competence or competencies you find most important, and thereafter note which, according to you, that are least important”. The individual responses were collected after the meeting and compiled together with the notes of the discussion. A total of six representatives from the industry were present during the meeting.

MAIN FINDINGS

The main findings from the questionnaire survey and the focus group discussion are presented for each subgroup and thereafter a summarizing discussion of the findings is held. Due to the small data sample, and the use of the Likert scale, mean values are used for ranking. The results are presented using stacked column graphs, where each column represents the total number of answers for the question expressed in percentages. The values range from 1 representing low importance to 4, representing high importance.

Knowledge

The current students’ view on the knowledge content is found in Figure 2 a). The students found knowledge about forestry and forestry planning as most important (median = 4). Material science was also seen as important (median = 3,5). The students found other engineering sciences and knowledge in construction engineering, i.e. knowledge outside their own discipline, as least important (median = 2). All knowledge types were ranked fairly high; except for forestry and forestry planning, material science and other engineering sciences and construction engineering, the median value was 3. Alumni ranked the knowledge content a bit differently. Highest median value (4) was found for forestry, material science, technology, people, society, as well as for wood-related industrial engineering and manufacturing. The alumni scored higher median values in general than the current students; between 3 and 4. To point out any particular area that was of less importance is therefore hard. From Figure 2 b) we can distinguish a tendency for lower scores for other engineering sciences and construction engineering, i.e. same as for the current students. Also, the forest fuel knowledge is rated slightly lower.

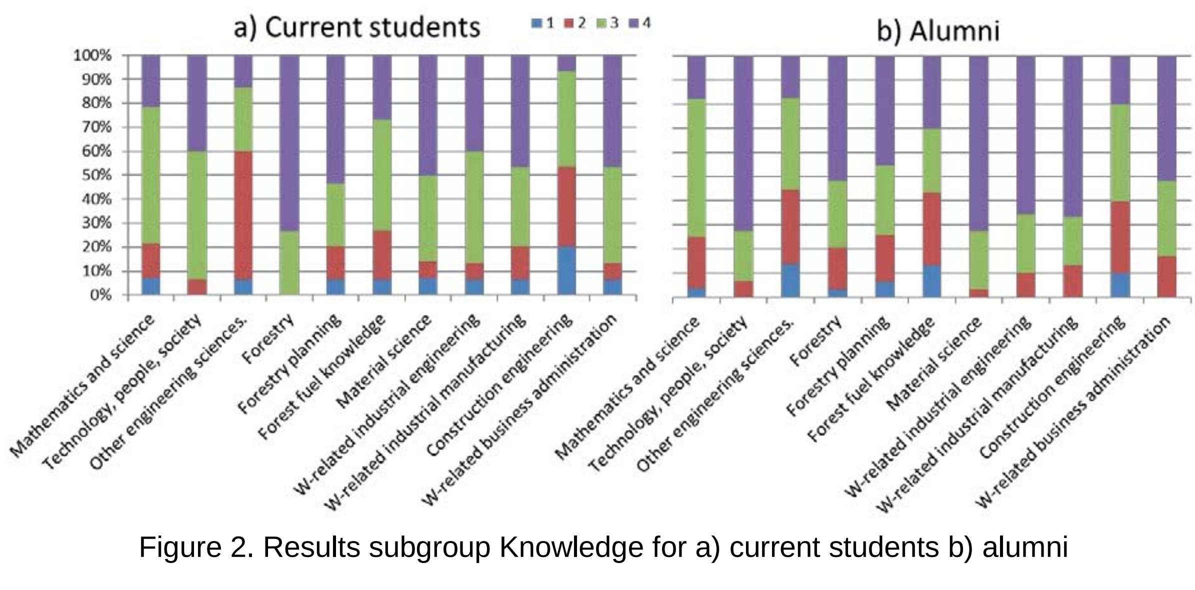

Figure 2. Results subgroup Knowledge for a) current students b) alumni

The industry representatives found knowledge in mathematics and science, technical expertise, and understanding of forestry and wood as material as most important. Engineering know-how is based on the understanding and use of mathematics and the technical expertise is important because it forms the basis for an engineer. Discipline knowledge and general engineering knowledge forms the bases for the future engineer. In addition, understanding of forestry and wood as material is a prerequisite for wood-related product development and production planning. The least important knowledge was, according to the focus group discussion, pure forestry related courses and courses in construction engineering. While there was a consensus that basic understanding of forestry is required, the curriculum should not contain too much of forestry and forestry related courses, because that would change the focus from the whole value chain to the early phases of the value chain. Full consensus whether construction engineering was important or not did not exist though; some argued that the knowledge was important because a big application area for wood products is within construction. Others saw construction as too far from the program scope.

Skills

Personal, professional and interpersonal skills were ranked high both by current students and alumni, see Figure 3. Also here the alumni scored higher in total median compared to the students. In the student responses three out of eight skills scored 4, while the rest scored a median of 3. The skills with median of 4 were analytical thinking and problem solving, teamwork and communication. Alumni scored a median of 4 for six out of eight skills; only ethics, equity and responsibilities, and communication in foreign languages had a median of 3.

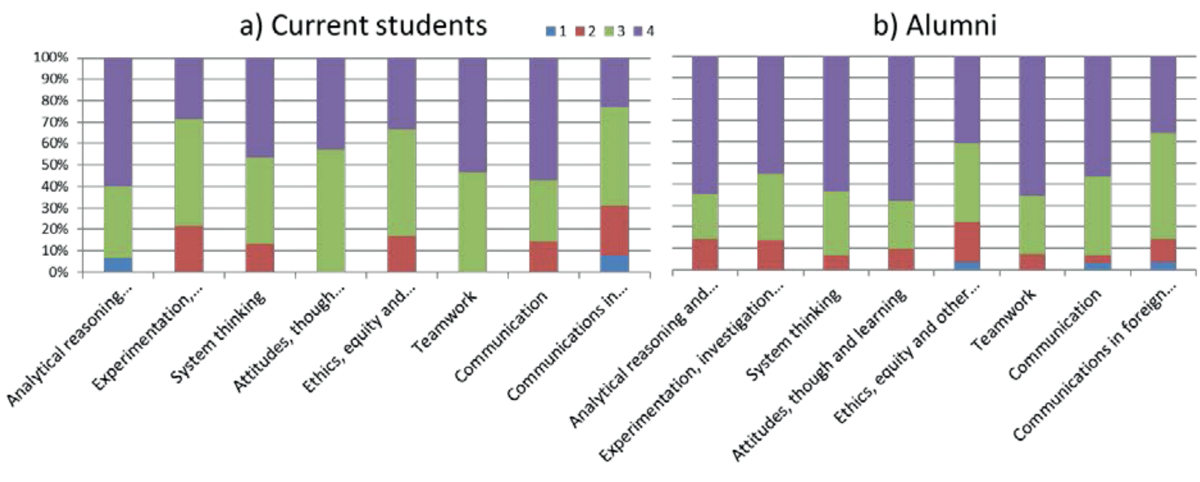

Figure 3. Results subgroup Skills for a) current students b) alumni

The industry representatives found analytic thinking and problem solving as well as experimentation, investigation and knowledge discovery important. These skills are strongly connected to the basic engineering know-how. Other important skills are the ability to work in groups and communication skills. Inability to communicate means that you cannot convey ideas and the engineering expertise is not realized. Ethics, attitudes and other responsibilities were also seen as important: “As an engineer, I lay the foundation for future products, and therefore these skills are important.” Least important was the ability to communicate in foreign languages, according to the focus group. Even if the corporate language often is English today, it is hard to train the language capabilities to reach a high enough level within a three year program. The most important is the ability to discuss and converse with others, but this ability did not have to be an obligatory part of the curriculum, some representatives reasoned. The group also disagreed about the team work abilities; while many saw this as an important skill, others saw the engineer mainly as a leader, and not as a team worker, thus not necessarily needing team working abilities. The focus group suggested adding leadership abilities and several skills connected to attitudes, though and learning. The latter indicates that this skills' group was seen as important even if it was not specifically mentioned in the discussion.

Professional and societal understanding

The current students pointed out only one area of higher importance in this subgroup: entrepreneurship (median = 4). The rest of the skills areas scored a median of 3. Notable in Figure 4 a) is the relative weight put on implementing systems. In Figure 4 b), accounting for alumni results, understanding how to operate systems is in focus. Understanding of enterprise and business contexts was scored highest amongst alumni (median = 3,5).

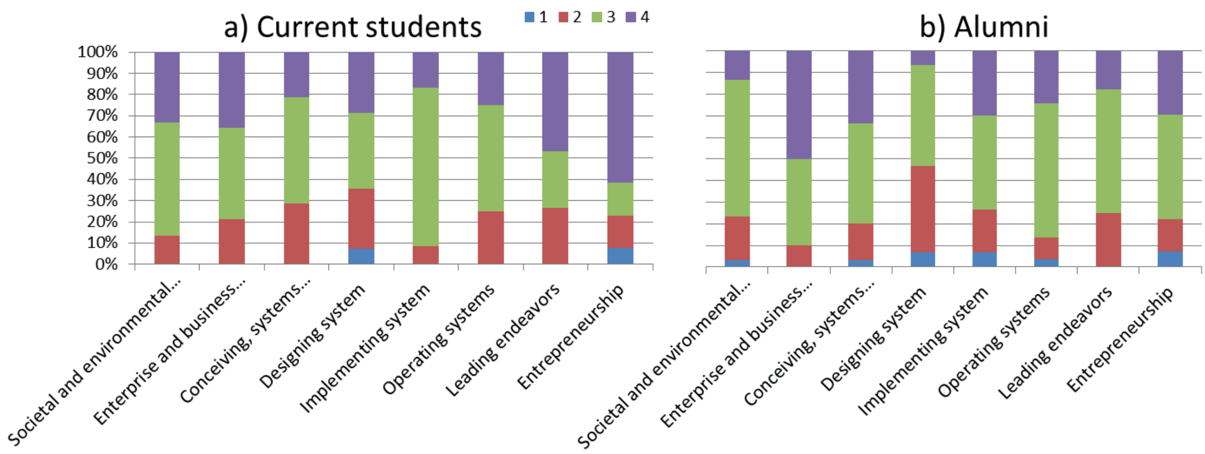

Figure 4. Results subgroup Professional and societal understanding for a) current students b) alumni

In the focus group understanding of enterprise and business context as well as entrepreneurship were seen as important. A fairly long discussion regarding entrepreneurship was held, because some representatives saw this as least important. An argument in favor for entrepreneurship was that "An engineer must be able to see new ideas and realize them", while others saw the engineer as not being an entrepreneur. It was also discussed whether an entrepreneur would enroll in higher education at all – many famous entrepreneurs are self-learned. The importance of entrepreneurship depends on where you fall in employment. A larger company has in-house training and their own way of working with innovation, while in a small business, innovation skills could be extremely important. The group agreed upon that all students would benefit of a certain understanding of entrepreneurship, and that the ability to lead innovations is more important for an engineer.

Results discussion

The stakeholders have in common that they believe that material science and understanding forestry, i.e. the conditions in which the material is produced, are important. Participants from industry emphasizes the general engineering knowledge, such as mathematics and technical expertise, while alumni focus on the later phases of the value chain (wood-related industrial engineering and manufacturing). Alumni also rank knowledge in technology, people and society, i.e. courses offered to all engineering students that give insights in the economical, business related, societal and environmental aspects of engineering. Least important was deepened knowledge in forestry and in construction engineering. These courses are today optional (except for the course in forest fuel science), so from the knowledge perspective, the current curriculum seems to be well fit to student expectations as well as future takers' needs. Suggestions from the industry representatives of more wood industrial courses and to add product development to the curriculum were given. The stakeholders agree that analytical thinking and problem solving, teamwork and communication are important skills, even if there was a slight disagreement within the focus group regarding teamwork. Communication in foreign languages was seen as less important, while there were different viewpoints on the ethics and equity; the alumni ranked this skill low while industry representatives saw this as important. The importance in understanding enterprise and business contexts was common for all stakeholders. The students ranked entrepreneurship as important as well, while the industry representatives saw the ability to lead innovations as important. These results were used as input for curriculum change decisions together with several other findings, in which the mapping of the curriculum with respect to the CDIO syllabus was one major input. The mapping pointed out strong areas (connected to CDIO syllabus skills 1.1-1.3, 2.1-2.3, 3.2, 4.1) as well as areas in need of further development (connected to CDIO syllabus skills 2.4-2.5, 3.1, 4.2, and 4.7-4.8). To mention some improvements in the curriculum, a course in leadership was introduced that strengthened the teamwork and leadership training as well as training in ethics and equity, and several activities in entrepreneurial thinking, i.e. in seeing and acting on opportunities, were added to the current courses.

CONCLUSIONS

This paper reports on a study aiming at understanding different stakeholders' preferences with respect to curriculum contents. The data gathering was made using the CDIO syllabus as a basis, and it is concluded that this approach was workable and resulted in useful findings. Thus, it is possible to survey different stakeholder preferences with the same set of questions, even if the actual survey setup and distribution form differs. If possible, the same data gathering technique should be used for all participants, and we find both strengths and weaknesses in the three data gathering techniques used in this study. The focus group discussion gives deepest understanding but it is hard to distinguish individual preferences, while questionnaires give possibilities to compare results within and between stakeholder groups but no explicit explanation to the patterns one find. It is therefore suggested, for best results, that the questionnaire survey is combined with focus group discussions for each stakeholder group included in the survey. This was not possible in the study described in this paper due to time restrictions as well as geographical spread of respondents but future studies would take advantage of for instance program meetings that gather the current program students and the alumni gathering held in December each year.

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BIOGRAPHICAL INFORMATION

Mirka Kans is an associate Professor in Terotechnology at the department of Mechanical Engineering and has been program director for several educational programs since 2004 and forward. She is active in developing the education practices and curriculum according to student centered and active learning concepts (e.g. in form of CDIO), and in close collaboration with industry. Research focus lies within data and information systems for industrial management, and especially on data and IT requirements for maintenance management and how to support maintenance by means of IT to achieve cost-effectiveness.

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APPENDIX 1. QUESTIONS INCLUDED IN THE SURVEY

All questions used a four point Likert scale, such as the example provided below. The respondent has the possibility to not answer the question either by skipping the question or by the option "Do not know".

1 --------------------2--------------------3-------------------- 4 Do not know: ☐

Knowledge:

2.1 Mathematics and science. For example basic algebra , vector geometry , mathematical statistics and physics.

2.2 Technology, people, society. For example quality engineering, environmental engineering, sustainable development, industrial management or organizational learning.

2.3 Other engineering sciences. For example CAD, electrical engineering or control engineering.

2.4 Forestry. For example forest measurement techniques, silviculture and forest economy.

2.5 Forestry planning. For example how to develop a forest management plan, quality issues in the value chain from the forest to the final product , and forestry applications of geographic information systems (GIS).

2.6 Forest fuel knowledge. For example forest-based biofuels in terms of assets, properties and handling.

2.7 Material science. For example the wood structure and properties, and how the properties are expressed in various wood products or wood processing.

2.8 Wood-related industrial engineering and processing technology. For example processing methods for wood or techniques for processing in the wood industry.

2.9 Wood-related industrial manufacturing. Such as production management or production economics.

2.10 Construction engineering. For example civil engineering, building physics, building materials and building mechanics.

2.11 Business administration with specialization in forest and wood industry. For example logistics (handling of materials / information / monetary flows within and between enterprises) or the forest industry markets (market analysis, sales, purchasing, trade and contract).

Skills:

2.12 Analytical reasoning and problem solving. The engineer must be able to simplify complex problems by constructing relevant models and analyze these models to draw quantitative and qualitative conclusions.

2.13 Experimentation, investigation and knowledge discovery. The engineer must be able to make hypotheses about the engineering issues, to demonstrate how these hypotheses experimentally could be tested and be able to draw conclusions from these experiments.

2.14 System thinking. The engineer must be able to view components of a subsystem in an overall perspective and be able to prioritize and compromise in order to optimize the operation of the system as a whole.

2.15 Attitudes, though and learning. The engineer must be able to seek new solutions to technical problems as well as being critically curious about the technological developments in their own discipline, and adjacent areas.

2.16 Ethics, equity and other responsibilities. The engineer must be able to act ethically with integrity within the discipline and exhibit a professional demeanor.

2.17 Teamwork. The engineer must be able to understand and be able to perform in different roles in a project. The engineer should also be able to build effective teams and lead development projects.

2.18 Communication. The engineer must have good written, oral and electronic communication skills as well as have the ability to interpret and communicate messages through diagrams, flow charts, and other graphical methods. The engineer should also be able to analyze a text with respect to the underlying message and be able to develop messages based on its strategic role.

2.19 Communications in foreign languages. The engineer shall easily read, write and speak about the own discipline in the English language. Languages in the European locale or other major language groups are a great asset.

Professional and societal understanding:

2.20 External, societal and environmental context. The engineer must understand and evaluate their own role and impact of technology on individuals, society, environment and external environment and be able to evaluate the technology in a global long -term perspective. The engineer must also have knowledge of the laws governing the operations of their own industry and in activities related to research, technology development and production in general.

2.21 Enterprise and business context. The engineer must understand the implications of the economic basic terms and understand the economic conditions for business activities. He / she must have the ability to make commercial considerations in the process of system development, design and production.

2.22 Conceiving, systems engineering and management. The engineer must be able to analyze technical systems, breaking them down into subsystems, detailing the objectives and requirements of each of these subsystems and define the interfaces between sub-projects. He / she should have knowledge of the use of project models, how to participate in and lead development projects and how to formulate system descriptions and project plans.

2.23 Designing systems. The engineer must have the knowledge that he / she can construct the prototype system within their technical area and have experience in prototype construction in multi- disciplinary environments.

2.24 Implementing systems. The engineer must have knowledge of the adjustments in the design, layout and design must be done when prototypes are developed into products and systems adapted for manufacturing, distribution and sales, and have the ability to implement this adjustment in the context of a project.

2.25 Operating systems. The engineer must have knowledge about methods of quality assurance and ability to lead efforts to maintain and develop the technical systems. He / she should also be able to contribute in the process of analyzing the product or system material and energy impacts in a lifecycle perspective.

2.26 Leading endeavors. Be able to develop and implement visions, ideas or solutions.

2.27 Entrepreneurship. Leadership and organization, business development, networking and financing of new ideas and activities. Marketing and business innovation.

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INTEGRATING AWARENESS OF CAREER PROSPECTS INTO YEAR-1 CHEMICAL ENGINEERING CURRICULUM

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ABSTRACT

This paper explains the effort from the Diploma in Chemical Engineering (DCHE) from Singapore Polytechnic in contextualizing education and career guidance (ECG) efforts to strengthen students' understanding of career prospects in their chosen discipline.

This paper introduces a national initiative from the Singapore Government called SkillsFuture aimed at providing Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points. This paper specifically focuses on the first of four strategic thrusts, which is to help individuals make well-informed choices in education, training and careers. More specifically, the paper shares our experience in designing a new activity for the Year 1 module *Introduction to Chemical Engineering* using the CDIO Framework that exposes our fresh intake of students to various job functions that can be performed by chemical engineering graduates. It firstly outlines ECG in Singapore's context, as articulated by the Ministry of Education, existing approaches to expose students to various job functions of chemical engineers, and some notable shortcomings. Secondly, it presents the outcome of a CDIO self-evaluation process for the module that highlighted the need to align student learning with requirements of ECG. The paper then focuses on detailing the design of the learning task, entitled “A Day in the Life of a Chemical Engineer”. An innovative feature of this activity is that we created a scenario whereby the entire class of 20-24 students are all employees of a fictitious chemical company, focusing on several department and/or divisions where chemical engineers are employed, including process design, technical support, operation, quality assurance, maintenance and EHS (environmental safety and health). The activity simulates a ‘typical’ day in a chemical engineering company in which students also need to situationally interpret and respond appropriately to elements of change introduced into the task scenario. The use of cooperative learning is employed to facilitate individual accountability as well as a focus on developing communication and team-working skills.

Next, the paper shares our findings from students regarding their learning experience in this activity. Although the results are largely positive, there is clearly an area for improvement in the most important aspect of the activity: career awareness. This is followed by our reflection of the learning points gained and concludes with several ideas for moving forward.

Keywords: *Chemical Engineering, Active Learning, Education and Career Guidance, CDIO Standards 1, 4, 7, 8*

INTRODUCTION

At the national level, the Singapore Government introduced a new initiative in 2015 known as SkillsFuture (http://www.skillsfuture.sg/) that has far-reaching impact on all educational sectors, in particular the polytechnics, which aim is to prepare graduates for the workforce. SkillsFuture is spearheaded by the SkillsFuture Council, whose task is to develop an integrated system of education, training and career progression for all Singaporeans, promote industry support for individuals to advance based on skills, and foster a culture of lifelong learning. SkillsFuture strives to provide Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points. Through this movement, the skills, passion and contributions of every individual will drive Singapore's next phase of development towards an advanced economy and inclusive society. There are four key thrusts under SkillsFuture: (1) Help individuals make well-informed choices in education, training and careers, (2) Develop an integrated high-quality system of education and training that responds to constantly evolving needs, (3) Promote employer recognition and career development based on skills and mastery, and (4) Foster a culture that supports and celebrates lifelong learning.

This paper focuses on the first strategic thrust, sharing the experience from the Diploma in Chemical Engineering (DCHE) from Singapore Polytechnic (SP) in designing a new activity for Year 1 students using the CDIO Framework to complement the Education and Career Guidance (ECG) introduced by the Ministry of Education (MOE) in support of SkillsFuture. The aim is to retain existing students who enrolled into our program to provide an understanding of the type of jobs a chemical engineer can engage in. DCHE is a 3-year program with annual intake of 120-125 students. The course aim is "to produce Chemical Engineering technologists equipped with a solid foundation in Chemical Engineering qualified to assume responsible positions in the chemical process industries and with the ability to continue learning after their formal training." Example of positions and responsibilities that are held by DCHE graduates in various sectors of the chemical process industries are as shown in Table 1.

Table 1. Profiles of DCHE Graduates in Chemical Process Industries

Industries	Profiles of DCHE Graduates
Chemical, Petroleum and Petrochemical	Graduates operate and supervise process plants, assist engineers in process development, quality control, effluent treatment, and waste and energy management.
Pharmaceutical, Bioprocessing, Healthcare, Fine & Specialty Chemicals	Graduates assume positions in the production and quality assurance of pharmaceuticals, biopharmaceuticals, healthcare products and other fine and specialty chemicals.
Environmental, Safety & Health	Graduates provide support in environmental management and pollution control, management of hazardous substances, NEWater production, and can assume technical positions in the area of process safety and industrial hygiene.
Process and Computer Control	Graduates provide technical support in the areas of instrumentation, control systems design and information management.
Process Design & Development	Graduates provide process system design support and customer services.
Semiconductor and LCD Industry	Graduates assume positions in production and/or plant utilities, and provide technical support in the areas of process instrumentation & control.
Allied Industries	Graduates assume positions in technical project management, sales and marketing. Given adequate working experience and skills upgrading, it is anticipated that DCHE graduates will progressively take on roles as senior technologists, engineers, shift team leaders or supervisors, and eventually management related positions.

EDUCATION AND CAREER GUIDANCE

Education and Career Guidance (ECG) is about equipping students with the necessary knowledge, skills and values to make informed decisions at each key education stage for successful transition from school to further education or work, and hence to manage their career pathways and lifelong learning throughout their lives (MOE, 2015). The aims of ECG are to:

1. nurture student's self-awareness, self-directedness and life skills for continuous learning and training; (Skills)
2. enable students to explore viable education and career options through the provision of accurate and comprehensive information; (Knowledge)
3. inculcate an appreciation for the value of all occupations and how they contribute to the well-functioning of society; (Mindsets) and
4. equip students with skills and means to positively engage their parents and other career influencers (Engaging the community).

Table 2. Key Features of MOE ECG

Education	Emphasis	Goal	Lessons
Primary	Awareness	To introduce students to the wide array of occupations, including new jobs created in this ever-changing world-of-work. Students will develop an awareness on their: • interests, abilities and career aspirations. • relation of self to others and work. • initial preferences in career roles assumed in play.	ECG lessons for the Primary 3 to 6 levels have been part of the Form-Teacher Guidance Period (FTGP) package since 2012. These lessons and interaction activities are designed to: • raise students' awareness of their strengths and interests. • help them plan their educational pathway and select secondary schools. • provide more opportunities to explore different careers and nurture their aspirations for the future.
Secondary	Career Exploration	To deepen students' understanding of self and relate schooling to different education and career pathways. Students would: • explore the career world. • understand the relevant courses of study. • develop awareness of their skills, interests and values.	For secondary schools, ECG lessons are conducted as a module under the Character and Citizenship Education (CCE) curriculum. These lessons are progressive in nature, with each lesson building upon previous lessons, and cover the following areas: • 3 Big Ideas: Identity, Choices, Relationships • 4 themes: Self-awareness and self-management, Awareness of relational support and decision influencers, Exploring the education landscape and planning pathways, Career sectors exploration • 3 ECG questions: Who am I? Where am I going? How do I get there? The pre-U syllabus focus on 'being ready for the future', and covers 3 themes: My career identify, Working in a globalized world, Preparing for the changing landscape
Upper / Post Secondary	Career Planning	To enable students to gather information from various sources to make informed educational and career decisions. Students would learn to: • clarify their career self-concept. • develop skills in gathering information. • develop decision-making skills.	

MOE noted that awareness, exploration and planning are necessary for all levels of students, and also acknowledged that there would be different emphases at the different levels to meet varying developmental needs. This is shown in Table 2. MOE also prefers that ideally, schools should be rolling out ECG through a multitude of platforms, in order to ensure good implementation of the total curriculum for ECG.

In our context, ECG will be implemented into all diplomas based on the framework shown in Figure 1 below.

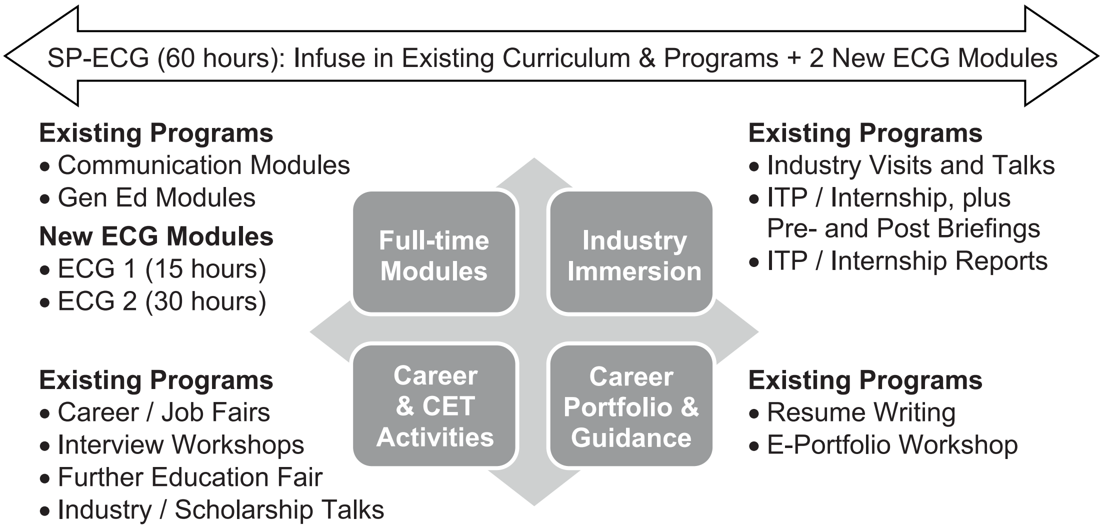


Figure 1. SP Framework for Integrating ECG into its Diplomas

EXISTING DCHE EFFORTS AT CREATING CAREER AWARENESS AMONG STUDENTS

Consistent with CDIO Standard 1, we used a variety of approaches aimed at instilling in DCHE students awareness of what chemical engineering is really all about. The existing efforts are mostly conducted within the diploma, where we explicitly expose students to the chemical engineering profession via core modules in all three years of study; and supplement these with Year 2 Industrial Training Program (ITP); Year 3 industry-sponsored projects as well as co-curricular activities (CCAs) such as industry talk, etc. For our Year 3 students, we also leveraged on the SP-wide Career Fair to introduce students to potential employers. In addition, we also hold career talks for companies on as-needed basis. The following paragraphs explain in greater details the within-diploma efforts conducted over the diploma's 3-year duration. Broadly, the effort can be categorised as follows:

- Year 1 – awareness of chemical process industries, roles and responsibilities of chemical engineers, technologists and technicians.
- Year 2 – in-depth experience in generic areas of chemical engineering professions in core modules via a variety of simulated work environment in the laboratories, which we termed 'engineering practice' (Cheah & Yang, 2013).
- Year 3 – more in-depth experience in generic areas via the remaining core modules, as well as specialized topics in free-elective modules from 3 Concentration Paths (Petrochemical Engineering, Biopharmaceutical Engineering and Environmental Engineering) which introduces students to specific nuances in these areas; or alternatively via real-world immersion in a chemical company for a minimum of 15 weeks in the Internship Path.

Year 1 students are first introduced to the chemical process industries by a dedicated core module, *Introduction to Chemical Engineering* which is taught to all students in Semester 1. The module aims to provide students with basic understanding of the profession of chemical engineering and fundamental of chemical engineering principles and applications of engineering measurements. It is a 75-hour module, of which 11 hours is devoted to introduce students to the profession, as noted by the following General Learning Outcome statements under the very first topic, Topic A “World of Chemical Engineering”:

1. Understand History, Evolution and Achievements in Chemical Engineering
2. Describe Roles and Responsibilities of Chemical Engineers

The other 4 topics in the module are:

B. Chemical Engineering Calculations
C. Chemical Engineering Processes and Process Variables
D. Unit Operations of Chemical Engineering
E. Introduction to Chemical Engineering Laboratory

It is worth noting that Topic E comprises of 15 hours of laboratory activities that serve to provide hands-on application of the concepts learnt in Topics B, C and D. There is no activity to support Topic A, and students only get to appreciate what chemical engineering is all about during lectures and tutorials.

As for CCAs, our Year 1 students take part in ChemEx, the annual Jurong Island Open Day. Our students partnered with the Singapore Chemical Industry Council (SCIC) in organising educational games for secondary school students who visited the event. We also invited SCIC as well as the Economic Development Board to deliver industry awareness talks to our students. In addition, we also organized plant visits for our Year 1 students.

In Year 2, our students are heavily involved in various laboratory activities which had been re-designed using CDIO Framework to simulate real-world working environment. Through scenario-based learning, students took on various roles and responsibilities in tackling industry-type work challenges such as troubleshooting plant operations, dismantling and assembling a pump, making recommendations of suitable packing material, writing technical memos, evaluating the performance of a heat exchanger, etc. In addition, our students need to complete a 6-week ITP either at a local company or at the Chemical Process Technology Centre (CPTC), a professional training company that offers live plant training that include working in shift teams. Students who successfully completed the CPTC training will be awarded the Singapore Workforce Skill Qualification (WSQ) Certificate in Process Technology (Chemical Production).

In Year 3, in addition to the SP-wide Career Fair mentioned previously, we also organize our own diploma-specific career talks for our students. However, it is usually done on an ad hoc basis, at the request of companies from the chemical processing industries. Specific career roles may also be emphasized in relevant core modules by the lecturer teaching the module (core or free electives), although this approach may not be consistently used by all lecturers.

DESCRIPTION OF THE NEW INITIATIVE

The motivation for the new activity came from the recent focus in Singapore to improve career guidance to our students. Even though DCHE ranked favorably in the annual Graduate Employment Survey, the DCHE Course Management Team (CMT) nonetheless felt that more could be done in this aspect. This is consistent with the spirit of continual improvement that we adopted to further strengthen our curriculum. We need to complement our DCHE training hallmark – engineering practice – as mentioned in earlier section.

This paper focuses on a new initiative implemented for *existing* Year 1 students. It aims to better familiarize these incoming students with what a career in chemical engineering is all about. With this, we hoped that any students who came in with different (or wrong) expectations will either see the value and opportunities this course offers and hence stay on; or make an informed decision to transfer to another course. Granted, attracting the 'right' students in the first place would be a better strategy, rather than dealing with students with mismatched expectations after they enrolled into the course. Indeed we have also been active in this area. However, we are all very familiar with the challenges one faced in today's digital age, and initiatives by the CMT in these areas are beyond the scope of this paper. There are already many publications on the need to interest secondary school students in pursuing careers in engineering (see for example, Reynolds et al, 2009; Prieto, et al, 2011; Klimovski, et al, 2012; Andrews and Clark, 2013). This initiative focus on existing Year 1 students, and is aimed at complementing existing campus-wide ECG initiative, by providing our students with understanding ECG in the disciplinary context for chemical engineering.

The initiative started with a review of the Year 1 core module *Introduction to Chemical Engineering*, as part of the annual module review exercise. This module was introduced into the DCHE curriculum for the first time in 2008, when we rolled out our CDIO-type curriculum. The module is meant to satisfy CDIO's Standard 4 Introduction to Engineering, which is "an introductory course that provides the framework for engineering practice in product and system building, and introduces essential personal and interpersonal skills." The review of this module is worth special mention. In the case of DCHE, with our adoption of the CDIO Framework, we had integrated the 12 CDIO Standards into the AQMS to drive our continual improvement efforts (see Cheah, Koh & Ng, 2013). We subsequently adapted the 12 Standards for use at module-level, both for review of existing modules (Cheah & Lee, 2015) as well as design of new modules (Cheah & Koh, 2014). A major outcome of the review of this module is an insight that students lacked learning experiences where they can better appreciate various other career prospects in chemical engineering besides the obvious manufacturing environment. This led to the need for a new activity to promote greater awareness on career options for chemical engineers. Consistent with CDIO Standard 7 Integrate Learning Experiences, it is ascertained that the design of this activity must permit students to immerse themselves in a simulated real-world work environment in which chemical engineers of various job functions, technologists and technicians work together and interact with each other in a typical working day. The activity is aptly named "A Day in the Life of a Chemical Engineer".

From the onset, we decided to inject a different learning experience into this new activity, to make it distinct from other activities in the module that emphasized applying technical knowledge learnt in class. Drawing on our previous work experience in the chemical processing industry and referencing the relevant section of the SP-CDIO Syllabus (see Table 3), we came up with the following desired learning outcomes for the new activity:

- Explain employment opportunities in a variety of job functions in chemical engineering
- Explain career progressions in the field of chemical engineering
- Explain importance of communication in technical coordination
- Explain importance of teamwork – within team and across teams
- Explain importance of staying current in latest chemical engineering practice
- Explain importance of managing and responding to change
- Explain importance of self-directed and independent learning

Table 3. Selected Section of the SP-CDIO Syllabus

2.5	PROFESSIONAL SKILLS AND ATTITUDES
2.5.2	*Demonstrate professional behavior at work and in society*
	Use ethical reasoning on issues relating to human conduct in personal and professional contexts
	Identify behaviours that demonstrate social responsibility
	Demonstrate behavior consistent with agreed codes of ethics and values systems
2.5.3	*Staying current on emerging research and practices*
	Analyse current research and practices in own professional field
	Identify the impact of new research and technology on engineering practices
4.2	ENTERPRISE AND BUSINESS CONTEXT
4.2.4	*Understand Organizational Structure and Dynamics*
	Define the function of management and organizational structure
	Describe various roles and responsibilities in an organization
	Describe the roles of functional and program organizations
	Describe working effectively within hierarchy and organizations
	Describe change, dynamics and evolution in organizations

In the design of the learning activity, we used cooperative learning to promote student engagement. According to by Felder and Brent (2003), several definitions of cooperative learning have been formulated, and the one most widely used in higher education is that of David and Roger Johnson of the University of Minnesota (1999). In this model, cooperative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements:

1. **Positive interdependence.** Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences.
2. **Individual accountability.** All students in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned.
3. **Face-to-face promotive interaction.** Although some of the group work may be parcelled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging reasoning and conclusions, and perhaps most importantly, teaching and encouraging one another.
4. **Appropriate use of collaborative skills.** Students are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.
5. **Group processing.** Team members set group goals, periodically assess what they are doing well as a team, and identify changes they will make to function more effectively in the future.

We created a scenario whereby all students are employees of a fictitious chemical company. We created a partial organization chart with several departments; and divided the students into 5 groups of 4-5 students, and each group belongs to a different divisions of the same department, or in different departments, as shown in Figure 2.

Some of the unique features of this activity are:

- Each group will have, within the broad general scenario, a specific scenario that focus on a particular work/functional area within the Department and/or Division
- All members within each group will have his/her own respective roles and responsibilities

- Cross-interaction between Departments and Divisions, which necessitates some memo writing
- Some of the process log data and laboratory test results were deliberately manipulated so that they are erroneous – this is to inculcate critical thinking among students
- “Unexpected” events being injected into the tasks, to simulate scenarios where the students need to deal with changes in routine/protocol
- Ethical dilemma where personal favour is being solicited using positional power
- Apply Excel in preparing technical charts, thereby making use of the skills taught during ‘Excel Day’ (one of the several ‘white space’ activities, organized the staff and/or DCHE Student Chapter)
- Need for information not-yet-taught in class or will not be taught in class: to inculcate information literacy skills essential for independent learning in support of lifelong learning

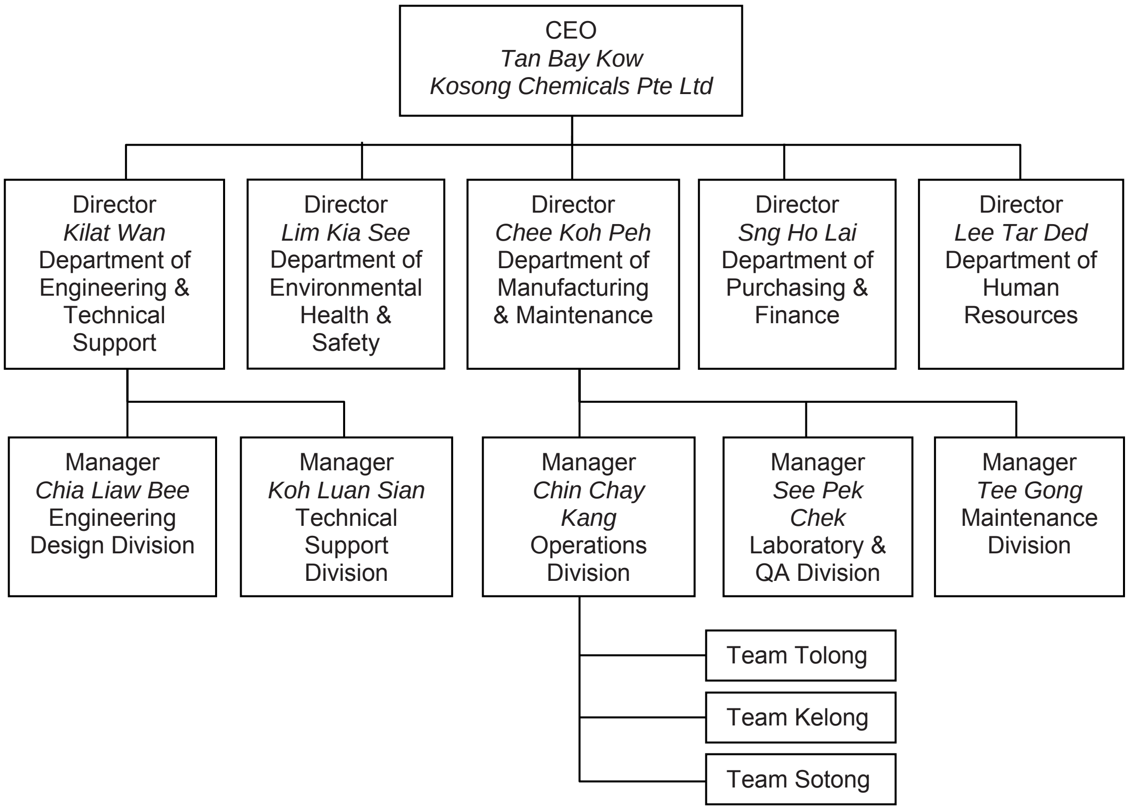


Figure 2. Organization chart (partial) for a fictitious chemical company

DISCUSSION: EVALUATION OF STUDENT LEARNING EXPERIENCE

We conducted a simple survey to ascertain students’ learning experience after they completed the activity. We use a 5-point Likert scale ranging from ‘1’ for ‘Strongly Disagree’ to ‘5’ for ‘Strongly Agree’; for the following questions:

1. The activity gives me a good overview of work life of a chemical engineer.
2. The activity improved my understanding of different job functions available for chemical engineer.
3. The activity improved my understanding of possible career paths for chemical engineer.
4. In addition to technical knowledge, it is equally important to possess “soft“ skills such as communication, coordination, team-working, etc

5. The documents used in the activity (e.g. data logging sheet, work order request, test result sheet, etc) add realism to the learning task.
6. I am able to carry out independent learning on topics that are required in the activity but not taught to me in class.
7. It is important to be able to deal with change or disruption that can happen in seemingly routine work.
8. It is important to understand the different perspectives of co-workers from other departments or divisions.

We also asked for comments from 3 open-ended quesitons:

- Name one aspect of the activity that you find **most** interesting, and explain why.
- Name one aspect of the activity that you find **least** interesting, and explain why.
- Suggest one area of improvement in the activity. Please be as detailed as possible.

The results are shown in Figures 3 – 10. Overall, our students felt that the activity gave them a good overview of working life of a chemical engineer (Figure 3), and the different job functions that a chemical engineer can engage in (Figure 4). Majority of the students felt that there is sufficient realism in the learning task (Figure 7). We are quite pleased with the response to this question, as it showed that our effort in painstakingly designing the various documents e.g. safety data sheet, log sheet, test result report, etc looked authentic, even though the company itself is fictitious.

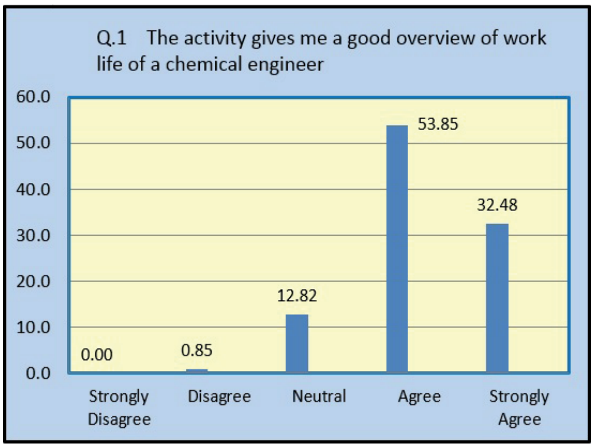


Figure 3. Response to Question 1

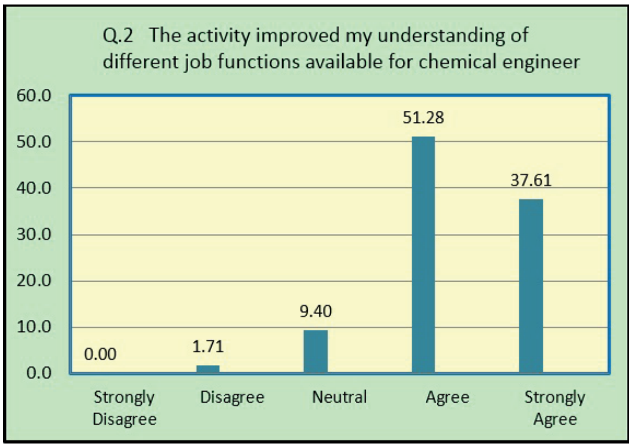


Figure 4. Response to Question 2

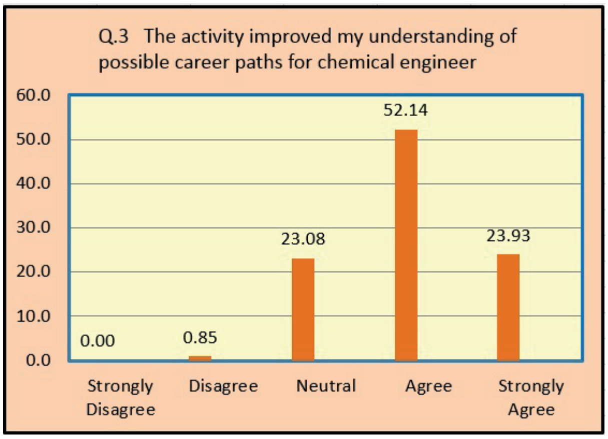


Figure 5. Response to Question 3

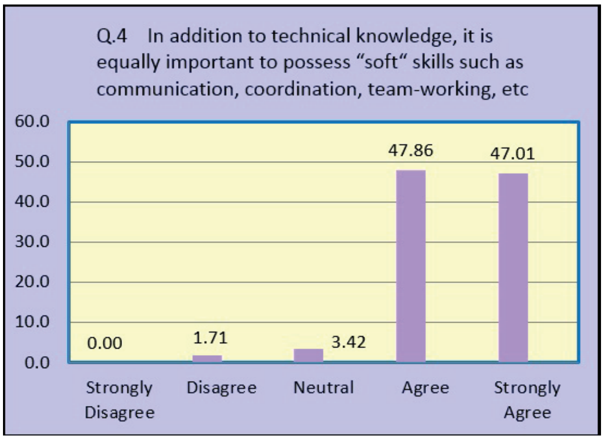
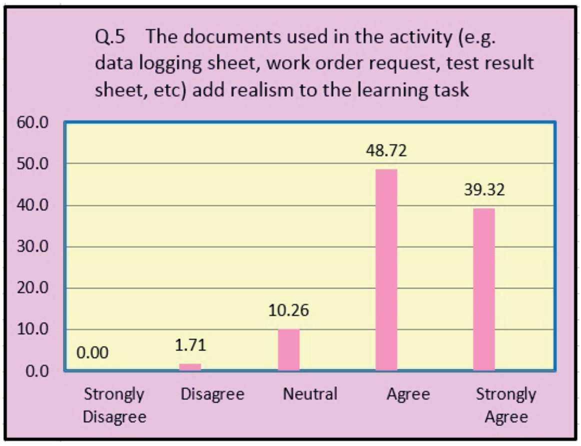


Figure 6. Response to Question 4



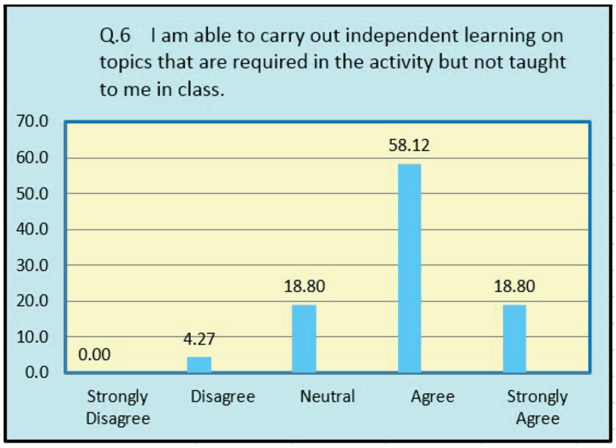
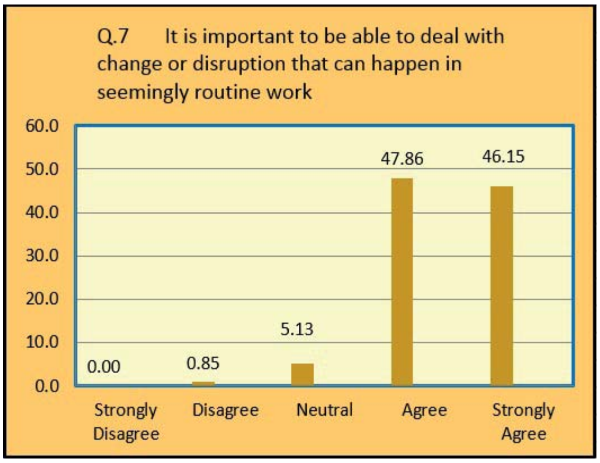


Figure 7. Response to Question 5

Figure 8. Response to Question 6



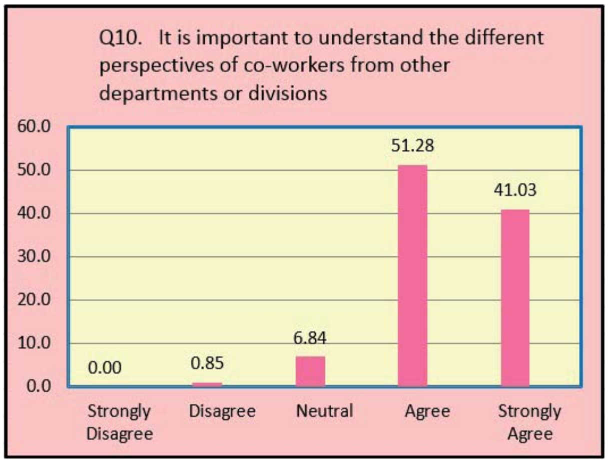


Figure 9. Response to Question 7

Figure 10. Response to Question 8

The students also agreed that it is important to possess the necessary soft skills such as teamwork, communication and coordination skills, in addition to sound technical knowledge (Figure 6), in particular, being able to see an issue from different perspectives (Figure 10). The students also understand the importance of being able to deal prompt with issues that may arise out of seemingly routine work (Figure 9). However, a significant number of students gave a neutral feedback about their ability to learn independently (Figure 8). We take this to mean that they are - at this early stage of study - still lacking in confidence in their own ability in this area, and this is certainly an area that we will continue to develop in our students in subsequent semesters.

Lastly, and most importantly, quite a large number of students (27, to be precise; out of 117 who responded to this survey, or 23.08%) noted that they are not very clear of career path available for a chemical engineer (Figure 5). Although there were clear instructions on allocation of roles among students within each Department, Division or Team, this does not appear to bring across the understanding of career pathways for employees in a chemical company that we had hoped for. This is perhaps because we did not explicitly highlight this in the activity but left it to the students to infer this for themselves from the organization chart.

As for the open-ended questions, almost all students cited the realism of real-world experience in working on the reverse osmosis (RO) pilot plant and collecting water samples for analysis as the most interesting part of the activity. Other interesting aspects of the activity include working together as a whole class, communicating using walkie-talkies, and being able to work out a solution for the RO pilot plant even though they had not learnt that topic. On the other hand, on aspects of the activity that they enjoyed the least, students mentioned report writing and other paperwork such as filling out test reports, data logging sheets, etc. Some found the preparation needed to get ready for the activity takes too much time, while others felt that for certain roles they did not interact enough with others.

Lastly, on areas of improvement, many students indicated that they wanted more interactions between the different groups. They also felt that some of the instructions are not clear and in fact requested for more information. And perhaps not surprisingly, many of them asked for less report writing. Many students also felt that they need more time to complete the tasks. A handful of students even asked for the tasks to be made more challenging.

REFLECTIONS AND MOVING AHEAD

Putting together an activity involving the entire class of 20-25 students with each one of them taking on different roles is a new challenge for the team. This effort is rather different from our past approaches. In the past, all our core module with lab component typically have 5 experiments, and each experiment requires students to work in group on a given pilot plant on a rotational basis. This is due to the very high cost of our pilot plants (each one is over S$100,000), and also due to scarcity of real estate (lab spaces). Unlike chemistry bench-top or electrical circuits stations whereby everyone gets to work on the same unit at the same time, we are not able to replicate identical units for training our students. The typical way laboratory sessions are executed in DCHE is as follows: a class of 20-25 students is divided into 5 groups, so that each group consists of 4-5 students. Each group of students is assigned to work on one particular pilot plant, and they take turns to work on the rest of the other pilot plants at different dates during the semester. Each pilot plant tend to focus on a specific subject matter in the module, and each is designed around a specific task scenario to bring out a specific aspect of working life of a chemical engineer.

This activity, on the other hand, need to involve all 20-25 students in one, single inter-related task. Drawing on our own previous experience working in the chemical industry, we henceforth conceived of the learning task mentioned in the earlier section. In designing the learning task, our foremost concern is that some of the students may not be fully engaged not so much because they are free-riders but more because there not enough activities to engage everyone. On the other hand, we were worried that we might "over-design" the learning task and it became too taxing on the students. We were also worried that students may get overwhelmed by the large amount of background materials that they need to read up to prepare for the activity. Lastly, in designing this learning task, we also need to always be mindful to ensure that all groups are given challenges of more-or-less equal difficulty. Likewise, within each group, care is taken so that no one group member is overly burdened with completing bulk of the group activity. Despite the best of intentions, obviously this challenge still remains, based on the feedback obtained.

Due to time constraint, we are able to repeat this activity only once, which means that each group of students only get to experience a different role once. We take the request from students for more sessions to mean that the students actually quite enjoyed this activity, and they wished that they can experience all the different roles.

Based on the feedback we obtained from students, plus a review by the module team, we identified several areas of improvement in the activity. We now more explicitly connect the activity to Topic A by giving a 10-minute pre-activity talk, so that students are made more aware of the learning outcomes from the activity, and also revised some of the questions posed. We also added in an extra session so that the students can experience ‘working’ in 2 different department/division. In addition, we created an e-book for the activity to help student manage the information needed for each learning task. More importantly, we also emphasized the importance of writing reports and other paperwork as part and parcel of real-world working environment, and that is something that students need to learn to manage.

On reflection, one challenge is that we ourselves as lecturers may lack up-to-date career information. As noted by Cohen and Patterson (2012), in their study on role of science teachers in promoting career awareness among students, that "job definitions in biology are evolving rapidly ...difficult for teachers to keep apprised of prospective career descriptions and the new skills necessary to enter these fields". Given the fact that lecturers are already heavily burdened with academic and administrative workload, perhaps the Department of Students Services or the Library can play a bigger role in assimilating the latest information from latest available resources and re-package these as ECG tools that lecturers can use to keep abreast of the rapidly changing STEM careers and pathways, and in turn better advise the students of the various possibilities, especially in the context of the topics that one lectured on.

CONCLUSIONS

Students cannot become interested in a career or a field, particularly highly technical ones, without some awareness of the field's existence and the possibilities it offers (Dorsen, et al, 2006). Ekevall et al (2009) concluded from their study that "university student survey demonstrates that school-based educational experiences ***can*** (bold and italic in original) influences pupils' decision-making about their further study and career choices". This paper shared our approach to create better awareness among the incoming Year 1 students the possible job nature and career progression that awaits them. We hoped that this will help to stimulate interest in all students, especially those who did not really understand what chemical engineering is when they signed up for the course. Also, we will also need the secondary schools to do their part in instilling in students the proper mindset on ECG before joining the polytechnics.

ACKNOWLEDGEMENTS

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BIOGRAPHICAL INFORMATION

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THE IMPLEMENTATION OF THE CDIO INITIATIVE IN CUIT

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ABSTRACT

Due to the scale and complexity, the real world WEB applications, mainly websites, can only be developed by a team of engineers, who have different expertise. More specifically, team members must have the ability to create, tune and maintain the database by using Structured Query Language, the ability to retrieve data from database by using dynamic webpage programming, and the ability to create human friendly user interface by using Hyper Text Marking Language and Cascade Style Sheet. Above requirements must be considered for the bachelor program, Network Engineering, whose goal is to train qualified developer who can fulfill such WEB application development task.

In this study, we would like to present some highlights in our Network Engineering program, which adopts the spirits of the CDIO initiative. The details of our practice will be illustrated with emphasis on the implementation of integrated curriculum planning, active learning, learning assessment and program evaluation. Proved by both self-collected data and third party report, our effort is an effective method for the training of qualified engineers. Our work has been done in the Department of Network Engineering, Chengdu University of Information Technology.

KEYWORDS

Engineering Education; Network Engineering; WEB Application Developer; CDIO Standard: 3, 8, 11 and 12

INTRODUCTION

In this study, we will discuss our implementation of the CDIO initiative[1], mainly standard 3-Integrated Curriculum, standard 8-Active Learning, standard 11-Learning Assessment and standard 12-Program Evaluation (for completeness, details of those four standards are listed in Table 1), in our bachelor program of Network Engineering (NE), which aims to train students to be qualified WEB Application developers, who can handle various development tasks (from system design, programming to project management) of web applications, such as website.

Table 1 CDIO Standard 3, 8, 11, 12

Standard 3 -- Integrated Curriculum	A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills

Standard 8 -- Active Learning	Teaching and learning based on active experiential learning methods
Standard 11 -- Learning Assessment	Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge
Standard 12 -- Program Evaluation	A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement

Before we get to any detail about our work, there are some background information should be given so that it would be easier to understand our practice.

First, Chengdu University of Information Technology (CUIT) is a Chinese University, who has over 20,000 undergraduates and 1,600 graduates. Among 53 provided bachelor programs, 30 of them are engineering programs. Obviously, CUIT is dedicated to the development and implementation of engineering educational programs in bachelor level.

Another thing is that Chinese universities usually have more specific major settings (or bachelor programs) than western universities. Take Computer Science and Engineering (CSE) for example, in China we have Network Engineering, Software Engineering, Computer Science and Engineering, Internet of Things Engineering, Digital Media Technology, and even Information Security. On the contrary, it is common that western universities only have Computer Science or Computer Engineering or Computer Science and Engineering.

The rest of the paper is organized as following. In section 2, we first address the problem we are facing. Right after that, we describe our solution, i.e. our practice of the CDIO initiative. Then evidence is provided to prove our work is meaningful and effective. Conclusion and summary will be given in Section 4.

PROBLEM

In China, the pressure of getting a job for bachelor students, especially a well-paid job, has increased a lot in past several years, and is about to increase in the foreseeable future. Thereafter, many students try to get interns during the fourth year with a hoping that such experiences can add on the bargaining chip for their job seeking effort. Above situation makes it more difficult for the curriculum planning, which means it is not appropriate to arrange classes for the fourth year. And thus we have very limited time to prepare our students ready for future challenges.

Meanwhile, the Information Technology (IT) industry has evolved so fast, which makes the situation even more complicated. In order to meet the challenge, engineers need to master various up-to-date development skills. It is even true for start-up companies, in which one person always plays several different roles, for example the system designer, the programmer and even the project manager. So it is our responsibility to make sure that what students were taught in college is what employers really want[5].

To sum up, so much has to be done in such a short time. Extra effort is need for the curriculum scheduling.

What makes things worse is that the new generation of college students has become more and more self-centred. Many of them may not be easily convinced to do what professors told them to do. Moreover, it is common that they have very different and diversified interests, and it is not a surprise that some of they are not interested in computer science at all. How to inspire them to be self-motivated and active learners should be taken into account.

It is our opinion that the solution to the above problem has to meet following requirements.

First, the curriculum schedule has to be decided by real world job requirements. In our context, what we need is an integrated course design, which contains only necessary courses and covers all skills needed for NE students, who are meant to be WEB Application developers after their graduation.

Second, as a complementary, proper assessment methods should be selected to test whether students are prepared to meet future challenges. To be more specific, it is better to assess the system design ability by reports, evaluate communication skills by presentations, test the programming skills by computer-based exams, rather than use paper-based exams as the 'one size fits all' solution. In addition, the assessment system should keep students in track and give them a push even they are sloppy or not interested in those topics.

At last, an evaluation system has to be applied, so that we know how current methods work and what improvements should be taken.

METHODOLOGY

In this section, how the CDIO initiative is applied in NE undergraduates training by following the above mentioned principles will be discussed.

Related Position Survey

To decide what is necessary for a qualified WEB Application engineers, we conduct a survey by collecting job responsibilities or requirements for related positions on the Internet. Our survey covers several popular human resource and job hunting websites in China, including 51job, ChinaHR and ZhaoPin. The requirements among different employers are similar, besides basics of computer science, the frontend script language, the backend dynamic webpage programming skill and the ability to handle a database are popularly demanded abilities. The survey result will later be used in our curriculum planning. Combined with common criteria of computer science programs, the requirement matrix can be formed, which is listed in Table 2.

Table 2 Ability Matrix for a WEB Application Developer

WEB Application Developer	Mathematics
	Disciplinary Knowledge of Computer Science
	Development Skills
	Interpersonal Skills and Communication Skills

Integrated Curriculum Design

The compulsory courses for the NE program are listed in Figure 1, which is consistent with the previous survey result (For the ease of description, some courses, like physics and

English, are excluded from the figure). At the same time, individual demands are not ignored, for instance, in Object-Oriented Programming, both C++ and Java are available; in Database, two most popular database products, Microsoft's SQLServer and Oracle's MySQL are provided; and in dynamic webpage programming, J2EE and .NET are available options. For consistence, if one chooses Java for Object-Oriented Programming, it is highly recommended that he should choose MySQL for Database, and the like.

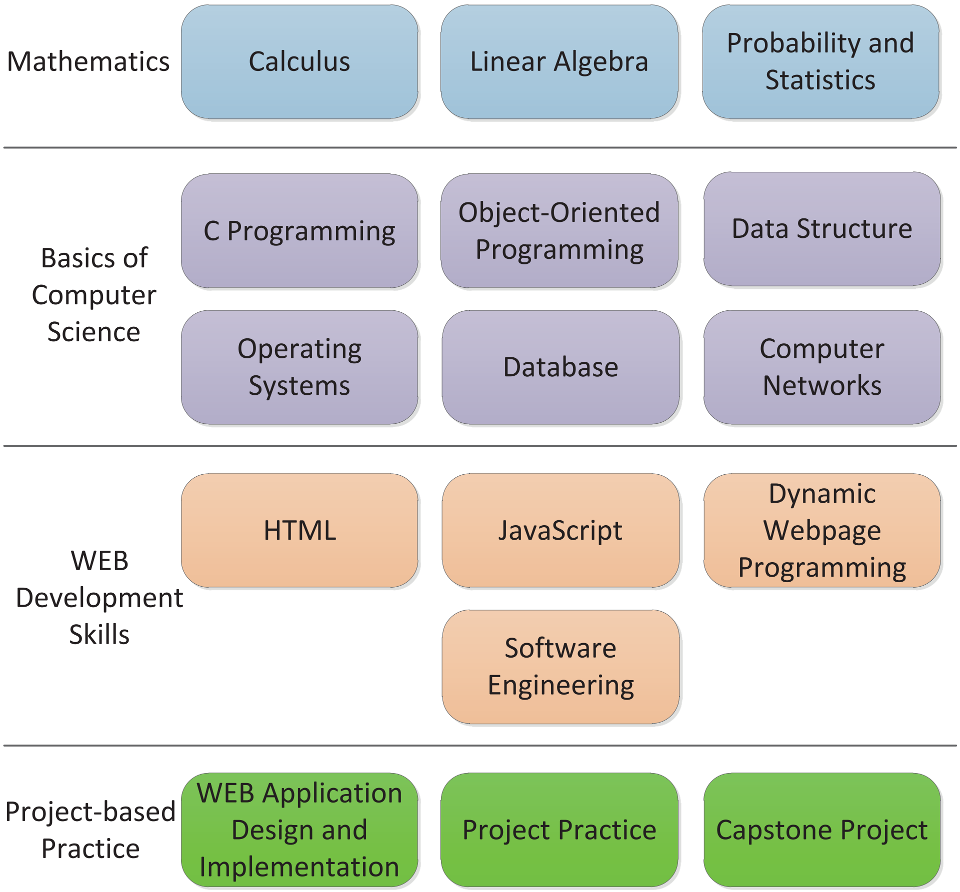

Figure 1 Part of the Curriculum Schedule for NE

At the top of the curriculum, there are mathematics courses. After that, we have courses for basics of computer sciences, such as Computer Networks, Operating Systems, and etc... Then there are courses for development skills, from the frontend programming, HTML and JavaScript, to the backend programming, Dynamic Webpage Programming. Moreover, it is necessary for a qualified software engineer to know the lifecycle of software development, the organization of software development process, and the modelling or management tools for software development. All of those are included in Software Engineering.

Needless to say, just theory is not enough for future IT engineers, hands-on experiences are essential[2]. Then there comes the WEB Application Design and Implementation, Project Practice and Capstone Project. In all of the above project-based courses, what students have learned from WEB Development Skills module will be combined and be put into practice. By doing so, students can have a holistic view of the WEB application development task and a deeper understanding for the connection between those development skills. A further illustration for the content of project-based courses is given below.

In WEB Application Design and Implementation (as the design - implement experience at basic level), students are asked to develop a simple Information Management System individually, such as human resource information management system, student information management system and customer information management system. And it is required that the system has a backend database and several frontend webpages.

In Project Practice (as the design - implement experience at advanced level), students work in teams to develop a more sophisticated WEB application, namely a more complicated website, like online bookstore and online hotel booking website. Working together as one team, students will play different roles, like the project manager, who is in the charge of task assignment and process control, the frontend developer, who uses his HTML and JavaScript programming skills to shape webpages, and the backend developer, who is responsible for data modelling, database create and data retrieval. It is also believed that they can learn interpersonal skills, communication skills rather than just programming skills through such settings. Furthermore, it mimics the lifecycle of the real world software development scenario, in which students can have hands-on experience of the whole development process including the requirement analysis, system architecture design, source code programming, system test and even maintenance.

Last but not least, the capstone project gives an over-all test of how well they grasp those knowledge and skills. As a matter of fact that many students spend their fourth year in IT industry companies, for students' interests, the projects they participated during their internship can be used as their capstone projects. It not only saves them a lot of time, but also improves the quality of capstone projects.

Extracurricular Activities

Though it is supposed that graduates of NE program will seek for WEB application developer positions, they should be allowed to develop their own interests as well. Those demands can be quite diversified and thus hard to fulfil in just classroom studies. Moreover, a well-known rule for a successful college life is that you cannot be satisfied with what you learn in classrooms, you have to work hard after classes. Thereafter, it is necessary to provide an engineering workspace where students can develop their own interests in after-class time[3].

Figure 2 A Four-Axis Unmanned Aerial Vehicle

In our department, there is a lab for student clubs, in which students are allowed to do whatever they want. Proven by facts, it is very useful for inspiring active learning. Several teams are formed for software design competition and innovative contest. Besides that, they can find guidance or financial support if necessary.

Moreover, there is a campus-wide policy that students can receive credits by participation for related competitions. And they can receive even more credits if they can win an award in contests. Many students are encouraged by such policy, lots of eye-opening applications and devices are developed by these talented young men and women. Figure 2 gives a glance for their innovative works.

Assessment System

As aforementioned reasons, it is not appropriate to use just paper-based test for all courses. Depending on contents and characteristics of courses, different assessment methods should be used, for example computer-based tests for programming courses, presentations or defenses for project-based courses.

In HTML programming, students take their final exam in a computer lab. At the beginning of the test, they are given randomly chosen questions, to create a static web page by using HTML and CSS. At the end of the test, the professor will go through students' source code and challenge them, and they have to answer those questions. At last, based on the quality of the source code and whether they answer questions correctly, final grades will be given.

Figure 3 The Login Page of Our Online Test System for C Programming

In C programming, an online test system is developed to replace the traditional paper-based exam (Figure 3 is a snapshot of its login page). And it is not only used in the final exam, but also in regular tests or quizzes. Furthermore, a stage-based test mechanism is adopted for regular tests, which means student has to pass one test in order to move on to the next stage. For instance, to move on to the chapter loop structure, students need to pass the test for chapter selective structure. Such a mechanism guarantees students achieve all setting objectives and forces them to be active participants, otherwise they fail the entire course.

Another highlight of the online test system should be mention is that students can type real source code in webpages rather than write 'fake' code on test papers, and the correctness and completeness of their code will be tested by an imbedded compiler and test cases. Such design has several advantages, to name a few, students can know their scores immediately after they finish the test, teachers can save precious time for manual checking the source code by naked eyes, mistakes can easily be ignored by manual code inspections, like missing terminators or brackets, will never be missed, and students can practice for tests whenever they have time and wherever they can access the Internet.

As shown in Figure 4, due to the introduction of the online test system, the average final grade for C Programming has continuously increased since 2010. What is not shown in Figure 4 is that there was a sudden drop in the average final grade in 2010 compared to 2009, which we believe is caused by students were not yet used to the new testing method and the more strict assessment criteria. It is also worth mentioning that the online test system is kept in update, now it supports four courses, C Programming, Object Oriented Programming, Data Structure, and Database. Not a surprise, final grades for those courses show similar trend as the C Programming. In the future, more courses will be added.

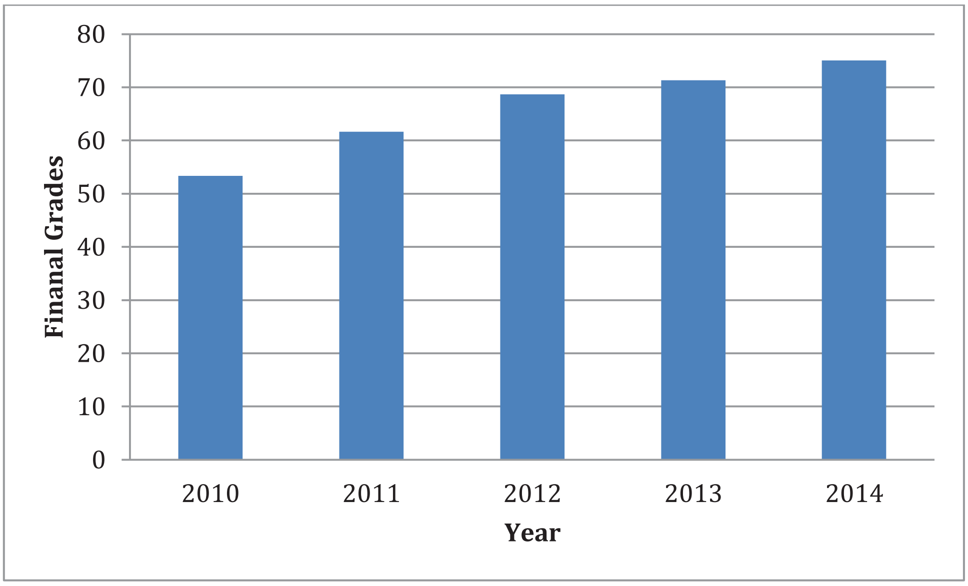

Figure 4 Annual Average Final Grades for C Programming

For those project-based courses, instead of a test, a report has to be submitted other than the source code. Then students have to give a presentation which introduces their works and explains details of their design and implementation. It is certain that they have to take professor's questions after they finish the presentation.

Program Evaluation and Continuous Improvement

The program evaluation is carried out from several different perspectives and by corresponding means, which are listed as following.

Self-evaluation

Every year, the commission of senior professors will randomly pick several courses for inspection. During the inspection, course materials including slides, assignments, test papers and lab reports are reviewed. After the inspection, a report covering three parts is formed. Those parts are the course content, effectiveness of assessment, and student's performance.

For the course content, the commission checks whether the content is update-to-date and gives suggestions for what should be added to the course and whether some topics should be renewed. Take the course HTML for example, HTML5 and CSS3 was added in 2013 after the inspection. For the effectiveness of assessments, professors go through assignments, exam papers and lab reports, to see whether those assessments have covered the course syllabus and whether the teacher has given students enough practice. For the performance, students' grades comparison between this year and last year is conducted to determine what kinds of methods are necessary to inspire their interests and improve their performance.

Informal Meeting

It is a routine that informal meeting is hold between professors and undergraduates after they finish their capstone project defenses. During the meeting, they can complain whatever they are not satisfied, especially about what kind training they needed to find a job is missing from the current program. The fact that those complaints are made based on their very own job seeking experiences makes such suggestions are extremely valuable for the future curriculum adjustments. A very good example is that the Android Mobile Application Development has already been added to our curriculum in 2015 based on feedbacks.

Third Party Survey

Every year, a consulting company named MyCOS (MyCOS is a leading consulting company with a focus on education industry in China) is hired to track all graduates and provide an employment status report. Generally, the survey gives an overview for payments, degrees of stratification for the training they received during college life, and some other aspects. Among those statistics, what we care most is whether graduates really benefit from our efforts, or simply speaking whether they can get well-paid jobs or not. As we can see from Figure 5, the average annual income for bachelors of NE program keeps increasing, from 2010's ¥3142 to 2014's ¥4430. And the employment rate keeps above 90%, which is demonstrated in Figure 6. Both of the income and employment rate are extracted from MyCOS annual graduates reports. Above data could be more persuasive if the average income for all bachelors of NE program across the country can be found. Unfortunately, such data is not available at the time. At least, we can conclude that our effort has positive influence on the employment quality.

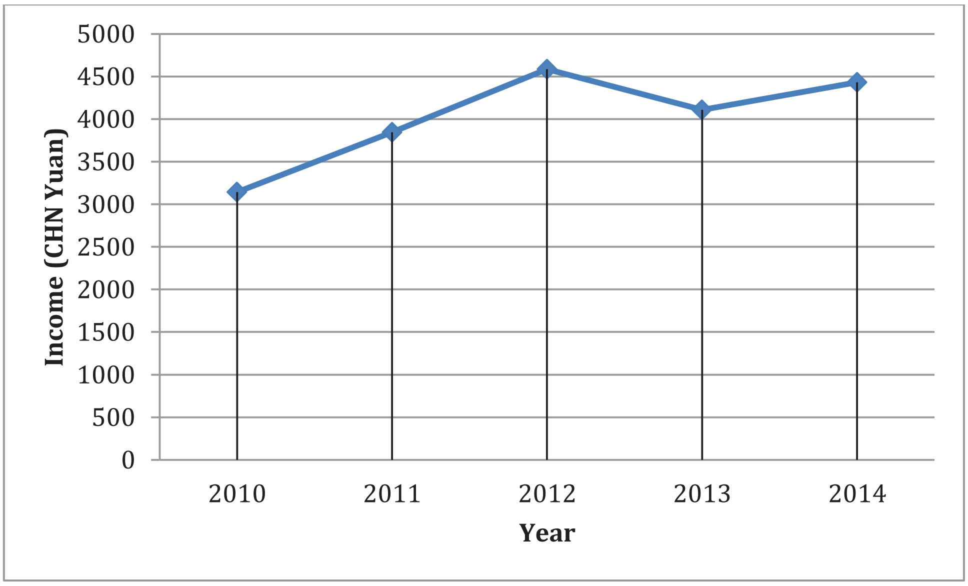

Figure 5 Annual Average Incomes for the Bachelor of NE Program

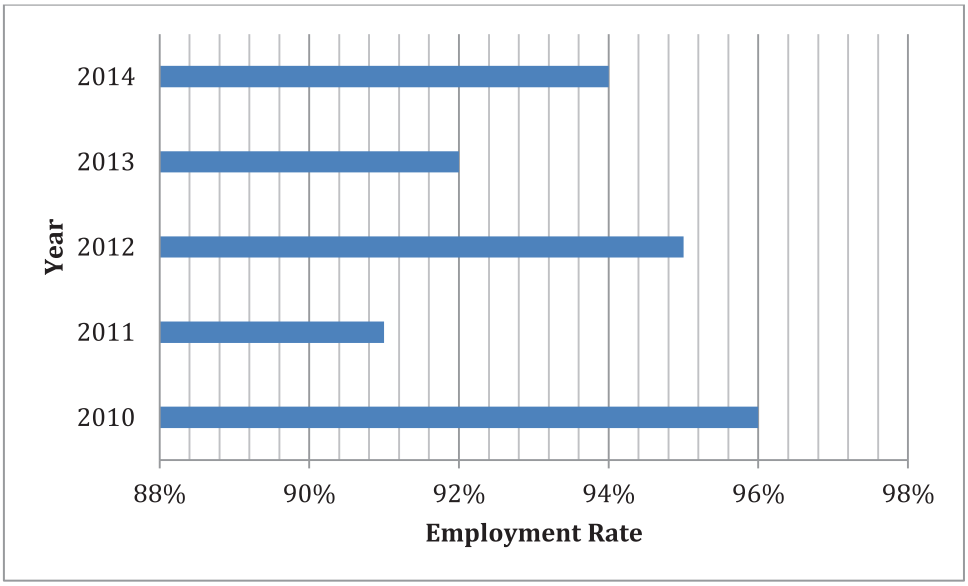

Figure 6 Annual Average Employment Rate for the Bachelor of NE Program

CONCLUSION

Gather from the above, it is safe to say that the adoption of the CDIO initiative and our effort has finally paid off. Both our self-evaluation data and the third-party job market report prove that our practice has positive effect on students' performance. And we believe the application of our experiences is not just limited to NE program, and it can also be used in other CSE related programs.

For future work, there are still possible enhancements can be made, to list a few, a closer collaboration with industry companies for project-based training[4], more engineering workspaces and laboratories can be provided, and a full-scale evaluation system for all twelve standards should be established.

ACKNOWLEDGEMENT

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WAVES OF REFORM – ANALYSING A HISTORY OF EDUCATIONAL DEVELOPMENT CONCEPTS

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ABSTRACT

Luleå University of Technology (LTU) joined the CDIO Initiative in 2015, and a pilot project involving four engineering programs is now well underway. Studying this case, it strikes us as interesting that this happens now, as LTU could obviously have joined CDIO at least a decade earlier. In order to understand the internal processes leading to this outcome, we studied documents and consulted with key persons. In this paper, the history of reform approaches at LTU is described and analysed. We focus in particular on the Arena concept, which appears to have kept LTU from joining CDIO, and the Pedagogical Idea, which is compatible with CDIO and eventually led to the adoption. Reflecting critically on the lessons learned from the LTU case, and drawing on theory and literature, we consider what can support or hinder the adoption of an educational reform concept in the organisation. Some factors concern the nature of the reform and the strategies of implementation. Further, what other universities do can be an influence.

KEYWORDS

Reform concepts, adoption of innovation, travelling ideas, The Creative University, LTU Pedagogical Idea, CDIO adoption.

AIM OF THE STUDY

Luleå University of Technology (LTU) joined CDIO in February 2015 and is currently implementing CDIO in a pilot project with four programs: the Master of Science in *Civil Engineering*; *Mechanical Engineering*; *Industrial Design Engineering*; and *Engineering Physics and Electrical Engineering*.

Being involved in this implementation project, we became curious about why this happens now, as in retrospect it seems that LTU could have decided to join CDIO anytime during the past decade. To understand why it happened in 2015, and not earlier, we decided to investigate the history of educational reform at LTU during the period 2000-2015. Particular focus is on two internally developed reform concepts, the “Creative University” and the “Pedagogical Idea”, and on the history of CDIO at LTU.

RESEARCH APPROACH

Several complementary methods for data collection have been used; in particular document studies, a focus group and several interview discussions. Our aim was to be able to triangulate, i.e. to explain more fully the richness and complexity of human behaviour by studying it from more than one standpoint (Cohen, Manion & Morrisson, 2011). Still, our findings tell only one version of the story, collated in retrospect and from a limited number of witnesses, and there may be many other ways to remember and interpret the process.

Focus group

The key participant in the focus group was Roland Larsson, who has witnessed and been instrumental in shaping the events described here. During the time period studied he was a faculty member, then vice Dean; this year he became the Dean. Other participants were authors Gedda and Wikberg Nilsson, and Edström facilitating the discussion. Gedda was the coordinator of one Arena, and Gedda and Wikberg-Nilsson are the creative team behind the Pedagogical Idea. Presently, Gedda leads a newly formed educational development unit, supporting the implementation of the Pedagogical Idea and the on-going CDIO project. Wikberg-Nilsson is Director of Studies in the Industrial Design Engineering program, part of the pilot project. The focus group was explorative in character and semi-structured around largely chronological prompts (Wibeck, 2000). As the facilitator was not part of the history of events at LTU, the level was set by the need for explaining to her, making the discussion more explicit and assumptions more openly scrutinised, than if all participants had been talking from a basis of shared experience. The discussion was allowed to continue until the participants found consensus in their interpretations, in total two hours. In the days following the conversation, the participants gathered complementary materials in the form of old emails and internal materials, for retrospective reflection. The focus group discussion was recorded and transcribed verbatim. The quotes in the following have been translated from Swedish and slightly edited for brevity.

Interviews and discussions

Interview discussions were held in different constellations over several months. First of all, we consulted with two key persons, Ann-Britt Almqvist and Erik Höglund, to solicit their memories and interpretations, and to test the validity of our tentative conclusions. These interviews were documented through written notes. The aim was to compare different memories and impressions, until sufficiently intersubjective interpretation was reached. We also tried to corroborate details with written documentation (e.g. emails, minutes from meetings, presentations, and strategy documents). Other more informal discussions involved the authors, who have been deeply involved in the different educational development projects described here.

Document studies

Data from the focus group, the interviews and the discussions were complemented by documents from 2004 to 2015. We have briefly probed how concepts of educational reform have been described in documents regulating activities at LTU, including meeting protocols, agendas and annual reports. A straightforward application of systematic content analysis (Hall and Wright, 2008) was used, where pre-selected terms related to educational reform were located in the texts.

USEFUL CONCEPTS AND THEORY

Change management

Much literature on organisational change suggests that a majority of initiatives fail to reach their set goals (e.g. Hughes, 2011). It is thus imperative to better understand how to improve success rate. Though numerous studies (see e.g. Durlak and DuPre, 2008), many aspects require further investigation (Harvey et al., 2011; Greenhalgh, 2004).

The three main motives for adopting CDIO are, according to Malmqvist et al. (2015), the ambition to make engineering education more authentic, the need for systematic methodologies for educational design, and the desire to include more design and innovation in curricula. Top success factors were that "CDIO is well aligned with the vision and strategy of our department/university", "University management strongly supported our CDIO implementation" and "The CDIO implementation was associated with higher ambitions for our education".

Hallencreutz and Turner (2011) pinpoint two beliefs about how organisational change occurs, basically a dichotomy of top-down vs. bottom-up: a) organisational change can be planned and managed through an understanding of a structured approach to transitioning built on a set of sequential steps, see e.g. Burnes (2009) and Lewin (1951), and b) organisational change is an emergent and organic learning process which cannot be managed, see for instance Burnes (1996, 2009).

Isomorphism and travelling ideas

DiMaggio and Powell (1983) explain how organisations of the same kind often adopt similar structures, behaviours, and values, calling the phenomenon *isomorphism*. Isomorphic forces may be related to legal environment, norms and values, and the role of professions and education. Of particular interest here is *mimetic isomorphism*, the imitation of other organisations perceived as successful and legitimate. The need to imitate increases with environmental uncertainty, vague relations between means and ends, and ambiguous goals.

Czarniawska and Joerges (1996) describe how ideas travel between organisations like fashions. Following fashions is a competition mechanism, at the same time conformist and creative. Sahlin and Wedlin (2008) describe how ideas and concepts are not just imported, but actively translated and edited into the organisation, evolving differently in different settings. They conclude: "*To imitate is not just to copy, but also to change and innovate.*" Stensaker (2007) points out that by taking up ideas and concepts organisations can innovate and become more effective. At the same time, the organisation must protect its activities from passing fads that will turn out to be useless or inefficient.

Reform as Routine

Brunsson (2009) notes that many organisations are under constant reform, driven by tensions between how the organisation is presented, i.e. how it should work, and the way it actually works. Reforms are basically efforts to apply solutions to problems, both of which are in rich supply. Since organisations are subject to conflicting demands, it may be "*impossible in practical terms to find any balance that could readily be regarded as the right one*". Therefore every solution "*is susceptible to criticism for failing to satisfy one or other – or both*

– *of the needs sufficiently*" (p.95). A reform furthering one side of such a balance may therefore soon create impetus for new reform in the other direction. It is easy to design reforms that are attractive in comparison to the current reality of the organisation: "*If we set a simple, clear, and good reform idea against our knowledge of the current situation with all its slack, ad hoc solutions; and its uncertainties, inconsistencies, conflicts, compromises, and complicated relationships, then there is a good chance that the new solution will appear better*" (p.97). Common sources of solutions are professional reformers, as well as other organisations (through mimetic isomorphism).

Alvesson and Sveningsson (2008) illustrate risks of repeated reform initiatives: "*Leaders often have unrealistic expectations and start too many projects, of which many are discontinued or failed. The result is often cynicism, a waste of time, institutionalisation of negative expectations and a 'wait-to-see-if-something-happens-thinking'. This makes it harder to implement change next time*." Alvesson and Sveningsson bluntly conclude that a good condition for making successful reform is to have fewer reform initiatives.

FINDINGS: PREVIOUS REFORM APPROACHES AT LTU

The Creative University concept

After 25 years as a technical college LTU became a university in 1997. Three years later the vision "*The Creative University*" was launched. It used the label "*Knowledge Building*" to denote a shift from teacher-centred to learner-centred education. Instead of traditional programs, education was to be organised in interdisciplinary areas, known as "*Arenas*". Each Arena offered a wide range of subjects that could lead to different degrees. Advised by faculty, individual students were to assemble their own education. The model was later modified, with coexisting Arenas and programs.

Early on, the concepts of Knowledge Building and Arena were contested within the university and, at times, the debate was intense and infected.

> "They went out to preach in the departments, met by people throwing things. It was a classic when someone said: 'If this is so damn good, why hasn't KTH done it before?'"

The Creative University was implemented top-down, i.e. the idea was created and decided in a management context. However, the handover to the teachers who were expected to implement it in a teaching context was weak. As the concept was based on principles of student-centred learning, it made high demands on educational knowledge and teaching skills among the university professionals.

> "The Creative University was a fun idea, but how do you go about it when no one has done it before? We stalled due to a lack of real direction, competence, and professionalism in the implementation. It was all based on enthusiasm. I myself remember giving project courses that were truly inadequate."

The legitimacy of the Creative University gradually lessened. Two surveys (Garvare, 2005; Garvare & Lovén, 2005) showed polarised views on the Arenas, with some representatives strongly in favour; others strongly dissatisfied. The concept and its Arena organisation were gradually phased out.

The Pedagogical Idea concept

A few years later, the faculty board felt a need to support cohesion and success in educational programs.

> "We needed to do something in the education. We asked: how do we create a concept and what is it that really characterizes our education?"

The decision was made to formulate a common pedagogical idea, communicating core values of teaching and learning for the whole university (including e.g. healthcare, art and teacher education). It should build on existing work, most notably a "Pedagogical Signum" developed for the engineering programs (Johnson et al., 2009) emphasising professional engineering practices and projects, and a pedagogical idea for flexible learning (Runardotter et al., 2011). The project leaders (Gedda and Wikberg-Nilsson) were to incorporate these into a unifying concept illustrating "the LTU way of learning".

The Pedagogical Idea formulated an overall objective of LTU's educational programs, to create *autonomous professionals* in their respective fields, emphasising a constructivist approach. During the development, a teacher said:

> "Teachers should motivate and help students in their learning. The teachers' skills are key for this to work well. Teachers are guides, while the students try and test their way themselves. The traditional approach with teachers transferring knowledge does not work."

Through workshops and other activities involving students and teachers, a model of student's learning path was described in the steps of (1) developing the identity of a *professional student*, learning how to approach and what to learn, (2) being *participant contributors*, taking responsibility for their own learning process with help of others, and (3) taking on the identity of *autonomous actors*, furthering the know-how of professional practice. This model can be compared to Alverno's idea of the learner, contributor, and performer (Riordan & Sharkey, 2010).

The Pedagogical Idea emphasizes an integrated student-centred learning role described through the concept of *commitment*, *perseverance* and *autonomy* (Wikberg Nilsson & Gedda, 2013). Each program ought to translate this vision into a strategy as guidance for decisions on purpose and content.

To support implementation, various materials were developed, e.g. guides for constructive alignment of programs (Wikberg Nilsson & Gedda, 2013) and guides for development of courses and teaching activities with a focus on student-centred learning (Gedda & Wikberg Nilsson, 2014). In 2013, it was decided to implement the Pedagogical Idea in all basic education. The experiences of the Creative University had revealed difficulties in introducing top-down pedagogical change (consistent with Gedda 2008, 2014). Therefore, the Pedagogical Idea was not to be implemented through putting pressure on individual teachers, but through creating a capacity for change within the organisation, by addressing micro-, meso- and macrolevel within the organisation.

FINDINGS: THE HISTORY OF CDIO AT LTU

The first official encounter with CDIO at LTU was in 2003, when the Royal Swedish Academy of Engineering Sciences arranged (in collaboration with KTH) a visit to MIT to learn about CDIO. LTU sent Lena Antti and Roland Larsson as delegates, both of whom were to later take on leadership positions. Larsson remembers that timing was poor:

> “When we went to MIT in 2003 we had been working on the Creative University for a couple of years. We were in the middle of these creative processes, and perhaps a little full of ourselves. We could still appreciate the systematic approach in CDIO, in particular the idea of progression. But it died out when we came home, and it never occurred to us that we could join the network. Also, back then I was just a normal faculty member without any formal role. I remember bringing up these ideas at the department in 2004, but nothing came of it. I had no mandate, no professionalism, I didn’t know what to do really, and no one to turn to.”

At this time it was not obvious that an institution could become CDIO collaborator. Ten years later the situation had changed so that a Swedish engineering institution could almost need a reason for not joining. At LTU, the gradual abandonment of the Creative University and the initial implementation of the Pedagogical Idea had brought about a much more favourable situation. Larsson was now the Vice Dean:

> “As a Vice Dean I was hungry for networking, for ideas. In April 2014, at the SEFI Dean’s Convention, I ran into CDIO implementers again. I thought: Let’s do it, let’s join CDIO! Now I could propose it, as my responsibility as Vice Dean was education. When I came back, we acted swiftly. A project leader was appointed, pilot programs selected, and by January 2015 we were CDIO Collaborators.”

Joining CDIO is a part of a general increase in attention for educational development among the middle level of leaders and teachers at the university.

> “We have done many things in the past few years: Pedagogical Idea, the Pedagogical Guide, the Centre for Teaching and Learning. It’s all connected and it feels like exponential growth.”

CDIO is seen to concern not only didactic and pedagogical aspects but also has the advantage to support the organisation in making priorities, with potential economic consequences:

> “Ten years ago our economic situation was bad. We had too few students and too many dropouts in the first year. There was a proliferation of courses, some 1500 different courses. We tried hard to reduce that number by 30 per cent, but the result was an *increase* with “only” a few per cent that year! This is another strength with CDIO. Now we are making it clear that the program is the starting-point, and program leadership is key in making priorities.”

CDIO can be seen as a method to support implementation of the Pedagogical Idea, however, they are not fully compatible. For instance, the system for yearly quality assessment of educational programs was based on the Pedagogical Idea. CDIO self-evaluations are partly overlapping, and can thus be seen as an addition to the administrative work. Further, while the Pedagogical Idea was influenced by CDIO and the concepts are considered to be essentially compatible, there are still accommodations to be made:

> “In CDIO there is Active Learning, but it is seen in a program perspective. The Pedagogical Idea has a student perspective, the Active Student. We had to merge these views.”

Finally, we saw clear signs that the organisation has experienced so many attempts at reform, that there is a certain weariness, and a mistrust that new initiatives are seriously meant. People protect themselves, or the education, against unnecessary disruptions. The result is a dampening filter, affecting future attempts at reform:

> “Some of the most engaged people hesitated over the Pedagogical Idea, unsure if the management would really go through with it. It was wait-and-see. They like the idea, they identify themselves as innovators, but they doubt it will be implemented. Some had burnt themselves on the Creative University. Many had invested heavily, both in terms of work and of open commitment. Then when it becomes a bad word, that hurts.”

ANALYSIS AND DISCUSSION

Comparing the concepts

In the above, we have investigated the history leading to the eventual adoption of CDIO at LTU. Thus prepared, we will now compare the different reform concepts, the Arena concept, the Pedagogical Idea, and CDIO.

The alignment to the ways of working

The overall vision of CDIO has resonated with engineering faculty at LTU. Further, the CDIO approach is aligned with the present way education is organised at LTU. Hence, instead of implying a disruptive threat to the existence of programs like the Arena concept did, CDIO reinforces the current program structure without fundamentally challenging the disciplines (Edström & Kolmos, 2014). Nevertheless, when aiming to strengthen the programs, CDIO can also become a challenge to existing power bases, e.g. the central administration and its preference for standardisation, and individual faculty or research groups who feel ownership of a course. The Pedagogical Idea can here be seen as a combining or bridging concept, retaining some values of the "Creative university", e.g. the student perspective, while also aligning closely to the program perspective of CDIO, whose integrated curriculum promotes the development of personal, interpersonal and professional competence.

The models of intervention

The Creative University was largely created on the top management level and its implementation focused mainly on individual teachers. It could be argued that implementing the concept was a high-risk venture, as the university went *all in*, switching to a radically different model for organising education. Complexity was high, and so were demands on faculty and administration. This is in contrast to CDIO, starting as a pilot project involving only four programs whose participation was voluntary. Further, each program can select and prioritise what aspects it wants to develop, and everything can be customised, as CDIO is characterised by an open source approach. Both CDIO and the Pedagogical Idea take a more operative perspective, focusing on the programs and courses, and trying to strengthen meso-level structures such as program leadership and the educational development unit at the university.

The framework of the Pedagogical Idea does not stipulate a specific development. Instead, each educational program is asked to initially define its own specific objectives. However, this has created some uncertainty around program objectives and the link between the education and the professional practice. Within LTU's engineering program, this uncertainty of the Pedagogical Idea seems to have given the prescriptive and action-oriented methodology of CDIO considerable appeal.

The change strategies

The Creative University was implemented in what could be considered a top-down approach, conceived mainly on management levels and then communicated to departments and teachers. While there was certainly much enthusiasm, there was also resistance and conflict. In retrospect, it seems that the concept had vague relations between means and ends, and it raised questions among the teachers. Although many questions were fully legitimate they could sometimes be interpreted as covert resistance, provoking persuasion rather than dialogue. This can be compared to the more emergent, guided and incremental implementations of both the Pedagogical Idea and CDIO.

The environment

LTU went its own way with the Creative University as it was developed in-house. We think this might be an expression of a young university in search for its own identity; LTU wanted to build something new and unique. But with the Arena concept, LTU had no obvious role models among other universities, and no clear proof-of-concept elsewhere. Our findings suggest that this created three obstacles: (1) it was difficult to imagine the vision and (2) even harder to know how to get there, and (3) it also weakened the internal legitimacy. It was also an important factor that the Arenas collided head-on with the deep-rooted tradition of how the educational programs were organised. The Pedagogical Idea was also developed in-house, but in addition to incorporating ideas and strengths emergent from the organisation, it drew on models and successful concepts in the environment. By the time that LTU joined CDIO, it was widely known in the engineering education community, and implementers included high-status organisations.

CONCLUSIONS

We will now venture an answer to our initial question, why it came that LTU joined CDIO in 2015, and not earlier. In 2003 when LTU representatives first encountered CDIO, the full attention of the university was on the Creative University, which challenged fundamentally the programme structure. As CDIO is an approach to strengthen the program, it did not immediately appear as useful. LTU made no serious evaluation of CDIO and there was no proposal to join. The Creative University aimed at the level of individual student learning, while CDIO has a strong program improvement perspective and therefore may have been seen as irrelevant.

Ten years later, there was an advocate in a leadership position, with a mandate to take initiatives in relation to educational reform. Also, CDIO had changed and was now a large community. In the light of the experience with the Creative University, and with the on-going implementation of Pedagogical Idea, some of the characteristics of CDIO appeared as particularly attractive. In this case, LTUs current pedagogical initiative builds on former reforms, but has gained strength and structure from the CDIO approach. As Sahlin and Wedlin (2008) conclude; “to imitate is not just to copy, but also to change and innovate”.

The transmission of an initiative and how it is communicated, supported, and performed in another practice is identified as a critical aspect of the diffusion of innovations in higher education. The Creative University emerged from a group of 30 people, with support of the vice chancellor. Despite this fairly wide representation in the idea generation group, the implementation came to be seen as top-down. In contrast, the Pedagogical Idea and the CDIO approach build on faculty initiatives coordinated on the program level, which can be seen as a combination of top-down and bottom-up strategy.

After long periods of mainly internal development, the CDIO national and international community with access to networking with peers were seen as particularly attractive features. Here, mimetic isomorphism (DiMaggio & Powell, 1983) may have been a driving force. Also, the CDIO vision resonated with the existing culture of LTU education, and the roadmap for implementation felt clear while not overly prescriptive. In Brunsson's (2009) words, CDIO now appeared as a "*simple, clear, and good reform idea*", and as a framework that is compatible with the current Pedagogical Idea.

To conclude, this paper may contribute towards a better understanding of the potential in combining development strategies, if they are aligned and mutually reinforcing, and united by a common vision. The LTU Pedagogical idea is an attempt to build on former concepts and build a university-embracing pedagogical initiative. CDIO served as inspiration, being perceived as a successful and legitimate educational improvement concept. The findings presented here may also have implications for CDIO as, besides engineering, the LTU case indicates a wider applicability of the CDIO approach.

Finally, we want to point out that a university clearly has a limited capacity for reform. The available attention and resources are easily flooded with interrupts such as evaluations, new policy deployment and national reforms. Thus, the remaining capacity for development that the university itself has discretion over should be used very wisely.

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DESIGN AND INNOVATION OF PHYSICS EXPERIMENT BASED ON CDIO MODEL

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ABSTRACT

For undergraduate students, the course of Physics Experiment (PE) introduces the general knowledge of laboratory research and experimental skills about science and engineering. Through the course, students can learn the principles about college physics and practice their scientific thinking and skills. By implementing CDIO engineering education model, PE teaching model is innovated in aspects of curriculum design, teaching method and outcome assessment. The 7th and 8th CDIO standards are enhanced in this CDIO practical course [1].

We proposed an ability-oriented teaching pattern for PE. We construct four-level experimental projects, including elementary physics experiment, knowledge application experiment, system design experiment and innovation experiment, which are responsible for the training of students' experimental skills, laboratory research methods, scientific thinking and creative abilities respectively. We adopted CDIO engineering education innovation during the teaching process of PE to achieve these goals. In the course, students carry an active learning by following Concept, Design, Implement and Operate for every experimental project. The process evaluations are used to assess the outcomes of knowledge and abilities of students. The assessments from students and teachers of following professional courses are used to investigate the teaching results of PE.

In this paper, we present the objectives, contents, innovative design, implementation process, as well as the results achieved after reform in PE course teaching. The learning outcomes are verified from student’s surveys.

KEYWORDS

Physics experiment, Curriculum innovation, CDIO engineering education, Ability cultivation, Standards: 7, 8.

INTRODUCTION

Since 2009, CDIO engineering education mode has been introduced into our university. A series of reform in engineering education have been carried on, which emphasizes the cultivation of students' practical ability. As an elementary engineering course, PE course provides a platform that can effectively exercise the students' practical ability. Therefore, how to well combine PE teaching with engineering education, and give full play to the role of PE course in the cultivation of students' practical ability, is an urgent problem to be solved in our university.

Motivated by the concept of CDIO engineering education and the teaching method of Concept-Design-Implement-Operate(C-D-I-O)[2], a comprehensive construction and teaching reform of PE is being implemented in our university. We have innovated PE teaching model on curriculum design, teaching method and outcome assessment. We have proposed an ability-oriented teaching pattern for PE, and teaching practice is carried in the PE course.

In this paper, we present PE teaching system of students' ability-oriented cultivation and the innovate teaching pattern with doing C-D-I-O by students in details. We also present the objectives, contents, innovative design, implementation process, and the outcomes of students' and teachers' surveys achieved after reform.

ABILITY-ORIENTED TEACHING SYSTEM OF PE CURRICULUM

The curriculum of PE is the elementary class for introduction of laboratory research method and experimental skills for undergraduate students in the major of science and engineering. Through the course, students can learn the principles about college physics and practice their scientific thinking and skills. At the beginning of the PE reform, we firstly constructed a specific teaching goal about ability-cultivation for the course, which refer to experimental method and skill, scientific thinking and innovation consciousness and ability.

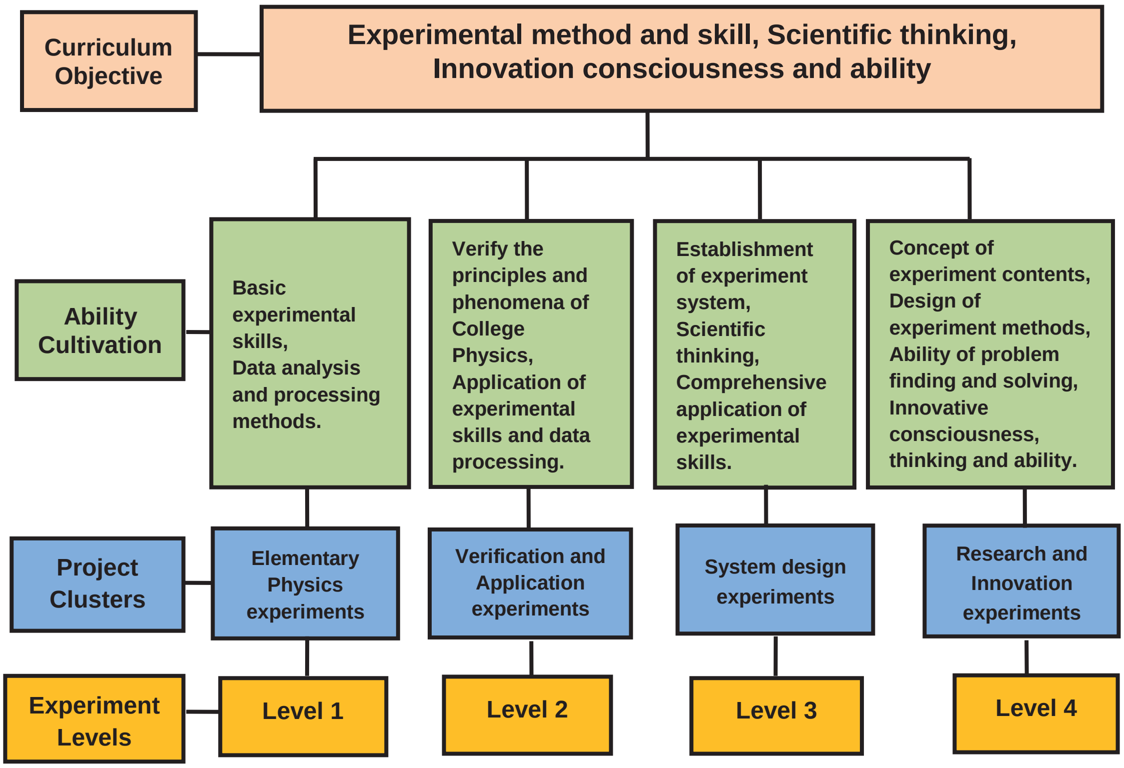

Figure 1. The framework of PE teaching system

Guided by the goal, we rebuilt the PE teaching system as shown as Figure 1. In the teaching system, there are more than forty experiments engaged into the contents of Mechanics, Thermotics, Electromagnetics, Optics and Modern physics. Some related technology and its application are added into the experiments too. The PE experiments are divided into 4 levels in the system and every level includes several projects called project cluster. The first level of project cluster is consisting of elementary experiments, in which students can practice their ability of basic experimental skills and data analysis and processing methods. The second level is the knowledge verification and application experiments, in which students can verify the principles of College Physics and apply the theories into explaining the experiments and builting the experimental methods. The third level is the system design experiments, in which students promote their ability of experiment system establishment, scientific thinking and comprehensive application of experimental skills. The fourth level is the research and innovation experiments, in which students can learn the skill of experiment contents, experiment design methods, problem finding and solving, innovative consciousness, thinking and ability. When students completed the four-level project clusters, curriculum objects of PE are achieved.

In order to achieve the goals of PE, we built the course standards according to the CDIO syllabus by designing three-level abilities, as shown in Table 1.

Table 1.The standards of PE course

First-level Standards	**Second- level Standards**	**Third- level Standards**
1 Technical knowledge and reasoning	1.1 Basic knowledge of Physics	1.1.1 Basic theoretical of physics
		1.1.2 Basic experimental research methods and skills
	1.2 Physical application of core engineering knowledge	1.2.1 Physics basis of application
		1.2.2 Conception and method of engineering application
2 Personal ability, professional ability and attitude	2.1 Ability of logical reasoning and problem solving	2.1.1 Discover and express physical or scientific problems
		2.1.2 Define concept, discover law and establish physical model
		2.1.3 Qualitative analysis and quantitative calculation
	2.2 Experiment and knowledge discovery	2.2.1 Problems discovery in experimental research
		2.2.2 Establish experimental exploration methods and skills
		2.2.3 Analysis and comparison of experimental results
	2.3 Personal ability and attitude	2.3.1 Logical thinking, innovative consciousness, thinking and ability
		2.3.2 Active learning
		2.3.3 Self-taught and lifelong learning
3 Interpersonal skills: team work and communication	3.1 Ability of Communication	3.1.1 Ability of expressing engineering and scientific problems
		3.1.2 Ability of teamwork cooperation

INNOVATIONOFPE TEACHINGPATTERN

Based on the ability-oriented system of PE, we carried on a reform of teaching mode in PE course. We renewed the teaching concepts, methods and assessments by using the concept of CDIO engineering education and the teaching method of Concept-Design-Implement-Operate(C-D-I-O).

In the teaching pattern, teacher is responsible for the planning and supervising for PE project, while the students are asked to dominant the whole project. Before PE class, the teachers need to plan the objects and standards of experiment project, and design the main stages of experiment. The students should make the preparation for the experiment, understand the experiment plan and write a preparation report. During the PE class, the teacher explains the plan with students and helps them to do experiment. The students set up the experiment system and complete the experiment independently according to their own plan, then show experiment results to teacher. After PE class, the students would write the report of the project according to their own experiment process, and do the data processing and result analysis. The teaching make the assess for the report and the student's skill and ability. Thus, Project based learning are used in the teaching process of PE[4-5]. In each project, students can experience the whole process of C-D-I-O, and their skills and abilities can be trained continuously during the active learning.

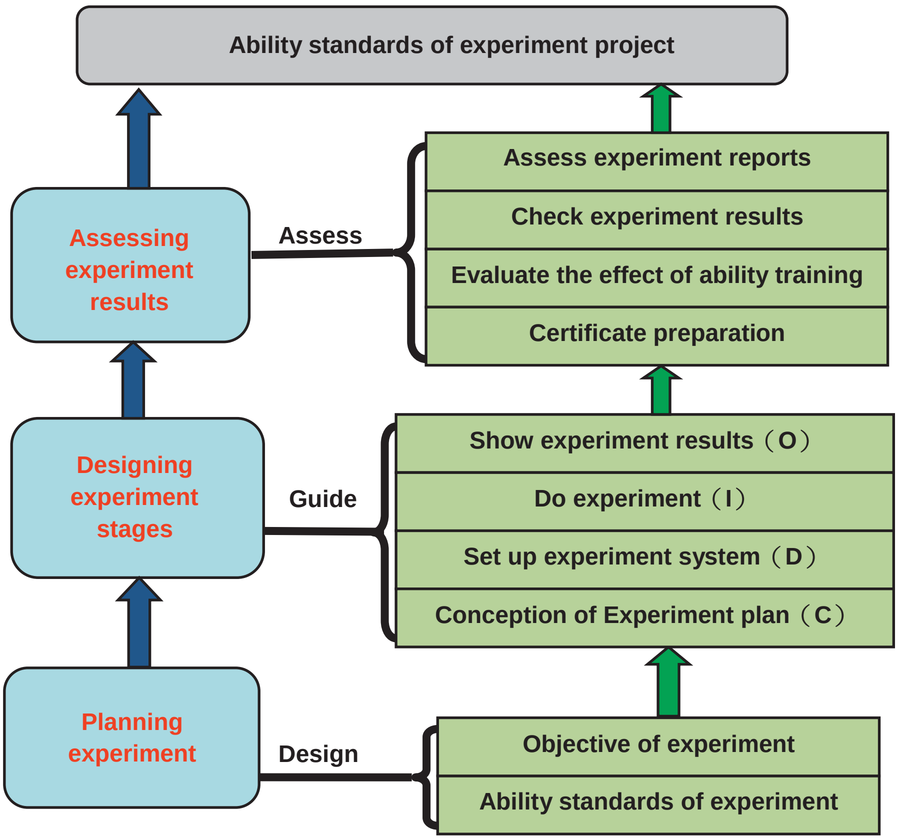

Figure 2. Teaching pattern of PE experiment project

TEACHINGPRACTICE OF PE COURSE

In order to achieve the goals of PE and work on the new teaching pattern, the ability cultivation is set for every experiment, which is called the project syllabus. CDIO stages are designed for every experiment. In every stage, several main tasks are designed, and the weighting of stage in the assessment and the related assessing standards are set according to the needs of experiment. All PE teachers are asked to implement the teaching program of project strictly during the classes. All PE students must do all the jobs designed in the program.

Table 2. Teaching plan of RLMO experiment project

CDIO Stages	Tasks	Weight-ing	Assessing Standards	Project Syllabus	Third-level Standards of PE course
Conception of experiment	Preview(Done before class): 1) Theoretical knowledge of Kinematics. 2) Measurement principle and method of velocity and acceleration.	20%	Sufficient and detailed experiment preview report	1)Survey of print and electronic literature 2)Comprehensive knowledge application	1.2.1 Physical basis of practical application
Design of experiment	Designing and Presentation: 1) How to measure velocity and acceleration according to experiment condition. 2) Experiment steps. 3) Experiment parameters.	10%	Reliability and rationality of designed process	3)Experimental inquiry 4)Oral presentation	2.1.1 Discover and express physical or scientific problems
Implement of experiment	Operating: 1) Learn operation methods of the instruments. 2) Measure velocity and acceleration according to the designed process.	30%	Operation ability of instruments and measurement results of velocity and acceleration	5)Design of experimental process	1.2.2 Conception and method of engineering application
				6)Experimental operation	1.1.2 Basic experimental research methods and skills
				7)Projects implement	2.2.2 Establish experimental exploration methods and skills
Operation of experiment	Demonstrating : 1) Design one experiment: project of kinematics individually 2) Finish the above experiment project process successively and independently.	20%	Quality of designed project and experiment demonstration	8) Logical thinking 9) Self learning	2.3.1 Logical thinking, innovative consciousness, thinking and ability 2.3.2 Active learning
Summary of experiment	Analyzing and Summarizing: 1) Obtain results based on the Arrangement and process of experimental data. 2) Analyze the experimental error and influence factors. 3) Improved experimental method and process. 4) Detailed experimental report.	20%	Validity of data handling and analysis, Quality of team report	10)Data handling and Analysis 11)Written Communication	2.1.3 Qualitative analysis and quantitative calculation. 2.2.3 Analysis and comparison of experimental results

For example, there is a PE project named Research on the Law of Motion of Objects (RLMO). Its teaching plan is shown in Table 2.As we can see, students can have their own ideas and experimental design in every stage so long as they are able to complete the relevant task. When they do the experiment stage by stage, they will experience an active learning process of C-D-I-O. During the experimental process, teachers will give evaluation and score for students' experiment skills and outcomes in real time. A set of pictures during the RLMO PE course are shown in Figure 3.

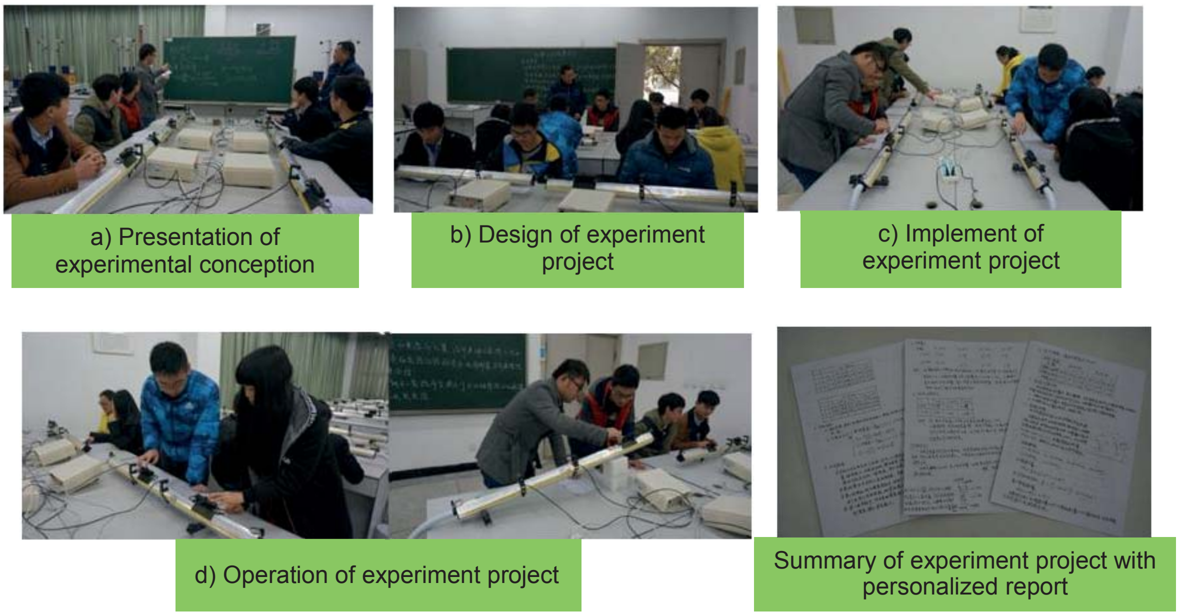

Figure 3. Active Learning in RLMOPE course

STUDENTS' AND TEACHERS' SURVEY AND FEEDBACK

In the past three years, we have introduced the reform and innovation PE course for all science and engineering students of grade 2012-2014 in our university. In order to investigate the effect of PE reform, a survey was used for the students involved in PE course, which included 9 questions as shown in Table 3. The other two surveys were used for the teachers involved in PE and professional experiment courses respectively, as shown in Table 4. The survey was conducted in the college of optoelectronic technology, and the resulting distribution chart is shown in Figure 4 and 5.

Table 3. Questionnaire survey for students

Numbers	Questions
1	Do you like the current PE teaching method?
2	Do you think the PE course can help you to understand the theories of Physics?
3	Do you think the "Conceive - design - implement - operation" process is helpful to carry the active learning in experiment projects?
4	Do you preview the Physics principles and conceive the experiment contents before PE class?

5	Do you design the experiment method and scheme according to the experiment content at the beginning of the PE course?
6	Do you carry the experiment and obtain experiment results independently during PE course?
7	Are you satisfied with your experiment process and reports after PE course?
8	Do you think the PE teaching method can train your brain and abilities effectively?
9	Do you think the PE teaching method can give you sufficient self-display space?
Answer options for the questions	A. Yes B. Noncommittal C. No

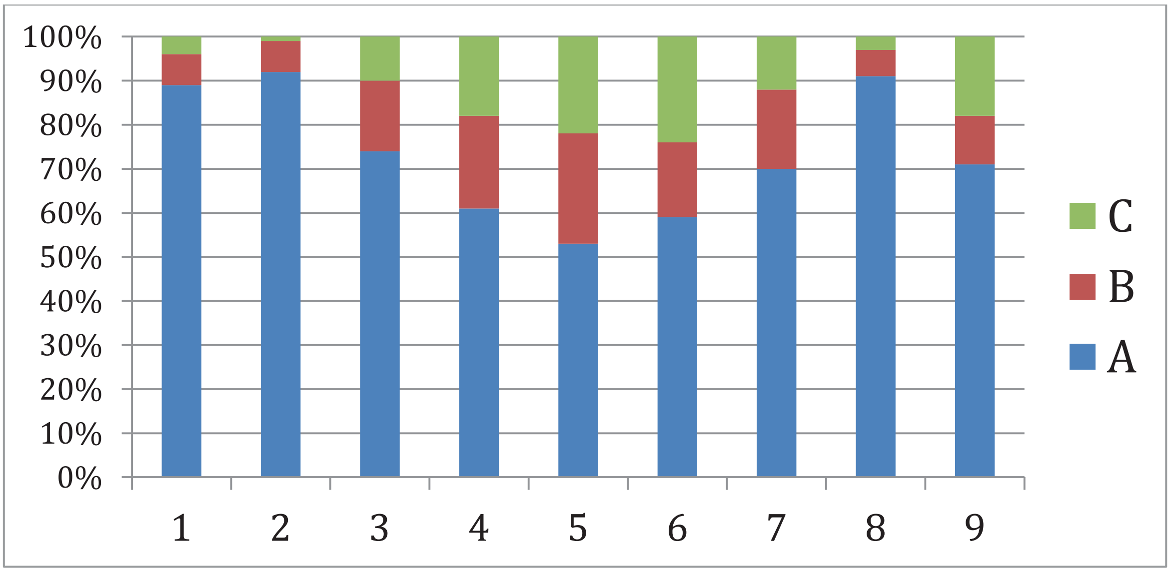

Figure 4. Result of students' survey

For students' survey, it was conducted in around 500 students of different grade. The result indicates that most of students have considered the PE teaching model is good and is helpful to train their abilities. More than half of students have had active learning during the process of PE course.

Table 4. Questionnaire survey for teachers

Numbers	Teacher type	Questions
1	Teachers involved in PE course	How do you think of the current PE teaching mode?
2		Do you think the PE teaching mode can train students' brain and abilities effectively?
3		Do you think the PE teaching mode can achieve the goal of the PE course better?
4		Do you think the PE teaching mode can increase the students' interest in PE course?

5	Teachers involved in professional experiment courses	Do you think the students in Grade 2012-2014 have more enthusiasm in the professional experiment class?
6		Do you think the students in Grade 2012-2014 show better scientific thinking abilities in the professional experiment class?
7		Do you think the students in Grade 2012-2014 show better experiment skills in the professional experiment class?
Answer options for the questions	A. Yes B. Noncommittal C. No	

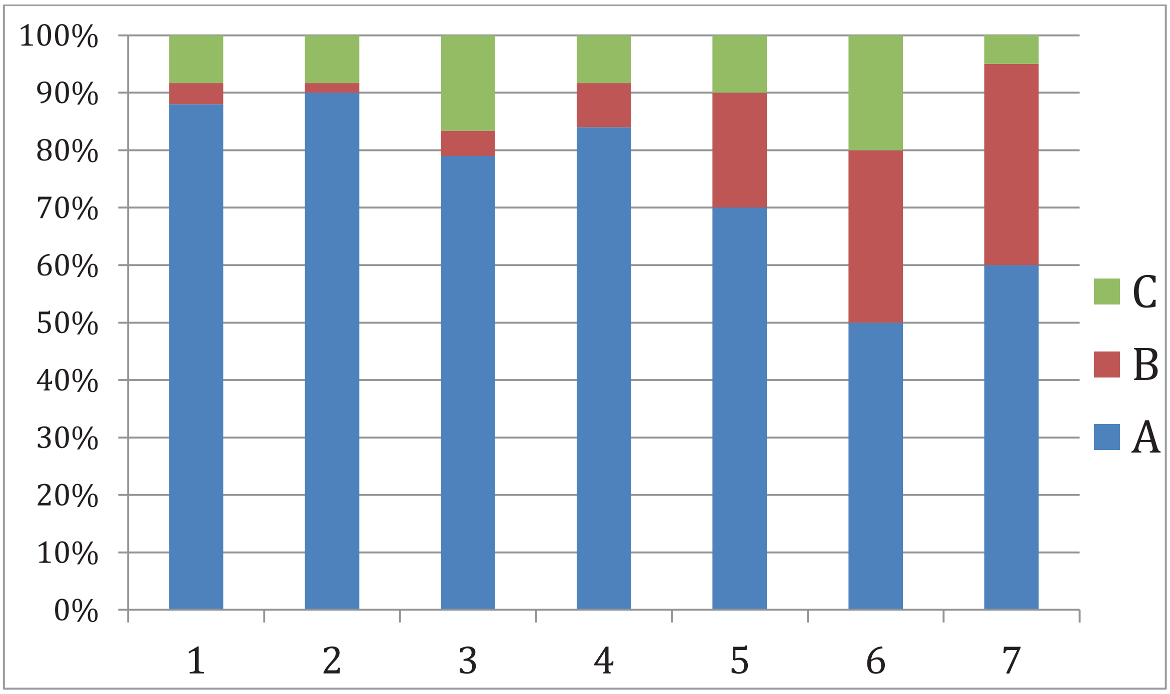

Figure 5. Result of teachers' survey

For teachers' survey, it was conducted in 15 teachers involved in PE course and 20 teachers involved in professional experiment courses. The result indicates that the involved teachers have positive attitude to the innovation of PE course. The PE teachers consider the PE teaching mode can train students' brain and abilities effectively and achieve the goal of the PE course better. More than half of the teachers of professional experiment courses consider the students who were taught with new PE teaching mode have better scientific thinking abilities and experiment skills than the students who were not.

RESULTS

Combined with conception and method of CDIO engineering education, we have innovated PE teaching model on curriculum design, teaching method and outcome assessment. An ability-oriented teaching pattern for PE course is proposed, and four-level projects are constructed, which are elementary physics experiment, knowledge application experiment, system design experiment and innovation experiment, which are responsible for the training of students' experimental skills, laboratory research methods, scientific thinking and creative abilities respectively. In the PE course, students carry an active learning by doing Concept, Design, Implement and Operate for every experimental project, and the process evaluations are used to assess the outcomes of knowledge and abilities of students. The surveys for students and teachers indicate that the students and teachers have positive attitudes to the reform of PE course. More than half of PE students have had active learning during the process of PE course. Most of the teachers consider the students have better experiment skills and abilities after the innovation of PE course. Therefore, the 7th and 8th CDIO standards are enhanced in this CDIO practical course.

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BIOGRAPHICAL INFORMATION

Min Chen is a Professor in Material Science and a teacher in the Department of Optoelectronic Technology at Chengdu University of Information Technology. She works on topics related to engineering education reform in the department, and focuses on the curriculum design and the improvement of teaching in recent years. She is also the education administrant of Chengdu University of Information Technology. Her current research focuses on implementing of CDIO engineering education model in the University.

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"ENGINEERING DESIGN" COURSE TRANSFORMATION: FROM A CONCEIVE - DESIGN TOWARDS A COMPLETE CDIO APPROACH

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ABSTRACT

"Engineering Design" is a discipline aimed at improving our understanding about the development processes of novel and successful products, processes and systems in general, and at providing engineers with methodical steps for enhancing such processes. It may well be the engineering discipline more linked to the CDIO approach and to the conceive-design-implement-operate process. The benefits of applying "Engineering Design" principles are better appreciated when facing the development of complex systems. In the field of Mechanical Engineering some of the more complex systems an engineer can develop are advanced mechanical systems and machines.

In this study we present the transformation process of an "Engineering Design" course, carried out in parallel to the implementation of the new Master's Degree in Industrial Engineering at ETSII – TU Madrid. In the old Industrial Engineering plan of studies, implemented in 2000, the "Engineering Design" course was taught in the 5th academic year for Industrial Engineering students specializing in Mechanical Engineering and lasted for one semester. In the new Master's Degree in Industrial Engineering, which started in 2014-2015, the "Engineering Design" course is taught in the framework of a School-level project-based learning initiative and can be chosen by students from all Industrial Engineering specializations. The new subject lasts for two semesters and it is taught, in the 1st academic year of the Master's Degree, to students having finished a four-year Bachelor's Degree in Industrial Technologies. When transforming the course, our first aim was to let students live through a complete CDIO process, as having a two-semester structure gave us additional time for reaching the implementation and operation stages. With the old one-semester structure they could just focus on the conceptual and design phases. With the new approach their experience is more complete but several challenges arise, which are systematically analyzed in the following pages. A comparative study, taking account of the opinions of students and teachers is also presented and helps to support the benefits from complete CDIO experiences. Key aspects, including: student motivation, coordination between teachers, supervision of the projects under a tight schedule, rapid prototyping resources for reaching the implementation and operation stages, among others, are discussed and the more relevant lessons learned and proposals for improvement are put forward.

To our knowledge it constitutes the first subject following a complete CDIO cycle in the field of Engineering Design applied to machines engineering in our country.

KEYWORDS

CDIO as Context, Integrated Curriculum, Integrated Learning Experiences, Active Learning, Engineering Design, Mechanical Systems, Machines Engineering.
(Standards: 1, 3, 5, 7, 8).

INTRODUCTION. THE EVOLUTION OF THE SUBJECT FROM A CONCEIVE-DESIGN TO A COMPLETE CDIO APPROACH.

"Engineering Design" course is being taught at the UPM Mechanical Engineering Department in the TU Madrid School of Industrial Engineering since the 2004-2005 academic year (Munoz-Guijosa et al., 2011). From its conception, in the framework of the Bologna curriculum philosophy, it was designed as a Project-Based, 6 ECTS, 5th year capstone course, in which students integrate the knowledges already learned and also develop professional skills (Díaz Lantada et al., 2013), (Schuman et al., 2005). Until 2014, students were instructed to perform the first development stages –product planning, concept design, basic and detail engineering- of a product selected by themselves. Deliverables included market study, patent analysis, business plan, technical drawings, assembly procedure, customer information, maintenance plan, risk analysis and a report in which students should also demonstrate the application of different design rules as safety, clarity, recyclability or aesthetics.

In 2014, the "Ingenia" initiative was launched at the School of Industrial Engineering (Hernández Bayo et al., 2014), through which the 1st year Master students must dedicate 12 ECTS to the complete execution of an engineering project in a CDIO-based course. 5-hour classes are taught every Monday. Nine courses were offered to the students in this initiative in the 2014-2015 academic year. In present year, students could select one out of eleven "Ingenia" subjects. Table 1 shows the subjects participating in the initiative.

As the course length is doubled, the inclusion of "Engineering Design" in the "Ingenia" initiative has permitted us to extend the scope of the development up to the prototype manufacturing and testing, in a complete CDIO experience (Chacón et al., 2015), (Crawley et al., 2007). We have also had the opportunity of sharing experiences and knowledges with our colleagues in other "Ingenia" subjects for continuous improvement, as well as dedicating a subject-specific budget for the execution. Presently, the "Engineering Design" course is the third most selected by students.

Table 1. Available "Ingenia" courses in the 2015-2016 academic year

Structural optimization based on modal analysis-adjusted FEM models
Industrial plant projects development and management
Bioengineering
Engineering Design
Automotive Engineering: Formula SAE
Products for everyday life
Systems engineering
Videogames design
The School of the future - Smart ETSII
Electrical systems design ("Ingeniando" un sistema eléctrico)

At the course beginning, students form 6-people teams, and think about different products to propose to the class. A product proposals presentation is carried out during the third week, in which students must convince their colleagues about each proposal benefits and novelty. A voting is then carried out, in which three to six products are selected for the development during the rest of the course. During the conceive stage, students study the potential market, comparable products functionalities and prices and existing patents. They also design and execute surveys through which more than 100 people is asked about desired functionalities. As a result, they design a product definition and a business plan which must guarantee an internal return rate greater than 20%. During the design stage, students create different concept alternatives, and select the most promising ones for the basic and detailed design stage, in which they design or specify the necessary components. In the implementation stage, during which students manufacture a complete, functional mechatronic prototype, they must source commercial parts from different international suppliers, dealing with price negotiations and billing and logistics management, as well as manufacture the specific parts, for a subsequent integration and assembly. In the operation stage, they create and execute a testing plan, redesigning the product if some test is not passed. Packaging and advertising must also be designed and executed. Finally, students must prepare a multimedia presentation for a specific Ingenia event. As sustainability is one of the most important drivers on the engineering education philosophy of our School, it is considered during the whole development experience, not only at product level, but also regarding the complete lifecycle and involved socioeconomic agents.

Figure *1* shows the course planning. Despite we try to maximize the time students devote to the product manufacturing and testing, product planning and design, CAE, theoretical and specialized classes, as well as evaluation must also be performed. We consider the credit distribution showed in the figure as a good balance between all the course activities.

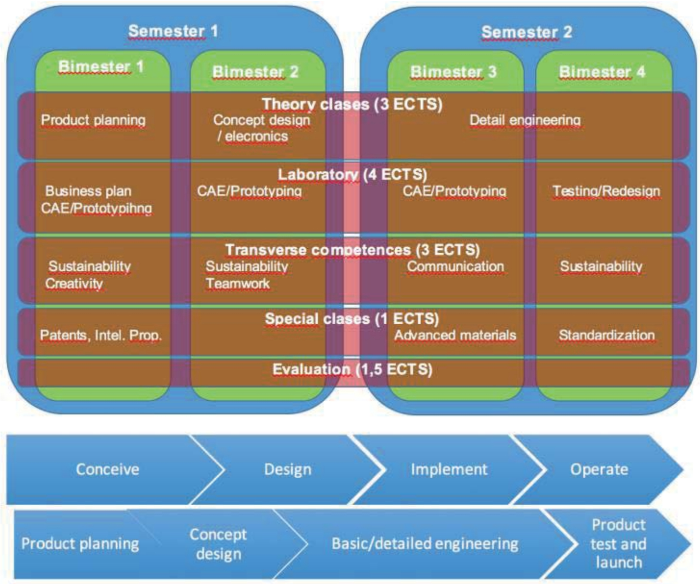

Figure 1. Course planning

CRITICAL ISSUES IN THE IMPLEMENTING OF THE COMPLETE CDIO APPROACH.

In the one and a half courses we have already lived in the “Ingenia” experience we have had opportunities of talking with colleagues and teachers of other “Ingenia” subjects, students and other focus groups, as well as thinking about the course performance. This has allowed us to detect some factors that have to be carefully considered when planning and executing it. We hope these thoughts can be useful to other colleagues involved in the design and execution of CDIO-based courses.

Laboratory, creativity, IT and other resources

A strong laboratory and IT capacity is needed (Table *2*) in order to fulfill the requirements arising in every project phase, but specially during the implement and operate stages. During the conceive stage, students must gather a vast amount of information related to the novelty of each product proposal, the state of the art, comparable products –including their specifications, prices and sales volumes-, potential market and market segmentation. This includes the use of patent and article databases and statistical modelling programs for the analysis of the surveys results. The business plan design involves the use of Montecarlo simulators for financial risk analysis. Likewise, the use of creativity tools during the concept design stage implies the need of brainstorming materials, solid modelling systems and rapid prototyping tools for students anytime along the whole day schedule. In the develop stage, mechanical and thermal FEM calculations are to be performed, which implies the use of CAE systems with those capabilities. Electronics development tools are also needed for the design of the product control and monitoring systems. For all the above tasks, we have configured an IT room with 15 computers managed by our IT technician, which is open from 9:00 to 18:00 every weekday. During the implement stage, harder laboratory resources, as lathe, mill or drill machining, solvents, resins and other dangerous products or processes handling, or the use of sensitive laboratory equipment -we will additionally use autoclave and other composite manufacturing tools next year-makes the contribution of professors and specialized laboratory personnel necessary. Finally, testing and data acquisition and analysis systems are required during the operate stage. Students must perform static and dynamic mechanical and thermal tests and measure the product response, as well as product fatigue performance. For accomplishing this, testing equipment and materials as traction-compression devices, fatigue bench, accelerometer, modal hammer, thermography camera, thermocouple, strain gauges are available, along with a data acquisition system and data analysis tools. Once again, the participation of professors or laboratory personnel is needed in order to guarantee the system integrity and adequate operational results. We have also reserved a workshop-type room so that students can work during the concept design and basic engineering.

Financing

A financial support must be available not only for the course preparation, but also for a long term subject sustainability. We take advantage of different assets already available at the machinery engineering division at UPM, used for different research projects and industry consulting works. An initial amount of approximately 4000€ was employed for the acquisition of the fixed assets that were not available at the laboratory. A yearly amount of approximately 4000€ is needed for the maintenance of the CAE licenses, as well as the purchase of the fungible materials for the year products. A substantial part of this amount is financed by the “School Friends Society”, which encompasses different companies where alumnae hold relevant positions. The maintenance of other computer programs and databases is held by the University or the Machine Engineering Teaching Group.

It is straightforward to think in a possible resource sharing between the different departments involved in this CDIO initiative. However, this may not be a working idea, taking into account the total amount of students involved in the course, about 250, which is hardly compatible with the normal department activities, personnel and workload. Specific collaborations are however kindly carried out when highly specialized problems appear during the development.

We are evaluating the use of sponsoring as an additional financing alternative, in the same fashion as the management of the industrial chairs and sponsored rooms. Despite its many advantages –for instance, not only financing is obtained, but also long term relationships with employers and technology transfer activities and research topics creators-, care must be taken for avoiding the possible reduction in the range of products which could be developed during the course because of restrictions established by the sponsors.

Assistant students

As in the prior, CD based course students did not value extra, out of class guidance, additional support is very well welcomed by the students in the IO stages our new subject includes. From our experience in other project-based subjects as “Machinery Elements Design II”, we are aware of the added value assistant students give to the class and out of it. We select one or two students for each academic course. They are selected from the prior course, so they have already lived the whole development process. Consequently, they know where the critical points are and help students in overcoming them. Furthermore, they establish a close relationship with the students and gather valuable information about the team evolution, conflicts and specialized learning needs. Students are prone to integrate them in the social networks and webtools (mainly WhatsApp, Dropbox, Google Drive and Google Calendar) they create for the subject, so information about potential needs can be processed in advance. As a selection criterion, we overestimate the electronics design application knowledge, provided that this is the area where mechanical engineering students have normally less experience. The assistant students normally take part in a special, school level program for earning up to three free configuration credits, and have a small economic reward financed by our group.

Table 2. Assets and fungible materials needed for the course

		Item	Financed by
Assets	Fixed	Laser stereolithography system	Other projects
		Vacuum casting system	Other projects
		Oven	Other projects
		Composite autoclave	Other projects
		Composite vacuum system	Other projects
		Lathe, mill, drill	Other projects
		Welding system	Other projects
		Traction-compression machine	Other projects
		3D microscope	Other projects
		Sound power and intensity meter	Other projects
		Termography camera	Other projects
		Accelerometers	Other projects
		Modal hammer	Other projects
		Data acquisition system	Other projects
		Hand tools	Other projects
		3D Printers	UPM-Ingenia
		3D scanner	UPM-Ingenia
		Power sources	UPM-Ingenia
		USB oscilloscopes	UPM-Ingenia
		Mini fatigue machine	Other projects
		Multimeters	UPM-Ingenia

		Item	Financed by
Assets	Current	Catia	DIM
		Unigraphics	DIM
		Solid Edge	Student version
		Matlab	UPM
		SPSS	UPM
		Crystal Ball	DIM
		Journal suscriptions	UPM
		Computers maintenance	DIM
		Electronic development platforms	DIM
		DC motors	UPM

	Item	Financed by
Fungible materials	Resins	UPM-Ingenia
	Photopolymerizable resin	DIM
	Silicons for vacuum casting	DIM
	PLA and other plastics for 3D printers	UPM
	Strain gauges	DIM
	Electronics materials (displays, switches, LEDs, sensors, buzzers, servomotors, diodes, resistors, coils…)	UPM-Ingenia
	Electric materials	UPM-Ingenia
	Cardboard	UPM-Ingenia
	PC or metacrylate panels	UPM-Ingenia
	Product specific fungibles	UPM-Ingenia
	Hardware (screws, nuts, flanges, bars, cables, gears,…)	UPM-Ingenia
	Glass, carbon fiber	DIM

Skills evaluation system

In the prior CD course, limited to the detailed planning and design of a novel product, evaluation was done with respect to technical criteria, as well as creativity and communication competences. As in the present CDIO course students have the opportunity of acquiring additional competences by reaching the final stages of implement and operate that novel product, not only a deeper evaluation accuracy can be reached, but also a wider field of competences can be evaluated. Regarding the number of competences evaluated, we have added “commitment to continuous learning”, and “teamwork”: in the prior CD course, student teams could easily split in different isolated subteams for the product design, provided that the interrelation level could be minimized by themselves, overcoming problems related with system integration. On the other hand, in the new course strong issues regarding teamwork appear in the implementation stage, due to the fact that students must construct a real working system, so integration is mandatory. Furthermore, in the same stage, students must deal with technical and commercial information provided by different suppliers, which force them to study some engineering concepts in a deeper detail with respect to what they learned in prior subjects. In the operate stage, different design and integration problems appear, which force students to redesign and face new teamwork and tight schedule working challenges. As a result, the new competences are now also evaluated by dedicated rubrics for team measurement and a 360º student evaluation for student teamwork performance measurement, where student behavior, compromise, goal fulfillment and workload are evaluated by the rest of the team members as well as by the teachers. In the implement stage,

With regard to evaluation accuracy, we have improved the use of evaluation rubrics: as a result of a task force composed by different UPM professors, we have developed up to six rubrics which allow for the measurement of the competences acquisition level in a four-level scale. As an example, Table 3 shows the rubric corresponding to the evaluation of the “creativity” competence acquisition level.

Table 3. Rubric to evaluate the “Creativity” competence

Indicator	Evaluation level			
	D	**C**	**B**	**A**
Number of different approaches or solution alternatives proposed.	Student is not capable of designing a valid approach.	Student provides at least one valid approach or solution alternative.	Student is able to create different approaches.	Student is able to create different approaches and solution alternatives.
Originality degree of those approaches or solution alternatives.	Proposed alternatives are frequently found in the reference group.	Proposed alternatives are sometimes found in the reference group.	Proposed alternatives are seldom found in the reference group.	Proposed alternatives are not found in the reference group.
Effectivity, feasibility degree of those approaches or solution alternatives.	Proposed alternatives do not solve the problem, are not a correct approach, or are not feasible with real world restraints.	Proposed alternatives do not solve the problem in an efficient way, or imply feasibility issues.	Proposed alternatives solve the problem in an efficient way.	Proposed alternatives solve the problem in an efficient way and do not create subsequent problems.

Individual and overall evaluation system

Due to the considerations explained above regarding number of students and limited budget, students must be grouped in big teams (6-12 people each, see “large groups management” section below). This fact eases the possibility of strong performance and learning divergences between each team member. In addition to the 360º student evaluation described above, we ask students to carry out individual works related to some lessons learned in different stages: application of different creativity methods to the solution of a problem and application of basic design principles to a simple problem. Furthermore, we nominate four task managers every two weeks in each team for the management of subteam works, and check if the assigned task was completed at the assigned deadline. Task manager selection is done according to each student’s major. However, in some cases, specially regarding electronics, the management role must be taken by the same person in different periods. Finally, we do not allow students to select who will carry out the follow-up presentations, so all team members have to prepare them.

Table *4* shows the evaluation scheme followed during the 2015-2016 course. We try to balance the weight of team and individual performance, as well as the weight of technical and professional competences.

Table 4. Evaluation scheme

Group evaluation (55%)								
Presentation 1 (product planning) (10%)		Presentation 2 (concept design) (10%)		Presentation 3 (Final design, packaging, advertisement) (15%)	Product performance (35%)	Teamwork (15%)	Creativity (10%)	Self learning (5%)
Small group (35%)	Big group (65%)	Small group (35%)	Big group (65%)					
Individual evaluation (30%)								
Work 1 (creativity tools) (20%)	Work 2 (application of basic design	Teamwork (20%)	Task management (20%)	Presentations (20%)				
Sustainability (15%)								

Teachers' coordination

The most remarkable organizational change we have faced is the increase in the lab personnel workload during the implement stage, as students require the use of the rapid prototyping facilities. Several rules must be given to the students in order to not overloading the facilities, as completing a Google Calendar and requesting teacher permission for 3D-printing –students tend to study the design performance in the 3D-printed prototypes instead of using the CAE systems, so there is a quite high risk of 3D-overprinting and consequently of resources waste-. We have also redistributed each teacher's workload, taking into account that several (up to four) teachers may be present at the same class in some key sessions (product proposals selection, concept selection, design freeze, final products presentation). We have experienced an increase in tutoring sessions request, which are frequently group sessions. As a result, we have set a fixed, 3 hours weekly tutoring session in addition to the regular class. This also implies an additional workload redistribution.

Teachers and assistant students training

Prior to the first complete CDIO course issue in 2014, a pilot development was carried out by teachers and selected assistant students in order to evaluate the student necessary working load, course planning and additional material and teaching resources needed. A self-powered trolley with connection to smartphone, which was one of the products designed in the last issue of the prior CD course, was selected as a representative example. Through the work, we issued the list of the estimated electrical and electronic equipment and materials needed for the course, created an electronic development 5-hour course and its documentation, and adjusted the course planning and student organization and roles.

CRITICAL ISSUES IN THE EXECUTION OF THE COMPLETE CDIO APPROACH.

As the map is not the territory, care must be taken to the field problems appearing during the subject execution. Environment variables as student high workload, students number and heterogeneity, limited resources and student attitudes can give rise to serious problems for obtaining the planned teaching outcomes. We have detected four main fields to take care to: relationship with students, selection criteria for the products to be developed, large groups management and student motivation.

Diffusion activities. Student selection. Success celebrations.

We have experienced the powerful influence "official" results presentation to different focus groups (students, teachers, companies, prospective students) has on the students' motivation as well as the prospective students' recruitment. On June 7th, 2015 a presentation event was held at the ETSII conference hall (Figure *2* (a)), in which multimedia assisted oral presentations were performed for each developed product in the eight Ingenia subjects taught during the 2014-2015 course. Afterwards, poster and product presentations were performed in several stands at ETSII main hall (Figure 2 (b) and (c)). Knowing the need of such a presentation in advance meant a fixed deadline and encouraged students to finish the product in time, and to prepare excellent marketing presentations and pitches. Prospective last year undergraduate students were impressed about the experience their colleagues lived in the subject. Additionally, the subject and the results of the 2014-2015 course were presented to the prospective students in an information event on September, 7th 2015. This increased the number of candidate students from 30 in the 2014-2015 course up to 60 in the 2015-2016.

Celebration of success is a key activity in any high performance team. We believe in this, and explain it to the students in the teamwork classes. A success celebration party was held after the demonstration (Figure *3*), where students and teachers had the opportunity of interchanging experiences regarding a full academic year relationship. Such an activity also brings teachers a wider insight about possible improvements for subsequent courses.

Figure 2. (a) Products presentation in the Ingenia results presentation event. (b), (c), Product demonstrations at the ETSII main hall.

Student selection is also a key issue for the course success. In addition to high academic levels, we try to keep a high heterogeneity in terms of student major –specially trying to include some electronics and automation students- and degree institution –trying to include some students coming from institutions different to TU Madrid-. Table 5 shows the composition of the 2015-2016 course groups. Even though no instructions are given to force students to keep heterogeneity, it is spontaneously created by prior student relationships. Motivation is also taken into account, and students which asked for their participation prior to the official course opening date and fulfilling the grade level and course selection requirements have a special consideration.

Figure 3. End of course party

Table 5. Groups composition by student major

GROUP NUMBER	PRODUCT	Machinery engineering	Electrical engineering	Electronics engineering	Industr. org. engineering	Energy engineering	Materials engineering
1	Automatic sunshade	10	1	1	1	0	1
2	Automatic pill dispenser	7	0	3	4	0	0
3	Unlockable snowboard binding	6	3	0	1	3	0

Product proposals evaluation

We are amazed about the amount of proposals the students provide in the proposals presentation class. A total of 80 product proposals have been presented for voting in the 2014-2015 and 2015-2016 courses, which means an average of 6 proposals per team.

Most of the product proposals show an impressive creativity and novelty, however also having a high pragmatism level at the same time, which demonstrates the underlying product planning work performed by the students as well as their high technical background. Being all the product proposals great, not all of them are suitable to be used for a complete CDIO experience with a success guarantee in the development during the course and consequently measurable results in skills acquisition. Hence, and a careful selection must be done for deciding the products to develop during the course. This fact has narrowed the scope of selectable products with respect to the prior CD courses.

Several criteria are to be used for the selection, in order to maximize the success probability at the end of the course:

- *Novelty*: students are noticed to perform patent searches in order to be able to propose products that are not in the market. The innovation may not be radical, but must be at least incremental. A new functionality is at least expected in each product proposal.
- *Student motivation*: for not reducing the number of proposals and trying to give rise to as much proposals as possible, students are instructed to look for any idea they may already have. Many students have product ideas since they were much younger, but they did not feel they were prepared to develop them. The environment created in this course (teamwork, teachers' help, lab facilities and other resources) motivates the students to take advantage of the opportunity.
- *Multidisciplinarity*: as the course is also planned as a capstone activity, where students integrate and develop the skills learned in prior ones, and the develop of teamwork and complex problem solving competences is expected, sufficient degree of multidisciplinarity is required for a product proposal to be selected. This includes the existence of at least two different energy domains. Most of the proposed products include mechanics and electric/electronic domains, having others also thermal or fluidic ones.
- *Budget*: as a budget limit exists for each product, only a limited number of products can be developed. Consequently, a tradeoff must be established between the number of products developed (which in turn must be coherent with the number of students and student teams) and the level of development of those products. In our course, which is the one most selected by the students among all the "Ingenia" course proposals, the number of students is about 40 and our yearly budget for current assets and fungible materials is about 4000€ per course, so we have chosen to develop three different products per year, having each one a budget of approximately 1000€ for fungible materials.
- *Obtainability with available resources*: for a proposal to be selected, the operations involved for the development must fit into the department available resources. Alternatively, the proposal may also be selected if the operations that cannot be performed at the own facilities can be subcontracted at acceptable cost and lead time.
- *Coherent student workload*: the student workload involving the product development must be carefully checked, taking the experiences gathered in prior courses as a measurement basis, so product proposals involving neither excessive nor insufficient workloads can be rejected. Factors as number of possible design alternatives available if the main one fails, necessary theoretical and numerical calculations, estimated number of prototypes necessary for obtaining a fully functional one, number of parts or number of parts suppliers needed must be carefully taken into account. Sometimes, the workload estimation initially taken into account to select a proposal can differ from the actual workload actually measured at midcourse. In such cases, students may be instructed to develop two different concepts for the same product idea, or reduce the number of functionalities.

Large groups management

Due to the need of creating teams of up to 12 members for the products development, we have developed different strategies in order to correctly distribute the workload and responsibilities. A strategy that is being successful is the creation of “teams” and “subteams” for the products development: at the beginning of a stage, work regarding each product is assigned to two “subteams” of 5 to 6 people, which must create and present solution alternatives in the next class. Once the two subteams working in the same product have presented their solution alternatives, a discussion is carried out to find out the best ones, as well as the possible improvements which can be performed in them. Then, subteams are joined in a 10-12 people team which must develop those best solutions and present them in the next class.

Role play is also needed in order to equilibrate student workload. From the basic design stage, students belonging to each team are grouped according to the different functional positions needed: electronics and testing, mechanics and materials, system integration, purchase and marketing, and project management.
Finally, we encourage students to assist to the extra tutoring class held every Thursday – at least two students must assist to this class-, and Google Calendar and Google drive are used for laboratory resources management and the archive of an open points list for each product.

Student motivation

In the two courses experience we have so far, we have noticed several student concerns about the feasibility of finishing the product in time and under the specification and budget restrictions. Their workload is intense not only because of our subject, but also because of the other ones they must also work in, so they are exposed to constant stressing situations. One important task for the teachers and assistant students is to constantly encourage them for a positive attitude, and let them be aware of the potential they already have due to the competences they acquired in prior courses, as well as letting them know the help the teachers and assistant students are willing to give. We also plan a former students presentation in the second class, so that the course students can assess the expected deepness and check that finishing the product in time, budget, quality and schedule is possible. In this presentations, we highlight examples of products that have been patented by the students, or obtained an interest by external companies. We think the example given by the teachers in the everyday classes is also very important. Most of the teachers have industrial, patents and/or spin-off experience, so an entrepreneurship environment is created. All these efforts are also effective for shifting the “study to pass the subject” attitude some students still keep to the “study to learn” attitude.

FIRST AND PRESENT COURSES RESULTS

Figure *4* shows different development stages of an automated fruit bag dispenser for supermarkets, which allows customers to select bag size and delivers bags already open. This product was developed during the 2014-2015 course. Figure 5 shows an automated fishing rod, also developed during the same course, which eliminates the “boring” time (according to professional fishers) elapsed from lure throw until fish bite by creating an automated lure movement. 3 programs are available for simulating 3 different lure behaviors. The product detects the bite and stops working, so that the fisher can take over control. Regarding the 2015-2016 course, we supply some pictures of the development stage as of the contribution submission date (February 2016). Figure *6* shows two concept alternatives for an automated pill dispenser, that is being developed during the present course, as well as a general product concept. The figure shows as well two concept alternatives for a snowboard boot fixing system with an additional quick release function.

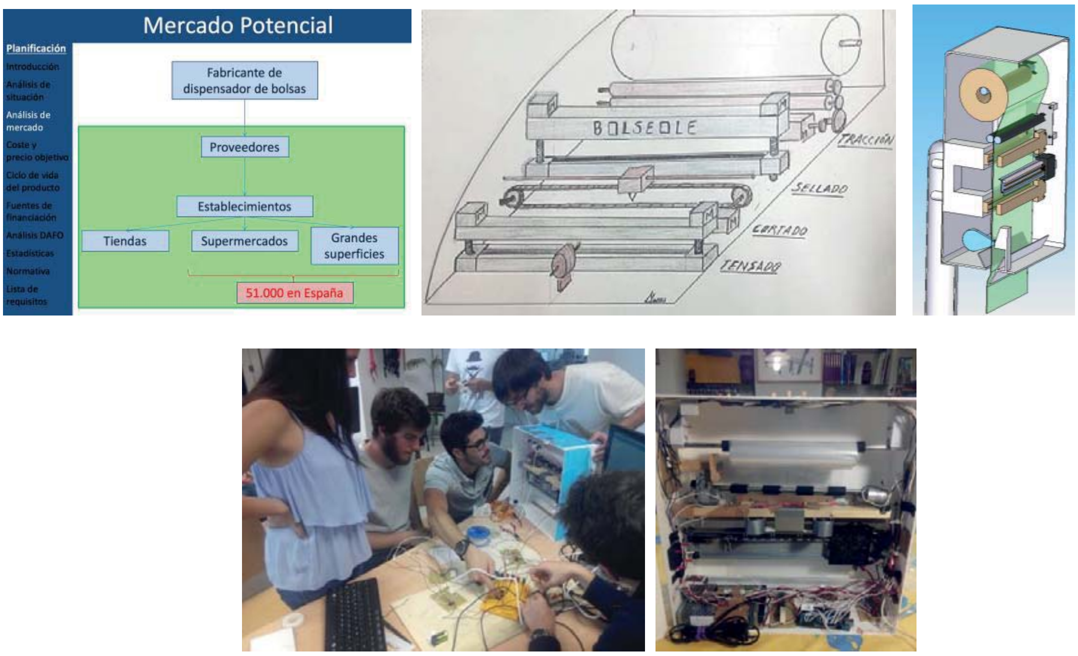

Figure 4. Different stages of the complete development of an automated bag dispenser: product planning, concept design, basic engineering, prototype manufacturing, prototype testing.

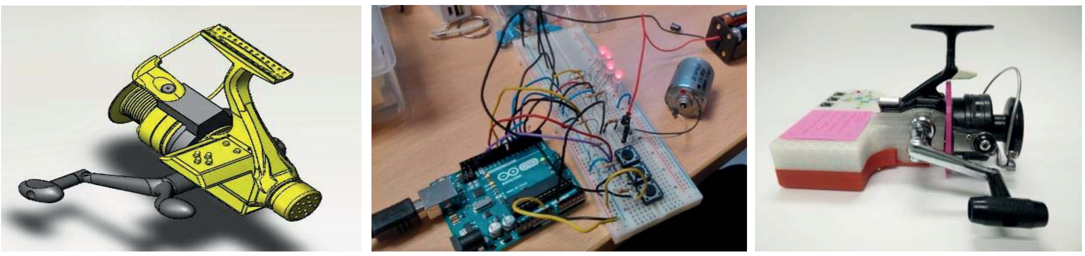

Figure 5. Different stages of the complete development of an automated fishing rod.

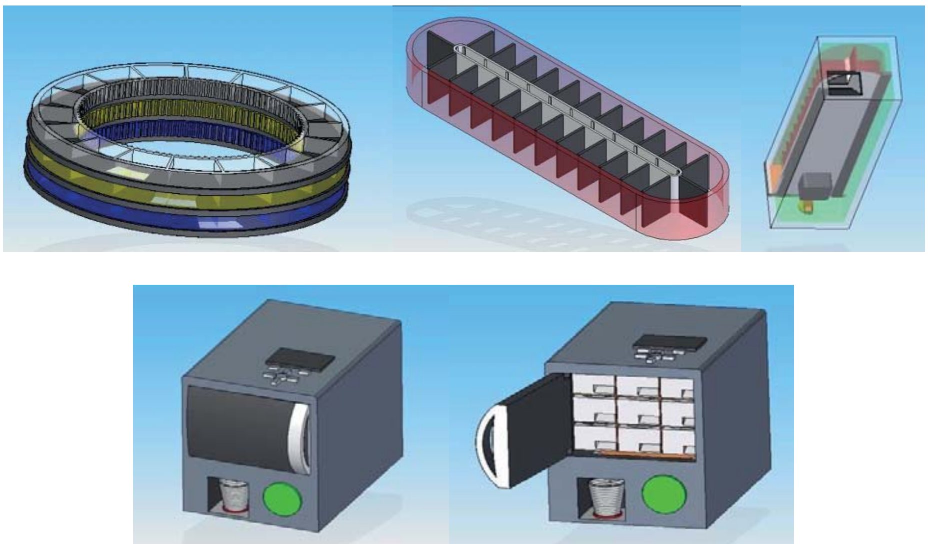

Figure 6. Different concept alternatives for pill+blíster management in an automated pill dispenser in present year course. Selected product concept alternative.

IMPLEMENTATION ASSESSMENT

Due to the fact that the 2014-15 course was the first one in which the complete CDIO approach was executed, limited information is available for assessing the success of the implementation. However, student surveys and competence evaluation results can serve as estimators of the first year performance. Figure *7* shows the results overview of the student survey. The overall impression is quite good. Regarding the acquisition of professional competences, “strategic analysis”, “planning”, “implement” and “continuous learning” competences are well valuated by the students.

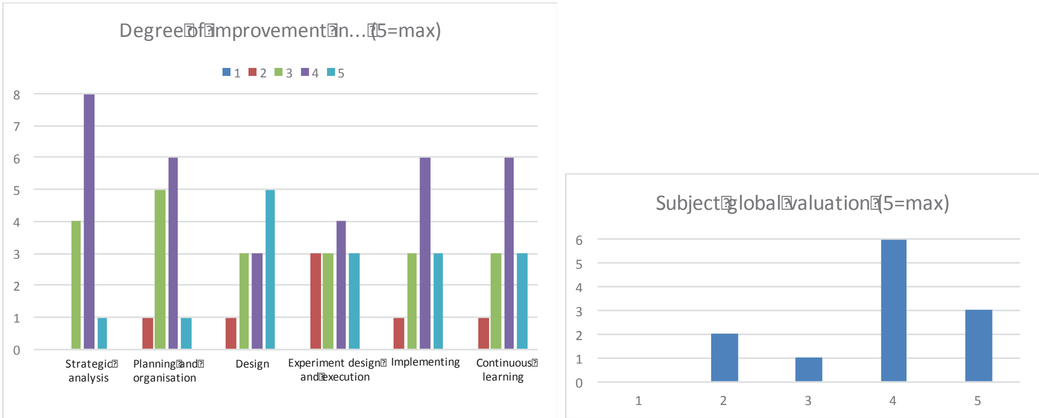

Figure 7. Results of the 2014-2015 student survey.

We are proud of one of the most frequent responses of our last course students: after the course, they feel capable to make their ideas come true. This is a very good overview of the learning outcomes, and the best argument for convincing the next year students to choose our subject. Students also highlighted the opportunity of integrating all the knowledges studied in other subjects, and the experience with real life problems related to tight schedule and budget, unpredicted errors, relationship with suppliers and invoicing. On the other hand, they feel that less theoretical classes should be given, and that the implement and operate stages should begin before. This year, we have advanced the beginning of the implementation stage one and a half months and moved some theory classes, so that they can be given at the same time students are working on their prototypes, and we asses that the knowledges to be given are necessary.

CONCLUSIONS. LESSONS LEARNED.

“Engineering Design” has been transformed in a complete CDIO experience in which students live the complete development process of a product which they propose. The results obtained during the last academic year, with respect to evaluation results in competences acquisition and student opinion are very good, as well as the course flow in present year. In the limited experience -one and a half courses- encompassing subject design, implementation and execution we have found several key issues for its success. Financing, human resources management, including teachers’ coordination and teachers and auxiliary personnel workload increase, lab facilities, evaluation scheme design and assistants and teachers training are the most important areas to handle during the subject planning. Student selection, activities diffusion, product selection and large groups management are the most important activities to care during the execution. Constant student motivation and support is mandatory for teachers, assistant students and lab personnel in order to convince students about the possibility of finishing the development in time, specification, budget, quality and schedule. The results of this effort are clearly detected in student motivation, self-potential awareness and attitude towards the subject. This subject is also being a great experience for teachers, giving us the opportunity of learning new things regarding teaching, product development and student behavior. The relationship established between students and teachers, who live the experience together, enriches both groups and is frequently extended to subsequent subjects during the master second year and the master thesis.

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DESIGN AND PRACTICE OF PRELIMINARY CLASS FOR A^3 LEARNING SYSTEM

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ABSTRACT

Young students are strongly required to have increased ability of critical thinking, versatile adaptation and basic competency, and knowledge to survive a new age. We offer a new learning system called A^3 (Advance, Active and Autonomous) learning system to stimulate students to have active and autonomous learning attitudes and at the same time to aim for reducing teachers' load of conducting classes. In order to implement this system successfully a new course for the first year students was designed. The program specially designed to promote an active learning manner among students and to build up the foundation of generic skills was executed as a part of the new course.

KEYWORDS

Active learning, Generic skills, Critical thinking, Global competency, New generation, Survival skills, Problem based learning, Project based Learning, Preliminary classes, Standard 7, 8

INTRODUCTION

Today, the globalization of society, complex economic structure, global competency and rapid development of technology urge us to drastically modify our education styles so that young generation can adapt to such complex and rapid changes and survive. The Ministry of Economy, Trade and Industry in Japan proposed Fundamental Competencies for Working Persons consisting of 3 competencies and 12 competency factors as the survival skill in the 21st century as shown in Figure.1. In Dec. 2014, the Ministry of Education, Culture, Sports, Science and Technology in Japan submitted the report on the improvement of higher education for the new generation and emphasizes the importance of survival skills such as critical thinking, judgment and the ability to express oneself and implementation of active learning style education in the classroom.

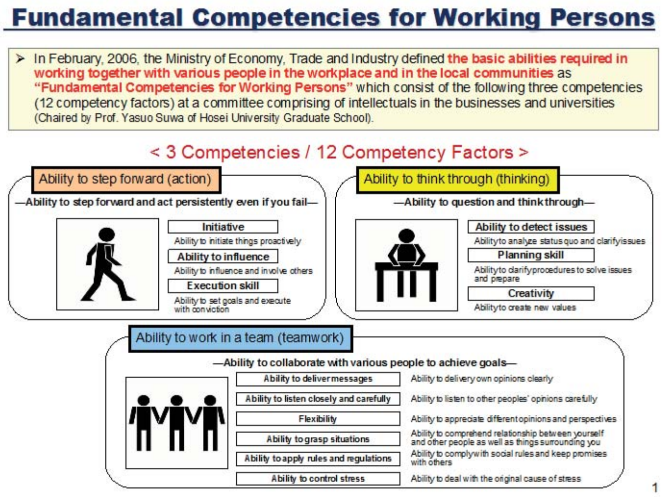


Figure 1. Fundamental Competencies for Working Persons defined by Ministry of Economy, Trade and Industry Japan in 2006

Adaptation to global society is also inevitable for young engineers who graduate from National Institutes of Technology (NIT) in Japan. National Institutes of Technology are well-known to be producing highly skilled engineers and to have long experience of PBL (Project/Problem based learning) education systems. Each institute offers the 5-year intensive education program to foster engineers with practical skills. Students enter the college at the age of 15 and continue developing his/her technical skills for 5 years. The importance of practical trainings is emphasized in the curriculum of every NITs. NIT Sendai College has also been offering the spiral education system with lectures followed by PBL-type practices. On the other hand, various newly developed technologies are changing the styles of learning and teaching drastically. The efficient use of IC technology and WEB technology expands the possibility of various learning styles of students. While we maintain the old good tradition in our educational system, we have yet to keep improving our system constantly to adapt to the global change, and making the best use of the latest ICT may provide us with feasible solutions for it.

Our college proposed a new learning system called A^3 (Advance, Active and Autonomous) learning system (Takahashi et.al., 2015). This system consists of Project/Problem based learning, Active learning and My-pace/Mastery learning and is expected to stimulate students to learn actively and autonomously and at the same time aims for reducing teachers' load of conducting classes. Students are sure to be strongly required to have increased ability of critical thinking, versatile adaptation, basic competency and knowledge to survive a new age. In order to meet such various requirements, we offer the A^3 learning system which flexibly matches each individual student with various degrees of knowledge, capability, interest and different background.

The preliminary educational program plays an important and key role for implementing the new learning system and developing it successfully. It is very important for us to foster students with positive attitudes toward learning in an early stage of the curriculum. We have to nurture student's motivation, and then create good learning atmosphere in classroom so that they appreciate the new leaning style and start taking advantage of it.

We designed a new course of 30 weeks with various programs for the first year students to nurture such motivation for learning. The course is divided into several parts and each part is designed to build up the foundation of generic skills of students. As a part of this course, we delivered a three-week program. This program is specially designed to promote an active learning manner among students. We focused on bringing out major abilities for their future study in this program.

In this paper, we introduce the detailed contents of this program and then summarize our first trail based on the feedback from the students and teachers. The analysis of the feedback is reported and we will discuss further improvement based on the result.

A^3 LEARNING SYSTEM

Various learning styles have been developed and implemented in response to the rapid change of the social structure and remarkable development of IT tools and/or WEB environment. For an example, MOOCs (Massive Open Online Courses) give people opportunities of taking courses more freely at any time anywhere by using WEB environment and a laptop or a tablet. JMOOC has dissolved the language barrier for Japanese who wishes to take such online courses. On the other hand IT has made it much easier for us to analyze a big volume of data such as learning records collected from each student year after year and to trace individual learning progress of each student. New learning styles, materials with better quality and ways of evaluation suitable to such online study have been developed.

The A^3 learning system consists of three types of learning styles (Fig.2). First, lectures are so designed that students can share knowledge in the benefit of Active learning. Students are expected to study in groups or by her/himself actively, sometimes with effective use of ICT, cultivating their learning skills while obtaining a certain amount of necessary knowledge. The second is PBL type lectures and practice, and students are expected to obtain various abilities such as thinking ability, analyzing ability, communication techniques and competency from working experience on a project or encountering various problems. The third is so-called My-pace or Mastery learning style. Each student studies on individual pace to obtain complete and total knowledge for his/her future career and sometimes can ask for personal assistance or advice from an instructor to ensure their own understanding if necessary.

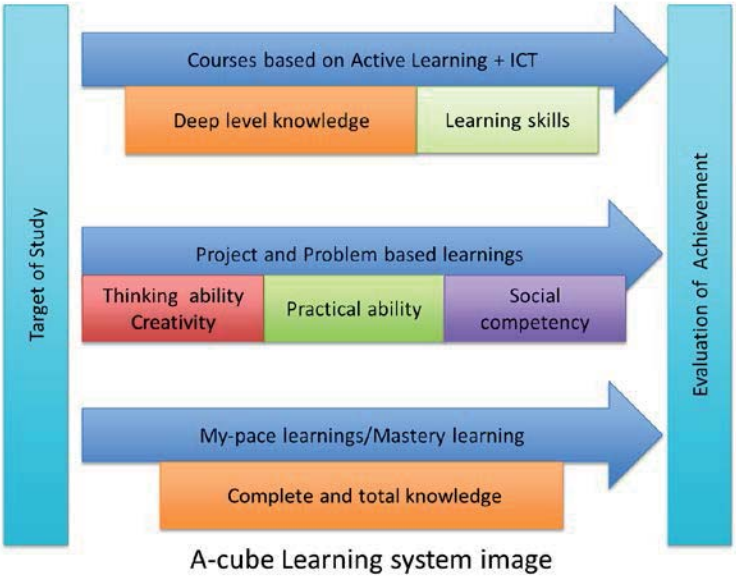


Figure 2. Three learning styles proposed in A^3 learning system

The school presents the standard criterion that students are supposed to reach during an academic year and evaluate their achievements at the end of that year based on the criterion. The whole curriculum should be designed as combinations of those three learning styles. Evaluation of active learning style is often likely to depend on rather subjective feeling. In order to evaluate the achievement of each student in a fair manner, we use PROG (Progress Report on Generic Skills) test which allows more objective evaluation.
PROG is the program developed by the collaboration of Kawai-juku education institution in Japan and Riasec Co. to foster generic skills of university students. PROG test consists of two types of multiple choice tests: a literacy test and a competency test (Ito, H., 2014). PROG is not an ordinary test measuring the amount of knowledge but is designed to measure how he/she responds, decides and acts to solve a problem by fully using of their own knowledge. The literacy test measures the ability to solve a problem with their own knowledge and the competency test measures general skills obtained from various experiences in the past.
It is expected that the A^3 learning system helps students to establish their own autonomous learning attitudes and flourishing communication skills among students, between students and teachers and even more so that students are able to gain extra learning benefits.

PRACTICAL TRIALS IN THE PRELIMINARY COURSE FOR THE FIRST YEAR STUDENTS

Positive attitudes of students toward their study are the most important key to the successful implementation of the new learning system. In order to nurture such attitudes in the early stage of academic program we designed a new course for the first year students called the training course for generic skills. There are about 128 students in the first year, we split them in a half and deliver various essential practices such as micro projects, basic experiments and group works for fostering basic social skills. The first 64 student group is referred as the group1 and the other is as the group2.
As a part of this course, we offered a practical exercise program of three weeks focused on developing basic social skills and promoting the use of several active learning methods. This program consists of three sequential different workshops. Each workshop is delivered in a similar manner based on active learning methods. The first workshop is called a micro

presentation, and the second workshop is a logical thinking practice and the third is a Jigsaw method workshop. Through these active learning practices, students are expected to learn gradually the following three major abilities in generic skills: the ability of expressing and explaining their own thought, the ability of settling arguments in a group discussion and leading to a proper conclusion, and the ability of communicating, contributing and collaborating in a group work. The program was designed in a way that students learn how to express their own thought first, then contribute in a discussion and eventually experience success in a group work.

Micro presentation: the ability of expressing and explaining own thought

This workshop is the introductory program of group works for the first year students. The time schedule of “Micro presentation” workshop is shown in Table 1.
Students are divided into small groups of 4 to 5 people. They start with ice-breaking time and then find a partner in the group and interview each other. The first presentation task is introducing the partner to another member in a group based on the interview result. Teachers act just as a time keeper or an observer during the first task.
After students become more relaxed and active, the lecture about Brainstorming method is delivered so that students are ready to understand one of technical methods for group work and acquire it as their knowledge.
The theme given after the lecture for a group work activity is “What is the good presentation?” and students discuss in a group by adopting the proper manner of Brainstorming. Each group presents the result of brainstorming in front of all participants at the end.
Students evaluate each other’s presentation and give a score on a five-point scale.

Table1. The time schedule of Micro presentation practice

Contents	Time	Feedback
Guidance and Icebreaking	30 min	
Pair work	30 min	
Presentation in a group	30 min	Evaluation sheets
Lecture about Brainstorming(BS)	15 min	
Group work (BS workshop)	50 min	
Presentation of the conclusion	30 min	Evaluation sheets
Briefing	20 min	Feedback sheets

Logical thinking: the abilities of settling arguments in a group discussion and leading to a proper conclusion at the same time

In this workshop, we adopted Logic tree method as a tool of critical thinking so that students can analyze the problem with certain depth of thought (Takeda, M. 2014). We present two ways to create a logic tree, one is “Why tree” and the other is “How tree”. Students approach the same given theme by creating two different types of trees so that they can look over the theme from different viewpoints and deepen their discussion on the theme.
Since the theme selected for a workshop is a good communication, the first target should be “why we can’t communicate well?” and then the second one should be “how we can communicate better”. Students are expected to create their logic trees after brainstorming in a group.
At the end of each session, each group presents their conclusion that the group has reached by applying the logic tree method in front of all participants. After the presentation of why trees teachers make feedback comments to students if necessary so that they can improve their analysis. Each student is supposed to make an assessment of each presentation.
The time schedule for “Logical thinking” workshop is shown in Table 2.

Table 2. The time schedule of Logical thinking practice

Contents	Time	Feedback
Guidance and lecture about Logic tree(LT)	25 min	
Group work (Why tree workshop)	50 min	
Presentation of the result	30 min	Evaluation sheets
Group work (How tree workshop) with LT	50 min	
Presentation of the result	30 min	Evaluation sheets
Briefing	20 min	Feedback sheets

Jigsaw method: the ability of communicating, contributing and collaborating in a group

This practice is offered based on Jigsaw classroom active learning method so that we can let everyone of a group be responsible and contribute to the group positively by assigning each student their own task. Students are presented various active learning methods which seem to be rather easy for beginners like the first year students to understand (Hall, S. 2002, Lestik, M. et. al. 2012, Kontio, J. 2013 & 2015). Because of such consideration, the four different methods like Formulate-share-create-revise, Mud cards, Recitation and Gallery walk were chosen in the workshop. Each student chooses one method that he/she wishes to be an expert of. Students form an expert group according to each method and discuss to deepen his/her understanding about the method. Then each student goes back to the original group for sharing their knowledge with others.
In order to confirm if students could share their knowledge with other members of the group successfully, a mini confirmation test was organized after the Jigsaw method workshop.
The afternoon session in the third period is supposed to be the compilation of all group works that had been done during three weeks; all groups discuss how they can deliver group works successfully and present their conclusions.
The time schedule of “Jigsaw method” class is shown in Table 3.

Table 3. The time schedule for Jigsaw Method practice

Contents	Time	Feedback
Guidance and lecture about Jigsaw method	35 min	
Group work (Learning an AL method)	30 min	
Group work (Sharing the AL knowledge)	40 min	Confirmation tests
Group work (BS workshop)	50 min	
Presentation of the conclusion	30 min	Evaluation sheets
Briefing	20 min	Feedback sheets

Analysis of the feedback

We gathered the feedback from students and teachers after each workshop. The feedback was made by scoring presentations delivered after each workshop, the mini confirmation test and the feedback sheets collected from students at the end of each day.
The scoring each presentation is made in four categories; delivery, attitudes during presentations, design of materials and contents of presentation. The figure 3 shows the average score of presentations evaluated on a five-point scale by all students. The first bar in the graph represents the average score of presentations of introducing a partner student in each group and the second bar is that of group presentations about “What is the good presentation” in the “Micro presentation” class.
It is interesting that each average score of all four categories for the group presentations is

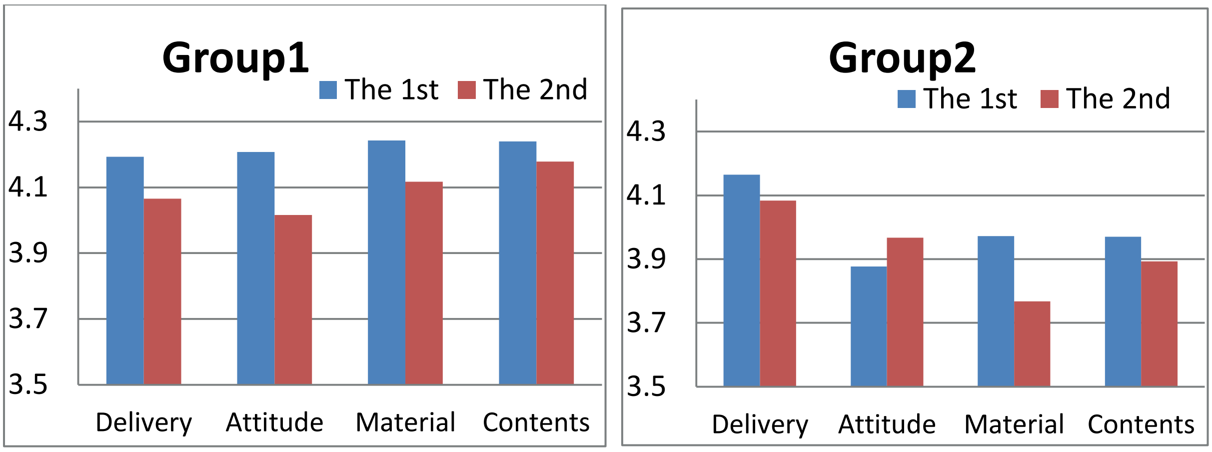


Figure 3. Average scores of the 1st presentations and the 2nd presentations in Micro presentation practice

lower than the first presentations in their own group for both of the first half (Group 1) and the second half (Group 2) of students. This result can be understood that students have learnt critical thinking after taking a lecture and discussing about a good presentation.
In the workshop for logical thinking, students had to present twice about their conclusions. The figure 4 shows the average scores evaluated on a five-point scale as well. All categories

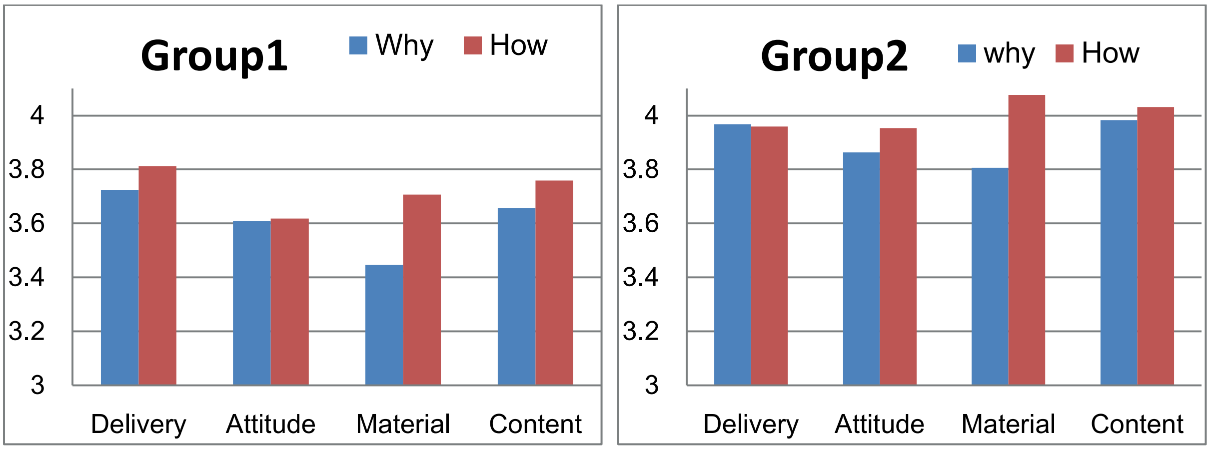


Figure 4. Average scores of the presentations for Why tree analysis and How tree analysis in the logical thinking practice.

of presentations for How tree analysis marked much higher than Why tree analysis. These results also can be understood to show that the logical thinking practices in the class helped students to analyze the problem better and explain their own thought well.
In the confirmation test done at the end of Jigsaw method practice, we asked all students to choose a proper method from four different Active learning methods which matches to each given explanation. Figure 5 shows the percentage of correct answers to the questions about three different methods. We can conclude from the graph that at least roughly 85% of students comprehended the basic meaning of each method.
The feedback sheet asked each student to rate their understanding levels of workshop contents and to answer three questions of what the target of each practice is, which kind of methods is applied in the practice and what the expected benefit obtained from the method is. A part of assessment for students is made by scoring answers for these three questions. The average score of 128 students evaluated based on the feedback sheets is 5 out of 15. It can be understood that students did not quite comprehend the meaning of the target of this program and the active learning methods introduced in workshops.

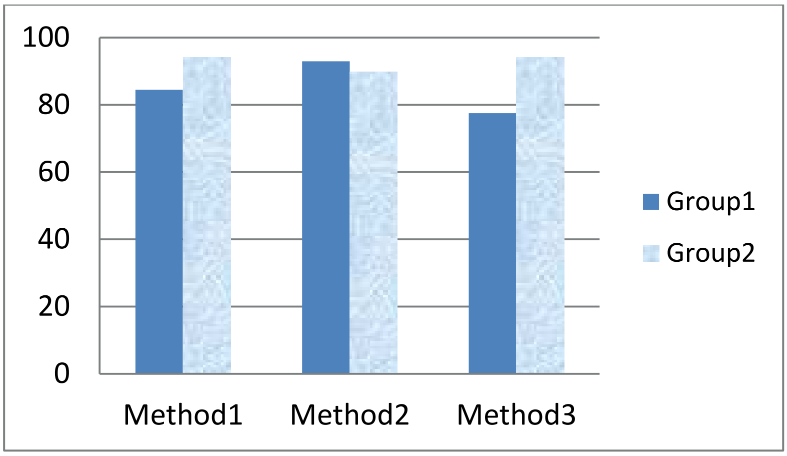


Figure 5. The percentage of students who did understand the three different Active Learning methods correctly after “Jigsaw method” practice.

DISCUSSION AND CONCLUSION

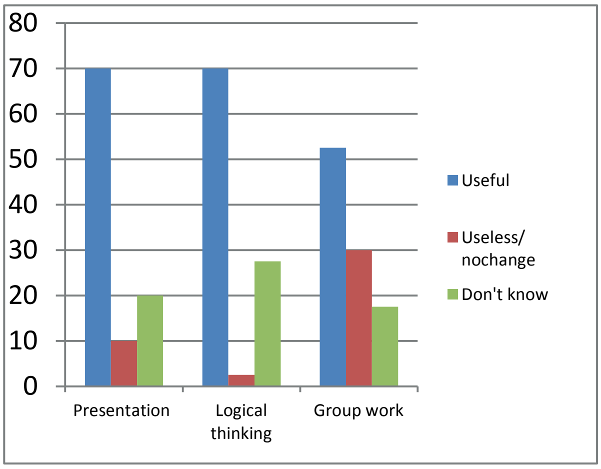
We designed the introduction course of Active Learning methods for the first year students. The preparation of this new program was started a half year before the beginning of academic year 2015. The detailed discussion of which methods to adopt, how to introduce and what proper size of groups is and etc. were repeatedly discussed. The prime concerns were themes of group discussion and choices of AL methods which could induce a lively discussion among students and easy to deepen the argument maintaining certain interest.
The feedback from the teachers suggested that Icebreaking worked well for relaxing the atmosphere in a group and Brainstorming helped students dragging out a lot of ideas and various thoughts on a theme.

The result shown in Figure 3 indicates that many students obtained a sense of critical thinking after the active discussion. Also Figure 4 showed that creating the two different logic trees helped students to analyze a problem better and deepen their understanding over the problem. We also could conclude from Figure 5 that the contribution to group work was made positively by assigning each student an individual task and students could communize their knowledge in own group successfully.

The average score of feed-back sheets collected from students was only about 5 points out of 15. We have to realize from this result and also from the feed-back comments from the teachers that many students did not understand about the correct meaning of the target of program and methods introduced and/or how to analyze problems with proper use of thinking methods like logic trees, for example.

Near the end of Academic year 2016, we picked one third of the first year students quasi-randomly and asked if those practices were helpful to their study thereafter. Figure 6 shows the questionnaire result collected from 40 students. The 70 % of them think Micro presentation and Logical thinking practices are effective and more than 50% answered they were able to contribute to group works more positively than before. We could acknowledge from these answers that there was certain effectiveness on the program.
The comparison between the PROG test results made at the end of the last academic year and this year is shown in Figure 7. The graph showed the average competency and literacy scores for all 1st year students in 2014 and these scores for all 1st year students in 2015. The competency in this year is higher than the last year result while the literacy in this year is lower than that in the last year. In order to draw any concrete conclusion, it is necessary to consider

the individual difference between two groups and also to follow up study of the same group of students. However, it might be possible to say that the A^3 learning system including this practical program for fostering generic skills is effective to improve the competency of students.



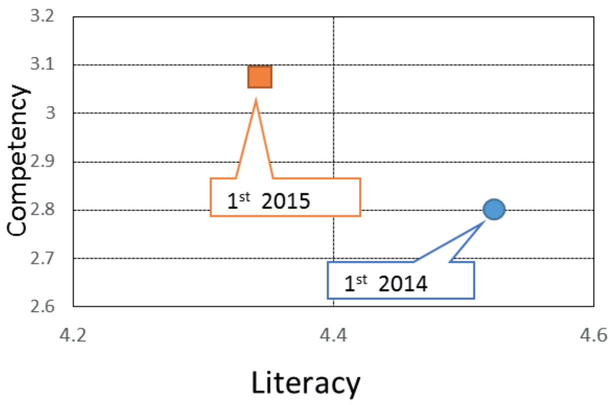


Figure 6. Percentage of answers for the question asking the effectiveness of each practice

Figure 7. The result of PROG tests in 2014 and 2015 on 7-point scales

It is quite important what kind of themes we should provide to younger students. Active learning methods also should be more suitable to their study background so that they could actually apply them under own circumstance. We surely have to keep continuing this program for a few more years and also revising the contents based on feedbacks, and the most important thing is that we have to follow up these students for some more years.

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PROJECT BASED LEARNING: AN APPROACH TO ONE ROBOTIC CELL DESIGN

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ABSTRACT

We are observing changes in all human activities and one sector impacted by these changes is engineering. Since the technological revolution, the engineering world has demanded more flexibility, extra qualifications and more knowledge of specific areas. Therefore, a key change to the engineering universities is to increase the efficiency in learning, which demands a methodological change in their curriculum. The Project Based Learning (PBL) is a systemic approach, which promotes students to ‘know how’ and knowledge acquisition, through the investigation of complex questions and tasks, accurate planning, focusing on efficient learning. In the PBL approach, the student is in charge of obtaining knowledge on their own and developing the obtained knowledge.
Robotics is the study of robot applications replacing human activities, which can be attributed not only to robots but also for other devices used with the robots. These robots can be classified in six classes based on characteristics, such as: payload, stroke, accuracy and repeatability. The industries are the biggest beneficiaries after obtaining the robot service applications.

The purpose of this work is to analyze the performance application of PBL used as the foundation of a robotic cell for handling design, to be developed by Mechanical Engineering students. It commenced by explaining to the students the new learning methodology, followed by the explanation of the robotic cell for handling considering the input data. Afterwards, the class was divided into groups, each in charge of one cell designed to handle anything. In order to promote the project management issues, each group created a timetable for all activities for basic tasks such as: cell design conception, layout projects, material purchase, assembly, try run and presentation for final approval. Concluding this study, the results of the PBL efficiency measurement are presented as well as recommendations for future projects.

KEYWORDS

Project-Based Learning, Robotics, Learning Innovation, CDIO-Standards: 1, 7, 8 and 11

INTRODUCTION

The development of the learning methodology based on project begun in 1900, when the American philosopher John Dewey (1859-1952) proved that "learning under doing" was a revolutionary way of studying. He conducted a survey about the capacity of the students in thinking how in a gradually way, the learning acquisition related to the ability to solve real projects, adding study area contents with the goal of developing the physical, emotional and intellectual sides by experimental means.

Constructivism explains that humans learn through environmental interactions and this experience is perceived differently by each person. Therefore, the 'student' learns based on his current knowledge of the subject (Markham, Larmer & Ravitz 2008**)**. Constructionism does an examination on individual learning, every step of the way, confirming that humans learn more when they build and share something with others (Grant, 2002).

Ergo, the learning based in projects is related to the constructivism, where the know-how is not absolute, but rather built by the student through his knowledge and global perception, sizing the necessity of deeply understanding, amplifying and integrating the knowledge (Bolander, Fisher & Hansen, 2011; Crawley *et al*., 2007). The main characteristics of the Project-Based-Learning (PBL) methodology are (Niewoehner *et al.,* 2011; Wilkerson & Gijselaers, 1996; Mazur, 1996): student as being in the center of the process; personal and professional skills; communication; team work integration; active process, cooperative, integrated and interdisciplinary and learning oriented.

We can argue that the CDIO program focus on the product lifecycle, where the four steps are: Conceiving, Designing, Implementing and Operating. With that in mind, we incorporated some of these standards in our as guide lines, in order to conduct the PBL. Under these standards, we oriented our students to consider the product's analysis, design and social responsibility. Following the standards, it was possible to identify the metacognition process as key for students increase in motivation, and understanding and connection of key concepts. Finally, following the standards, we evaluated the students based on how they implemented the concepts and how far they got (Roslöf, 2015).

According to the CDIO, we can define PBL as an instructional method in which students learn a range of skills while, also, creating their own projects, which could be a solution to a real-world problem. However, the most important part of the PBL is the knowledge gained by the students during this process. They work in groups and bring their own experiences, abilities, learning styles and perspectives to the project.

Niewoehner *et al*., (2011) conducted a study that supports the Susan Ambrose in "How Learning Works: 7 Research Based Principles for Smart Teaching" as the substantiation of PBL in engineering. In their work, they also conducted the trajectory of CDIO's desired Engineering Education Reform emphasizing that contextual learning is frequently embodied on hands-on projects, and the PBL commonly overlapped or coincided in CDIO programs.

According to Niku (2014), robotics is the study of robot applications replacing human activities. The robots can be classified in four categories, six different classes and their main characteristics are: payload, stroke, accuracy and repeatability. The industries are the largest beneficiaries after obtaining the robots service application. For university applications, we can have an assembled industrial robot, a kit that the students can assemble or build their own robots.

The conception of Arduino was emerged in Italy, 2005, with the subject creating a device which could be used in projects and prototypes as a cheaper alternative to the others in the market, focusing on the students and universities. The hardware and the software are cheap and available in several places. The Arduino is a processor able to measure variables in the external environment and transfer electrical signals, using sensors in its input and then processing all the information supplying output signals (McRoberts, 2011).

This paper describes the application of the Project-Based Learning as an innovative methodology using a robotic cell for handling design as a mean to motivate and teach the students. Starts by explaining the input data for the design and adopting the Arduino as the microprocessor, the students choose the robot design, programming and implementation. The CDIO standards were followed every step of the project development (CDIO, 2010). As a result, we present the final concept for the robotic cell and its features as well as the PBL efficiency measurement. Finally, some recommendations for further projects are presented.

MATERIAL AND METHODOLOGY

Microprocessor – The Family of the Arduino microprocessor used in the Project was the AT mega 2560, UNO version. This version has flash memory of 128KB and is indicated for robotics application, because of the number of inputs and outputs. This Arduino Maga has 54 digital pins for I/O and 14 of the total for analogical output signals PWM and 16 pins for analogical input.

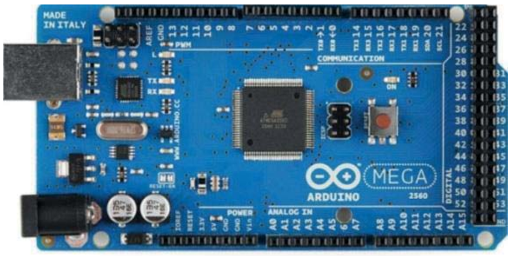

Figure 1. Overview of the Arduino microprocessor AT mega 2560 UNO

Robot – The robot concept used in the project was Class 3, which specifies the variable frequency, where one device executes steps according to one procedure allowing changes. The Category of the robot is number 2 in which the controller has one memory to record the moving sequence as well as the positions and speeds. The programming used was one method to control the commands through the control board with each component in charge by the moving sending signals and loaded in the programming code. The robot conception used 3 joints, 1 gripper and 5 servo motors. The robot structure was built by the students using hard plastic, as raw material, and laser cut shortly thereafter by the CNC milling machine.

Figure 2. Robot conception designed in 3D by the students

Project Time Table – The students were divided in teams and before they started their activities, each team elaborated a time table following the 5W2H concept. This methodology allows the project managing through the approach of the tasks answering the questions:
-What: The task which shall be done;
-Who: The person or group of people in charge of conducting the actions;
-When: The deadline to conclude the action;
-Where: The physical place to do the task;
-Why: The main reason to do the task;
-How: The way to conduct the task or the mean used to do the action;
-How much: The costs and investments involved to do each task.
The schedule was submitted as an assessment to evaluate the teams' capabilities in terms of project management skills. Afterwards, there were 'check-point' meetings with the teams and the students presented a new plan to correct the delays and the failure method analyze effect approach was introduced by each team in order to avoid that new problems appeared without any action to solve them.

5W2H Planning

Group	Student 1, Student 2, Student 3
Objective	Student 4, Student 5, Student 6, Student 7

What	Who	When		Where	How	Why	How Much	% Completed	Today	Situation
		Beginning	End							
Choosing the Project	Everyone	20-Aug	27-Aug	UNIVERSITY	Agreement	Starting Point	-	100%	100%	ok
Internet Research	Everyone	20-Aug	24-Nov	UNIVERSITY	Google, Mags	Concept (design)	-	100%	100%	ok
Theoric Research	Student 1, Student 4, Student 5	20-Aug	3-Sep	UNIVERSITY	Library, Google	Theoric Basis	-	100%	100%	ok
Project (Sketch)	Student 3, Student 6	27-Aug	10-Sep	UNIVERSITY	AutoCad	Sketch for assembly	-	100%	100%	ok
List of Material	Student 2	22-Aug	15-Oct	UNIVERSITY	Manual	To provide materials	-	100%	100%	ok
Prototype Assembly	Student 7	29-Aug	20-Oct	Student 7 House	Office	To prepare assembly	-	100%	100%	ok
Material Purchase	Everyone	2-Sep	2-Nov	UNIVERSITY	Manual or Tools	Prototype	-	0%	80%	not ok
Programming	Everyone	1-Sep	2-Nov	UNIVERSITY	Arduino	To move the arm	-	0%	60%	not ok
Prototype Testing	Everyone	2-Sep	24-Nov	University Lab	Function Test	To assure correct function	-	0%	50%	not ok
Final Assessment	Everyone	2-Sep	24-Nov	UNIVERSITY	MS Word	To show the professor	-	0%	30%	not ok
Presentation	Everyone	16-Sep	24-Nov	University Lab	MS Powerpoint	For final avaliation	-	0%	0%	not ok
Final Data	Everyone	14-Sep	26-Nov	UNIVERSITY	Written work and presentation	Avaliation	-	0%	0%	not ok

Figure 3. Time table of the main activities using 5W2H conception

Methodology for the PBL Efficiency Measurement – The data was collected via an electronic survey, which was answered by the students without the teacher's interference. The electronic survey generated statistical data and the results were exported to an Excel spreadsheet. The survey compounded for six questions presented in the following order:
- About the quality of the team job;
- Level of the team commitment with the results;
- The prototype conception;
- Team capacity in project management;
- Knowledge acquisition.

During the check point meetings, every group had their tasks checked and if a problem occurred, an action plan was adopted by the respective team, in order to correct the deviations.

RESULTS

Robotic Cell for Handling – The robotic cell was conceived, designed, assembled and implemented on time and its features were:
- Total length of the rod: 55 cm
- Stroke max. in x axle: 50 cm
- Stroke max. in y axle: 55 cm

- Stroke max. in z axle: 50 cm
- Maximum Moment: 11 Nm

The robotic cells for handling also reached the specifications for precision and repeatability.

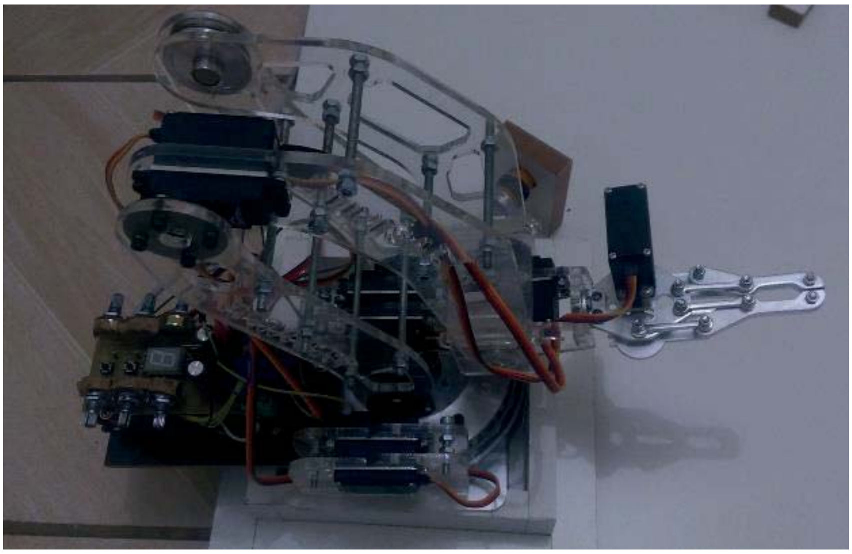

Figure 4. The robot final assembly located in the cell layout

The Project-Based Learning Efficiency Measurement Results – The survey was conducted to all students with six questions. The students had the choice between five levels of specialization conformity and in accordance to the personal perception of the PBL methodology. The outputs are as followed with comments being pointed out.

Figure 5. Evaluation of their work quality

The majority of the students have the perception that their work was conducted in accordance with the input data given to them in the beginning of the project as well as the quality of their work reached the established standards. In fact, the students amplified their range of knowledge in terms of automation and robotics, using a multidisciplinary approach.

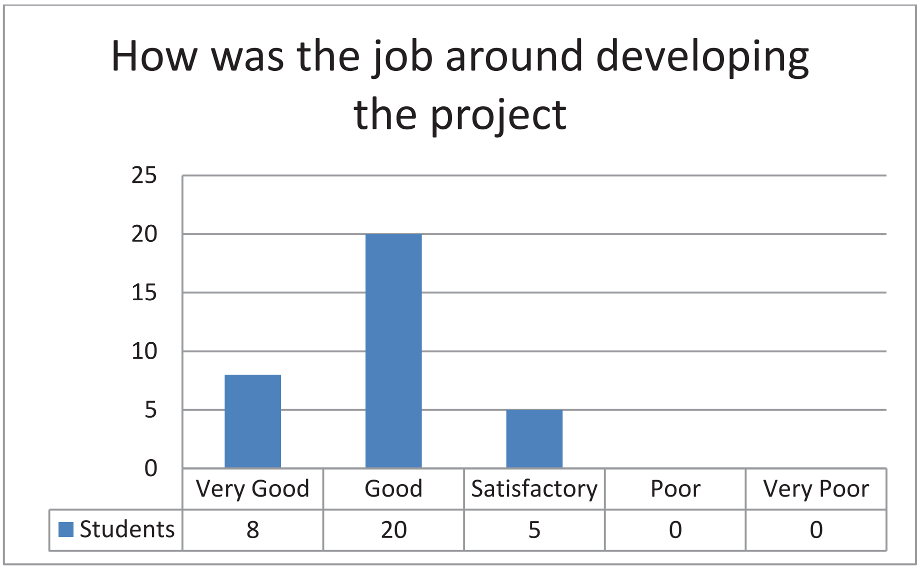

Figure 6. The job around the project and commitment with the results

Almost all the students had the feeling that they were responsible for the final results of the project. It shows that the PBL methodology gave them the sense of responsibility to conduct all the activities for the project success.

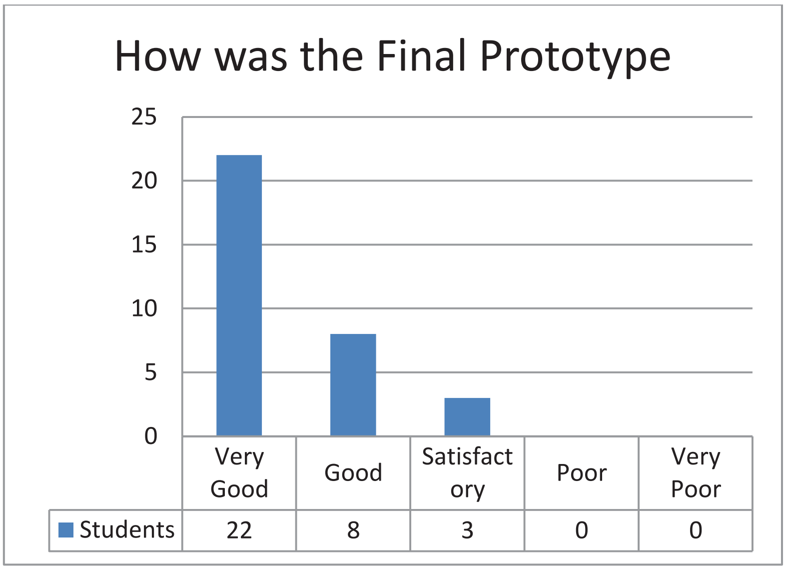

Figure 7. Evaluation of the performance for the final assembled robot

The methodology developed in the group had the capacity to go over their limits and encourage them to reach the goal established for the project. They worked in the conception, design, manufacturing, assembly and try run. All the robotic cells ran well within the specifications and on time.

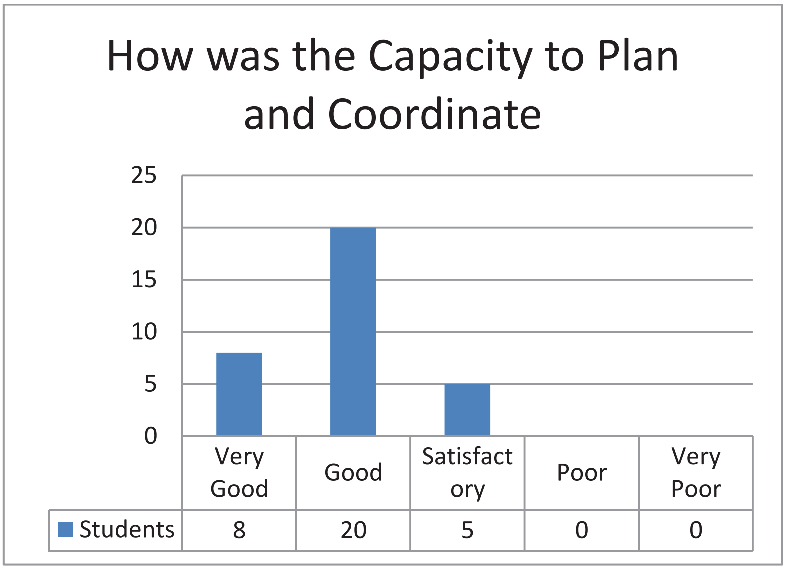

Figure 8. Project Management Abilities

The Project-Based Learning as the innovation learning methodology gave the students the sense of planning and project management abilities. Although the original discipline was related to Computer Aided Manufacturing the students learned deeply about management.

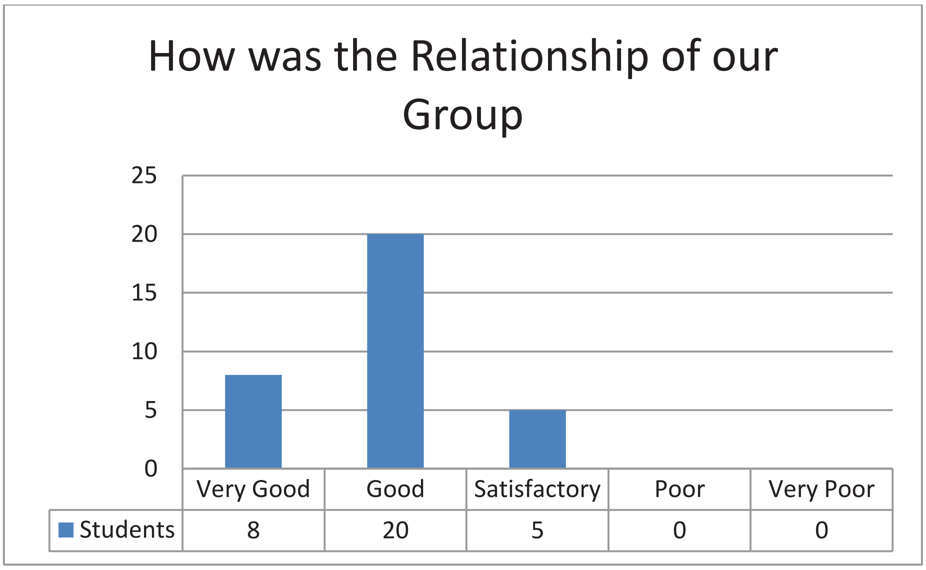

Figure 9. Capacity in team work

More than an interdisciplinary methodology, PBL motivated the students to work as a team. This ability is essential for an engineer in the job market and sometimes is neglected in the engineering curriculum.

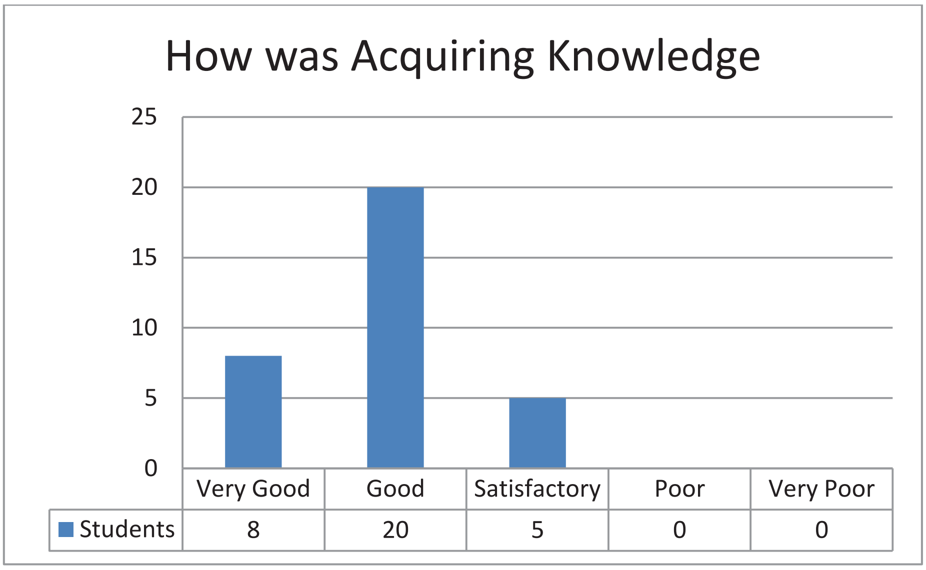

Figure 10. Knowledge Acquiring using PBL as the learning methodology

Finally, PBL showed that it was a strong tool when knowledge acquisition is demanded. The students faced many difficulties during the project development, but solved all of them with the knowledge acquired from several fields.

CONCLUSIONS

In this paper, the Project-Based Learning application was evaluated. It was discussed the PBL conception as well as the concepts regarded to robotics and automation as a mean to apply the innovation learning methodology.
The steps of PBL and the CDIO standards were followed and all project activities were controlled by 5W2H methodology as the tool to guide the project management. Using the hands-on concept the students conceived, designed, assembled and implemented the robotic cell for handling. The robot features were measured and checked with the project input data specification. The students' skills in terms of project management were developed.
A survey was used to verify the efficiency of the PBL using the robotic cell project as the main students' motivation. The results of this innovative learning methodology were presented with great grades and vast comprehension with the majority of the students to which the survey was conducted. As a result, the perception of the teams regarding to their job quality, commitment, prototype building, planning capacity, team work spirit and knowledge acquire were conducted in an efficient way when the PBL was applied as the learning innovative methodology.
As to further research works, it is recommended that a personal assesment should be conducted and followed by a peer evaluation, in order to measure the level of assimilation of the multidisciplinary contents by the students as well as a way to also measure the efficiency of the Project-Based Learning that could be obtained by the results evaluation.

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BIOGRAPHICAL INFORMATION

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CDIO Experiences in Biomedical Engineering: Preparing Spanish Students for the Future of Medicine and Medical Device Technology

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ABSTRACT

Biomedical engineering is one of the more recent fields of engineering, aimed at the application of engineering principles, methods and design concepts to medicine and biology for healthcare purposes, mainly as a support for preventive, diagnostic or therapeutic tasks. Biomedical engineering professionals are expected to achieve, during their studies and professional practice, considerable knowledge of both health sciences and engineering. Studying biomedical engineering programmes, or combining pre-graduate studies in life sciences with graduate studies in engineering, or vice versa, are typical options for becoming qualified biomedical engineering professionals, although there are additional interesting alternatives, to be discussed.

According to our experience, the graduates and post-graduates from multidisciplinary engineering programmes, not just from biomedical engineering, but also from more traditional fields including industrial, mechanical and telecommunications engineering, can play varied and very relevant roles in the biomedical industry and in extremely complex biomedical device development projects. In spite of the different ways of becoming a professional of the biomedical engineering field, it is true that their impact as successful professionals can be importantly increased, by means of an adequate integration into their curricula of fundamental biomedical engineering design concepts, methodologies and good practices, applied to the development of biomedical devices.

In this study we present the complete development and comparative study of three courses, belonging to different plans of study taught at the Technical University of Madrid and benefiting from using a CDIO approach focused on the development of biomedical devices. The three courses are “Development of Medical Devices”, “Bioengineering Design” and “Biomedical Engineering”, respectively belonging to the “Bachelor’s Degree in Biomedical Engineering”, to the “Master’s Degree in Industrial Engineering” and to the “Master’s Degree in Mechanical Engineering”. During the courses, groups of students live through the development process of different biomedical devices aimed at providing answers to relevant social needs. Depending on their background and European credits assigned to the different courses, students carry out more conceptual projects or are able to live through more complete CDIO experiences. Main benefits, lessons learned and future challenges, linked to these courses, are analyzed, taking account of the results from 2014-2015 academic year.

KEYWORDS:

CDIO as Context, Integrated Learning Experiences, Active Learning, Biomedical Engineering, Biomedical Engineering Design. (Standards: 1, 3, 5, 7, 8).

INTRODUCTION

Biomedical engineering a quite recent engineering field, as the first Biomedical Engineering programmes appeared at US universities in the late 1950s, with Drexel University, the Johns Hopkins University, the University of Pennsylvania and the University of Rochester as pioneers. In the late 1960s and 1970s other relevant universities followed them, including: Boston University, Carnegie Mellon, Harvard and MIT, Ohio State University, the University of Illinois, among other interesting examples (Fagette, 1999). Biomedical Engineering is aimed at the application of engineering principles, methods and design concepts to medicine and biology for healthcare purposes, mainly as a support for preventive, diagnostic or therapeutic tasks. Biomedical Engineering professionals are expected to achieve, during their studies and professional practice, considerable knowledge of both health sciences and engineering. Studying Biomedical Engineering programmes or combining pre-graduate studies in life sciences with graduate studies in engineering, or vice versa, are typical options for becoming qualified biomedical engineering professionals, although there are additional interesting alternatives, to be discussed. According to our experience, graduates and post-graduates from more traditional and multidisciplinary engineering programmes, especially industrial engineering, can play varied and very relevant roles in the biomedical industry and in extremely complex biomedical device development projects, even outperforming the graduates from programmes mainly focused in bioengineering. However, such impact of industrial engineers in the biomedical field can be importantly increased, by means of an adequate integration of biomedical engineering design concepts, methodologies and good practices into the traditional engineering curricula.

In fact, according to the Biomedical Engineering Society, a biomedical engineer uses traditional engineering expertise to analyze and solve problems in Biology and Medicine, providing an overall enhancement of healthcare. Students choose the Biomedical Engineering field to be of service to people, to partake of the excitement of working with living systems and to apply advanced technology to the complex problems of medical care. The biomedical engineer works with other healthcare professionals including physicians, nurses, therapists and technician. Biomedical Engineers may be called upon in a wide range of capacities: to design instruments, devices and software, to bring together knowledge from many technical sources, to develop new procedures, or to conduct research needed to solve clinical problems (BMES). The aforementioned duties are directly connected to the traditional corpus of Industrial Engineering (in its broadest sense) and, being applied tasks in direct relation with real and complex problems (pathologies) and systems (human body), can potentially be taught and promoted by means of project-based learning CDIO-related approaches (Crawley, 2007), both within Biomedical Engineering programmes, and in more traditional ones.

In this study we present the complete development and comparative study of three courses, belonging to different plans of study taught at the Technical University of Madrid and benefiting from using a CDIO approach focused on the development of biomedical devices. The three courses are “Development of Medical Devices”, “Bioengineering Design” and “Biomedical Engineering”, respectively belonging to the “Bachelor’s Degree in Biomedical Engineering”, to the “Master’s Degree in Industrial Engineering” and to the “Master’s Degree in Mechanical Engineering”. During the courses, groups of students live through the development process of different biomedical devices aimed at providing answers to relevant social needs. Depending on their background and European credits assigned to the different courses, students carry out more conceptual projects or are able to live through more complete CDIO experiences. Main benefits, lessons learned and future challenges, linked to these courses, are analyzed, taking account of the results from 2014-2015 academic year.

PROMOTION OF CDIO EXPERIENCES LINKED TO BIOMEDICAL ENGINEERING AT TU MADRID BY MEANS OF THREE COURSES IN DIFFERENT DEGREES

The three courses are implemented for the promotion of CDIO experiences linked to Biomedical Engineering in three different plans of study at TU Madrid. In order to promote students' active learning, project based learning strategies are applied, and seminars for the promotion of professional technical and "soft" skills are included, depending on the level of the degree and on the background of students. To provide a common pedagogical background for training bioengineers, mechanical engineers and industrial engineers, capable of working on projects linked to the development of real medical devices, some essential aspects are provided in form of "fundamentals" common to the three subjects. At the same time, as some courses are more basic and some more specialized, different specialization moduli are included to adjust each course to the expected profile and desired outcomes of our students. The more relevant topics of these courses are listed below:

Common Fundamentals:

- Introduction to Biomedical Engineering and medical devices.
- Introduction to sustainability and ethical aspects in Biomedical Engineering.
- Product planning: The relevance of a medical need.
- Conceptual design and creativity promotion.
- Basic engineering I: From the concept to the design.
- Basic engineering II: From the design to the prototype.
- Basic engineering III: Testing and validation of medical devices.
- Detailed engineering: Standardization and safety issues.

Special topics for "Development of Medical Devices"
(4 credits according to ECTS, BSc in Biomedical Engineering)

- Overview on human biomechanics.
- Overview on biomaterials for biodevices.
- Basic computer-aided design seminar.
- Basic FEM-based modeling seminar.
- Cases of study: Complete development of diagnostic devices.
- Cases of study: Complete development of therapeutic devices.

Special topics for "Bioengineering"
(3 credits according to ECTS, MSc in Mechanical Engineering)

- Advanced computer-aided design seminar.
- Advanced FEM-based modeling seminar.
- Special technologies for the mass production of biodevices.
- Micro- and nano-fabrication of biomedical micro- and nano-systems.

Special topics for "Bioengineering Design"
(12 credits according to ECTS, MSc in Industrial Engineering)

- Key aspects in human biomechanics.
- Key aspects in human fluid mechanics.
- Advanced computer-aided design seminar.
- Advanced FEM-based modeling seminar.
- Special technologies for the mass production of biodevices.
- Micro- and nano-fabrication of biomedical micro- and nano-systems.
- Cases of study: Complete development of diagnostic devices.
- Cases of study: Complete development of therapeutic devices.
- Future trends I: Tissue engineering and biofabrication.
- Future trends II: From labs-on-chips to organs-on-chips.

As can be appreciated, all subjects have a similar structure, with a first block linked to engineering design fundamentals, and a second block of specific knowledge and special topics for an improved personalization of each subjects to the expected inputs and outputs. Students from the master's degrees receive more in depth sessions on modeling and simulation technologies, while those from the bachelor degree receive some introductory seminars, as these resources are new to them. In all cases, they are divided into groups (of 2 students in the cases of "Development of Medical Devices" and "Bioengineering" and of 6 students in the case of "Bioengineering Design") and each group faces the development of a medical device. We aim at complete CDIO experiences, although in some cases it is only possible to cover in depth the conceptual and design phases, due to time restrictions. However, in many cases the complete CDIO cycle can be achieved as further discussed in the results section.

In these subjects, the conceptual stages are supported by creativity-promotion tools such as TRIZ, morphological boxes and systematic procedures for promoting the generation, combination and selection of ideas. The design stages count with industrial state-of-the-art modeling and simulation software of main engineering disciplines. In addition, the subjects count with the support of the "Product Development Lab", the "Material Strength Lab", the "Fluid Mechanics Lab" and the "Biosignals Lab", where several design and simulation software, testing facilities and rapid prototyping technologies, usually by means of additive manufacturing and rapid form copying, are available. Such facilities are very relevant for letting students live trough the complete development process of a new medical device, from the conceptual and design phases, to the implementation and operation stages, which are normally more difficult to achieve (Díaz Lantada, 2013). Arduino kits and libraries of sensors and actuators are also available, as well as biomechanical models for performance evaluation.

Regarding students' assessment, it is important to note that the proposed biodevices are complex enough to promote positive interdependence between members of the teams, so that each of the members is needed for the overall success and that there is enough workload to let all students work hard and enjoy the experience, thanks to learning a lot. In addition, we are encouraging individual assessment, complementing the teamwork activities with individual deliveries and during the public presentations of their final results (which account for a 30% of the global qualification). The evaluation of professional skills counts with the help of ad hoc designed rubrics, as part of an integral framework for the promotion of engineering education beyond technical skills, consequence of recent educational innovation projects (Hernández Bayo, et al., 2014), and we are also considering the introduction of peer-evaluation techniques to some extent.

The different courses contribute to the strategy for the overall promotion of CDIO-based teaching-learning experiences and of the related application of CDIO standards, which we are trying to achieve in different degrees. Following the advice from "CDIO Standard 5: Design – Implement Experiences", we are focusing on improving the curricula with two or more design-implement experiences, including at least one at a basic level (as in the case of "Development of Medical Devices") and at least one at an advanced level (as happens with the other two courses taught at Master's level). Even though the detailed experiences correspond to different curricula, it is also true that the "Bachelor' Degree + Master's Degree" structure (which is quite new in Spain) promotes the personalization of Higher Education. Some students may even finish the BSc in Biomedical Engineering and specialize with a MSc in Mechanical or Industrial Engineering, so it is interesting to have incorporated different special topics and seminars, as a complement to common fundamentals. It is also important to note that the proposed projects help to provide, in the different courses, integrated learning experiences, according to Standard 7. Additional details are provided further on.

COMPARATIVE STUDY OF THE THREE BIOMEDICAL CDIO EXPERIENCES: MAIN RESULTS, LESSONS LEARNED, GOOD PRACTICES AND CHALLENGES

The main basic information and results obtained during academic year 2014-2015 carrying out the three biomedical CDIO experiences in the three different subjects already described are summarized below in Tables 1 and 2. Table 1 presents the more relevant figures of the three subjects and details the different projects developed and the time devoted to the different phases of the CDIO. Table 2 presents data linked to success ratios, attendance and other motivation parameters.

Table 1. Basic information about the different subjects and the CDIO experiences linked to the development of biomedical devices. Academic year 2014-2015.

Basic aspect	**"Development of Medical Devices" BSc in Biomedical Engineering**	**"Bioengineering" MSc in Mechanical Engineering**	**"Bioengineering Design" MSc in Industrial Engineering**
Level	Grade (4th Year)	Master's (1st Year)	Master's (1st Year)
Credits assigned (ECTS)	4	3	12
Hours devoted by each student (expected)	100	75	300
Number of students	14	18	28
Number of groups – projects developed	7	9	6
Number of teachers involved	2	2	6
Biomedical devices developed along the different subjects by teams of students, as their central learning experience and the main assessment tool	- App for skin diagnoses - Cell culture device with electrical stimulation - Point-of-care testing device for celiac disease - Autonomous incubator for neonatology - Urine-loss detector - Special wheel-chair - Anti-drowning bottle	- Shoulder prosthesis - Ankle prosthesis - Elbow prosthesis - Knee prosthesis (3 different projects) - Muscle controlled 3D mouse for amputees - Special bicycle for disabled people - Special driver for exoskeleton	- Intra-dermal pump for drug delivery - Extra-corporeal pump for assisted heart surgery - Eardrum protecting device with water detection system - Tissue engineering scaffold for tendon and ligament repair - Device for sleep apnea management - Instrumented artificial heart valve
The projects mainly focus on:	The conceptual stage	The design stage	Whole CDIO cycle
Time devoted to the conceive stage:	60%	30%	25%
Time devoted to the design stage:	40%	70%	25%
Time devoted to the implement stage:	non compulsory, in some cases an additional 20%	non compulsory, in some cases an additional 20%	25%
Time devoted to the operate stage:	non compulsory, in some cases an additional 10%	non compulsory, in some cases an additional 10%	25%

Table 2. Some figures related to student and teacher motivation and implication in the different subjects. Data from academic year 2014-2015.

Control aspect	**"Development of Medical Devices" BSc in Biomedical Engineering**	**"Bioengineering" MSc in Mechanical Engineering**	**"Bioengineering Design" MSc in Industrial Engineering**
Success ratio (student completion rate)	100%	100%	100%
Value of the individual component for the global assessment	10%	20%	30%
Value of the group component for the global assessment	90%	80%	70%
Student attendance to scheduled lessons	>85%	>80%	>90%
Typical number of answers to debate questions	3 – 4	2 – 3	6 – 8
Typical number of student questions / hour	2 – 3	3 – 6	4 – 7
Number of teachers inside the classroom at once	1	1	2 – 4
Frequency of meetings between the teachers of the same subject	1 / month	2 / month	4 / month
Frequency of meetings between the teachers of different departments	1 / month	-	1 / month
Number of interactions with students outside the classroom / week	2 – 3	3 – 4	8 – 10
Resources needed for practical activities	30 – 50 € / student for practical sessions Some students prototyped with their own resources	30 – 50 € / student for practical sessions Some students prototyped with their own resources	75 – 100 € / student for practical sessions 750 – 1.000 € / group for prototyping tasks
Number of professional skills promoted and assessed	4	4	9
Hours devoted by the teachers outside the classroom / class hour	1 – 2	1 – 2	3 – 4
Students living a whole CDIO cycle	33%	15%	100%
Students aiming at enterprise creation based on their results	8%	5%	20% (with one group as finales of UPM Enterprise Creation Competition)

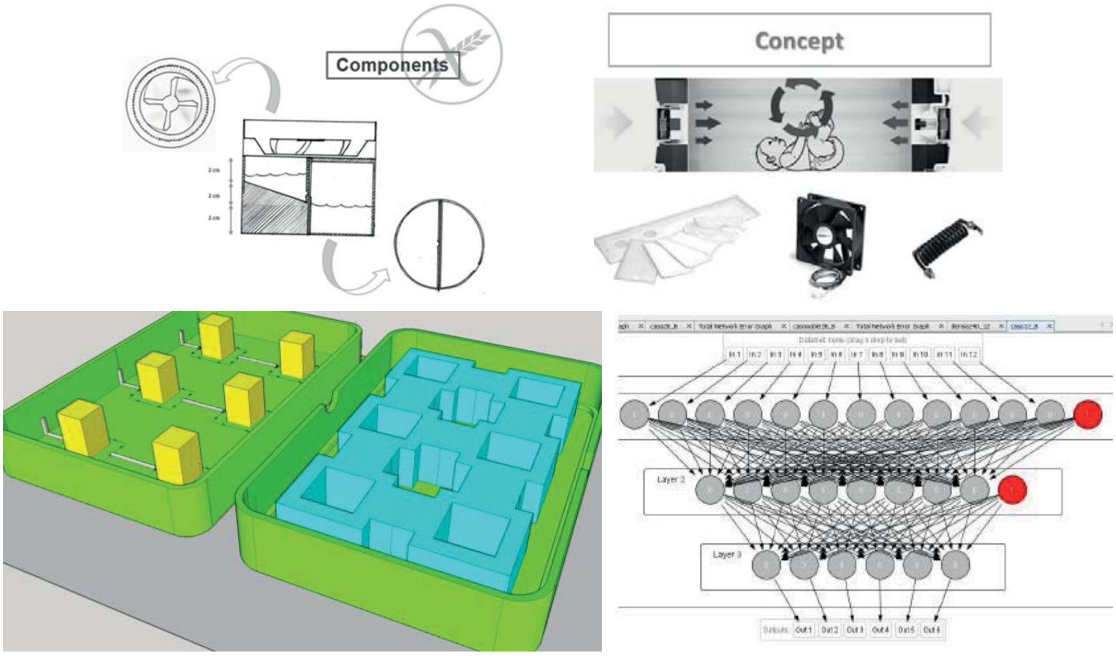

Figure 1. Examples of final results from different projects performed within the "Development of Medical Devices" course at the BSc of Biomedical Engineering. a) Point-of-care testing device for alergies. b) Autonomous incubator for neonatology. c) Cell culture device with electrical stimulation. d) App for skin diagnoses.

Figure 2. Examples of final results from different projects performed within the "Bioengineering" course at the MSc of Mechanical Engineering. a) Elbow prosthesis. b) Mouse for amputees. c-d, f) Knee prostheses. e) Ankle prosthesis.

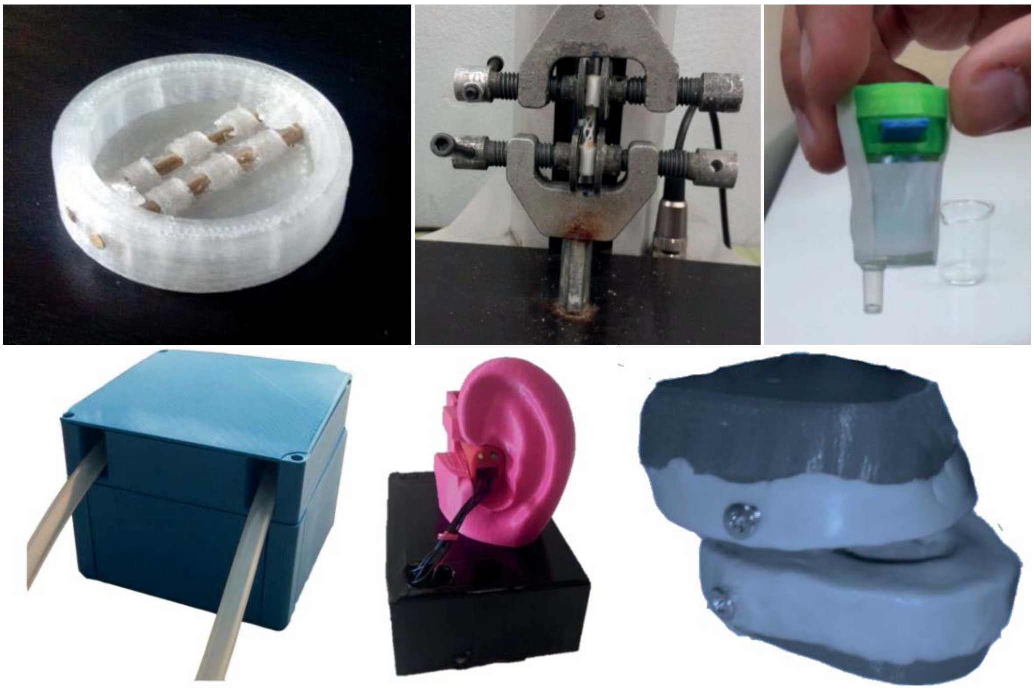

Figure 3. Examples of final results from different projects performed within the "Bioengineering Design" course at the MSc of Industrial Engineering. a) Instrumented heart valve. b) Scaffold for tendon repair. c) Intra-dermal micro-pump. d) Extra-corporeal pump. e) Ear-protecting device. f) Sleep apnea monitoring system.

Thanks to implementing the CDIO approach, students taking part in these subjects lived, for the first time, through the complete development process of an engineering system and are now better prepared for their final theses, as students themselves have highlighted in several occasions during these subjects. Some significant examples are provided in Figures 1, 2 and 3. In addition, they received, again for the first time, training in relevant engineering resources and improved their comprehension and application of several professional skills, all of which adds to the learning outcomes of these subjects. The experiences have been extremely rewarding, both for students and teachers, leading in some cases to spin-off proposals and to final degree theses.

As additional reflection, the proposed two-semester structure for the subject on "Bioengineering Design" is very appropriate, as the "conceive" and "design" phases are adequately carried out during the first semester and the "implement" and "operate" stages are tackled in the second semester. A whole academic year is ideal for maturing the development process of complex products and systems and provides better results, in terms of complete CDIO experiences, than in the one-semester cases of "Bioengineering" and "Development of Medical Devices". In the one-semester courses, only some motivated students are able to reach the implement and operate phases. In any case, the concepts provided by the "Development of Medical Devices" students and the designs provided by the "Bioengineering" students have been carried out with a remarkable degree of proficiency and leading to very interesting results. In any case, it seems interesting to focus mostly on the conceptual phase along the more basic subject on "Development of Medical Devices", while the more advanced subjects at Master's level clearly benefit from concentrating on the design and implementation phases, where students can apply more specific knowledge. Fulfilling the complete CDIO cycle is challenging, but can be achieved if students are well motivated and if teachers help them with a tight control of deadlines and an adequate planning.

Regarding CDIO standards, we have considered several of them for the design of the different teaching learning experiences. All the subjects are connected with standards 1-3, as the three programmes are evolving towards CDIO-based curricula and these subjects provide support to these transitions, as complementary CDIO experiences to the more traditional and common final degree projects. Standards 9-10 are also taken into account: The professors' attendance to CDIO congresses and the promotion of international teaching and research collaborations are part of our compromise with the enhancement of faculty competence. The subjects are implemented as integral learning experiences and promote active learning, in connection with standards 7-8, and the assessment of outcomes are linked to national and international accreditation procedures of the different programmes, which is linked to standard 11.

CONCLUSIONS

In this study we have presented the complete development and comparative study of three courses, belonging to different plans of study taught at the Technical University of Madrid and benefiting from using a CDIO approach focused on the development of biomedical devices. The three courses are "Development of Medical Devices", "Bioengineering Design" and "Biomedical Engineering", respectively belonging to the "Bachelor's Degree in Biomedical Engineering", to the "Master's Degree in Industrial Engineering" and to the "Master's Degree in Mechanical Engineering". During the courses, groups of students have lived through the development process of different biomedical devices aimed at providing answers to relevant social needs. Depending on their background and European credits assigned to the different courses, students have carried out more conceptual projects or have been able to live through more complete CDIO experiences. Main benefits, lessons learned and future challenges, linked to these courses, have been analyzed, taking account of the results from 2014-2015 academic year. Following a CDIO strategy has enabled students to live, for the first time, through the complete development process of engineering systems, linked to the biomedical field, and are now better prepared for their final theses and professional life.

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CDIO Standards 2.0: http://www.cdio.org/implementing-cdio/standards/12-cdio-standards

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ADAPTATION OF THE CDIO-FRAMEWORK IN MANAGEMENT COURSES FOR ENGINEERING STUDENTS - A MICRO-LEVEL APPROACH

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ABSTRACT

The CDIO-Framework is developed in order to enable engineering students to engineer (Crawley et al 2014) and is relatively straightforward when applied on courses and projects that have a high degree of practical, hands-on engineering elements, such as e.g. developing software or a physical product/prototype. However, in many engineering programs a large part of the courses concern managerial aspects such as project management, leadership, marketing, innovation and entrepreneurship, especially in later years of a program. We are well aware of the fact that the CDIO-framework is developed to work on program-level, however, applied on management courses, commonly only the Conceive and Design can be obtained. Furthermore, these courses are not always structured in such a way that they immediately builds on each other. This dilemma has caused us to adapt CDIO to circumstances of the courses that we give and to reflect upon how more of the CDIO spirit can be transferred to our own modules and activities on course level. The aim of this paper is therefore to develop ways for application on a micro-level where the CDIO spirit can be implemented in management courses at engineering programs. In the paper we give three different practical cases where the CDIO-framework have been applied. The cases show that CDIO works both on micro-level, e.g. in two hour exercises and within the frame of individual courses. For management courses, and especially courses in entrepreneurship and marketing, the framework need to apply a more extrovert focus, i.e. on verification of customer needs and benefits, rather than on technological solutions.

KEYWORDS

Micro-level CDIO, CDIO in management courses, extrovert approach on CDIO projects, Standard 8: Active Learning

INTRODUCTION

The CDIO-Framework is developed in order to enable engineering students to engineer (Crawley et al 2014). According to the CDIO-website (www.cdio.org), the CDIO-framework "is based on a commonly shared premise that engineering graduates should be able to: Conceive – Design – Implement – Operate". Conceive implies that the students should be able to achieve a comprehensive view over - and an understanding of - the context. This includes i.e. the underlying needs or problems from which the CDIO-project is to be planned. The design part is about forming and creating a solution that fulfills the needs, or solves the problems, identified in the previous phase. After this the implementation phase occur, and at this stage the activities is about test and verification - i.e. to make sure that the solution works. In the final phase - operate - the students "go live" with their solution. Following this chain of activities makes CDIO a very hands-on approach to learning while solving relevant problems. Furthermore, and according to Crawley et al (2014) active learning is an important part of the CDIO-framework. The students need to engage and take responsibility for their own learning, as well as for the learning of their colleagues. The use of mixed methods for learning is recommended as way to facilitate the level of activity, engagement and learning among the students (Norrman, et. al 2014).

The CDIO-framework has gained ground in engineering education all over the world and it is closely related to the thoughts of Biggs (2003). Biggs divide between declarative, i.e. theoretical knowledge and procedural (practical). When combined they generate conditional knowledge, i.e. knowledge of what theory that solves what problem and how this is done. The final step in the pyramid of Biggs is Functional knowledge, where a person is experienced and masters an area. The CDIO-chain, as framework for learning, is relatively straightforward when applied on courses and projects that have a high degree of practical, hands-on engineering elements, such as e.g. developing software or a physical product or prototype. However, in many engineering programs a large part of the courses deal with managerial aspects such as project management, leadership, marketing, innovation and entrepreneurship, especially in later years of a program. We are aware of the fact that the CDIO-framework is developed mainly for application on a program-level, however, applied on management courses, commonly only the phases "Conceive" and "Design" can be obtained within the frame of single courses. Furthermore, these courses are not always structured in such a way that they immediately build on each other, which in turn implies that the whole CDIO-chain cannot be obtained regarding these management oriented subjects even on a program level. This dilemma has caused us to adapt CDIO to circumstances of the courses that we give and to reflect upon how more of the CDIO spirit can be transferred into modules on a micro-level, e.g. exercises and activities that are not immediately connected to engineering per se.

Another phenomenon that we have noticed regarding the CDIO-chain is that it, to high degree, is compatible with the traditional product development chain, which according to authors such as Blank & Dorf (2012) works well in established firms where customer needs are identified and known, but works less well for innovative startups that not yet have verified that their ideas corresponds to the need of their customers. If the CDIO syllabus is regarded, this might be a shortcoming if entrepreneurship and innovation is aspired for, as is also noted in the second version of the CDIO Syllabus (Crawley et al 2011).

If it is important that our engineering students also should be able to innovate, or at least engineer in innovative contexts, verifications and tests needs to be expanded to cover also marketing aspects. Lean product or concept development could be used for this purpose, e.g. Minimal Viable Product approaches (cf. Eric Ries, 2011) that strive towards launching what e.g. Philip Kotler and Theodore Levitt referred to as “the core product” in their layer-based product models (Frankelius et al, 2015). An MVP-approach requires agility, iteration in fast loops in order to verify that the customer needs are as close to real as possible.

The aim of this paper is therefore to develop ways for application of the CDIO approach on a micro-level where the CDIO spirit can be implemented also in management courses at engineering programs.

Below we present three types of cases from our own teaching experience: one 2 hour exercise case, one real-life project case and one case concerning pedagogic experiment about including reality encounter. After each case description the case is connected to the CDIO framework.

CASE 1: “THE COLORING BOOK FACTORY”, A 2-HOUR CDIO-EXERCISE

“The coloring book factory” is an experience-based exercise where students learn about how different forms of work tasks can require different forms of organization, i.e. organic organization versus mechanistic organization. This exercise is a part of an organization management course given to first-year engineering students. For the purpose of this exercise the students are divided into groups of about 6-8 individuals. One observer (i.e. a person that does not participate actively in the exercise but observes and writes down what happens in the group) is also assigned per group. The exercise is done in two stages - the design stage and the mass-production stage (lasting 20 minutes each). To complete the exercise each group is given 8 crayons in 8 different colors and four bunches containing 20 preprinted A4 - front pages with an uncolored picture of a castle and the text “Coloring book”. The observers are informed of their task and they are given a form for their observations. The students receive written instructions in the beginning of the exercise, telling about the two steps, the time frames and the prerequisites and rules of the game.

When the first part is finished the students are sent on coffee break and the observers together with the teachers select the winning design. At this moment it commonly becomes obvious that some groups have staked for quality by means of looks and others for efficient production. The selected design commonly represents the best compromise between an attractive and a mass-production-friendly design.

In the second stage each group receives a copy of the winning design and they are given 5 minutes to plan the mass-production phase. At this stage they are allowed to buy extra production equipment (i.e. more crayons). As the mass-production starts they realize that the time frame is short. That implies that they need a leader and that they need to trim the production line. Commonly they also realize that they need quality control functions.

After the exercise is finished calculations of economy are done based on a price list received by the groups at the beginning of the exercise. Points are awarded per completed front-page and points are deducted for extra crayons (if the group has decided to buy any). The winner is the company that have earned the most. When the winner is designated the observers share their observations and the students discuss, both within the smaller groups and in class what happened during the exercise.

The coloring book factory exercise from a CDIO-perspective

This micro-level exercise gives us an opportunity to apply all steps of the CDIO framework to a single course activity. Both the product - the book cover - and the organization of the group develop during the exercise following the CDIO pattern.

For example the first two steps, Conceive and Design, can be seen as happening when students are given opportunity to analyze the instructions and rules of the game and from that plan their work and create strategies. This happens both before the design stage and before the mass-production stage. During these both stages both Implementation of plans and strategies, as wells as Operation where the strategies are tested and re-developed, are taking place. In parallel, Conceive and Design are also happening when the uncolored page is developed into a design proposal during the design stage. Here the students have to make strategic choices between quality aspects and aspects important for efficient mass production.

When both stages are completed, students’ learning is enhanced through discussions facilitated by the observers and the teachers. The teachers also highlight relevant organization theory that helps to explain what happened and what worked well during the exercise. Having the possibility to go through all four steps of Conceive-Design-Implement-Operate in one session creates a memorable learning experience that despite its seemingly simple tasks delivers vital insights into the pitfalls and success factors of organizing for creativity and for mass-production respectively.

CASE 2: PROJECT MANAGEMENT AND REAL-LIFE THESIS PROJECTS - A CDIO-INTEGRATED APPROACH

During their third year of studies our engineering students write theses for a Bachelor’s degree. In one of the engineering programs this is done in collaboration with firms located throughout the region meaning that the students work with real-life challenges that actual firms struggle with and get to visit their firm multiple times during the semester. The first part of the thesis writing consists of an initial project done in groups of 6-8 students where an overview of the firm and its challenges is created. During the second part the students work in pairs and write a scientific report based on a selected real-life challenge that the firm needs support with.

Our case involves the first part - the initial project - and deals with successful integration of learning about project management into the process of thesis writing itself. The project stretches over 15 weeks and begins with the student group receiving a mission statement that has been developed by the firm together with course teachers. Received mission statements range from vague to very broad to more specific - depending on factors such as developmental stage of the firm itself, its size and complexity, etc.

During the project the groups' main tasks include deciding and motivating a realistic scope for the project, planning and giving time estimates for project activities (e.g. collecting data), presenting their progress to a steering committee consisting of the course teachers, following up activities and fulfillment of goals, as well as providing the firm with proposals for further action. The projects are run as professional projects with one of the group members being assigned the role of project manager, a pre-study and a project plan, tollgate meetings with the steering committee, logging of work hours dedicated to the project, and a project report. This process is supported through a few traditional lectures on project management, as well as a textbook, but the most important learning experiences happen when the students work hands-on with project management tools applied to their actual real-life projects.

Throughout the project there are four tollgate meetings at set dates. For these meetings specific deliverables are prepared and presented by the project groups (e.g. the project plan on the second meeting). Before each tollgate meeting there is a "test presentation" session where students do a trial run of their presentations intended for the steering committee in front of each other as well as a teacher in communication. After these test presentations the students receive feedback on both their power point and the oral presentation and have the possibility to adjust these before meeting the steering committee on the following day.

The project ends with a conference where firms' representatives as well as all involved teachers participate. Every group presents their results both in a short written report, on a poster and orally. Firms' representatives get the opportunity to ask questions and learn more about the other participating firms and their project results. After the conference the groups write a report summarizing how they applied the project management tools and what they have learned.

Integrated project management course from a CDIO-perspective

As academic teachers we work within strict time constraints and we constantly try to convey more and more material in a limited amount of time. The type of course described here gives us an opportunity to include a lot of different types of learning in one course. The approach with integrated project management and real-life projects contributes greatly to the development of personal and professional skills and attributes highlighted in the CDIO Syllabus (Crawley et al 2011), e.g. task prioritization, making decisions in face of uncertainty, professional courtesy, as well as trust and loyalty. Furthermore, this approach also focuses on development of interpersonal skills connected to teamwork and communication, e.g. team operation and growth, networking, oral presentation, and advocacy. Simultaneously, the projects entail learning about the external context and business context through working with real-life projects while also letting the students engage in a conceive-design-implement process.

Many of the above skills can otherwise be considered difficult to fit into a pressed schedule of an engineering program, yet this approach lets us develop these skills while working on a program-relevant project. The students find this course demanding and confusing at times, however they are always proud of the end result and their own growth in their professional role.

From the teachers’ perspective the course is unpredictable since firms and real-life projects are involved. It is also a time-consuming process to find firms with interesting challenges that have the possibilities to engage with students on a project. Ultimately the course is very rewarding - for both students and teachers and we continue to develop this concept further with each edition of the course.

CASE 3: CDIO-INSPIRED MARKET RESEARCH COURSE

One philosophy at Linköping University is the ambition to stimulate both inter-disciplinary and trans-disciplinary knowledge. By inter-disciplinary knowledge we here refer to mixing of different scientific disciplines. In the educational context that means students can choose courses from a broad palette. It is notable that the Department of Management and Engineering include many disciplines at the same place, for example technology, entrepreneurship, business administration, economics, political science and juridical science.

By trans-disciplinary knowledge we refer to the ambition to mix academic and practical knowledge. In educational context this is expressed by giving students the opportunity to learn both academic and practical knowledge.

In combination inter-disciplinary and trans-disciplinary knowledge form something that we have called intra-disciplinary knowledge (“in” from inter and “tra” from trans). See figure 1.

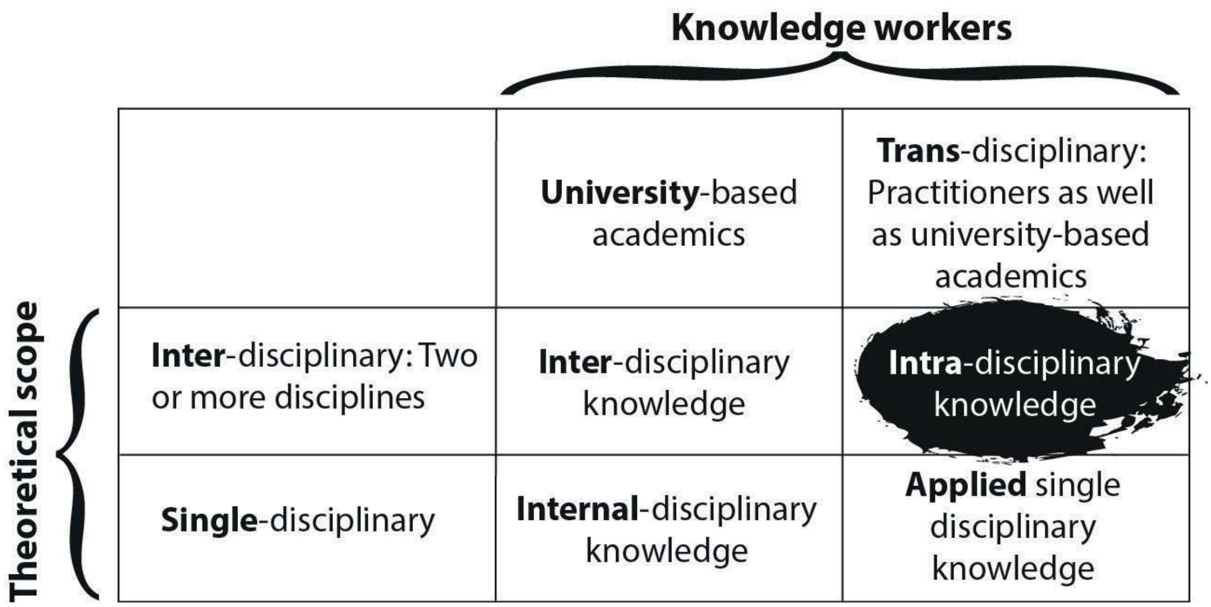

Figure 1. Matrix model describing theoretical scope vs. kinds of knowledge workers.

One illustration of the mentioned knowledge philosophy (intra disciplinary knowledge) was our experiment conducted in 2016 in the business administration course Marketing and Consumer Behavior. The class consisted of about 50 students from countries such as France, Germany, Sweden, Australia, Spain, England, Peru, Taiwan, China and Switzerland.

In the experiment students had to investigate consumer behavior and motivational factors behind certain behavior. In CDIO language, the students should design a solution to the mysterious problem of understanding real-world consumer behavior in the farming business. We focused on products with probably high customer involvement because the product is important and expensive. We also focused on a certain sector in which products could be assumed to be important both for business use and pleasure, and we here connected to an on-going research project at Linköping University (the Grönovation project). The product category was farm tractors. The idea came from Christoffer Anderson, CEO at The Rural Economy and Agricultural Society in East Sweden region. He wanted a solution to the mysterious problem of farm tractor buyer's behavior. The student's team mission was to identify 5 persons that have bought a new farm tractor during the last year. The information on each person (case) should then be collected by means of visits, telephone conversation or mail correspondence (or combination of these methods). Questions to be analyzed were the following:

- Why did the tractor buyers choose to invest their money in a tractor instead of something else?
- Why did they choose the specific brand among tractors?
- Why choosing that size (= price level) of tractor?
- What is special with the tractor brand chosen (according to the customer)?
- What do they say about the value-price relation?
- How, in short, did the buying process occur?

Planning for this work can be seen as Conceive and Design in CDIO language. The students were asked to write a report on their findings. After the empirical result students should have an analysis section in which they related their main empirical findings to well-selected concepts and models found in the course literature. In the middle of the work period, each student team had the opportunity to present their work in progress to the rest of the class and get feedback on how to proceed in the best way. The conduct of the investigation, fieldwork, as well as writing of the report was inspired by the CDIO frame of reference.

The way we organized the final seminar could be of general interest because it was an example of Implementation and Operation in CDIO language. We co-operated with Vreta Kluster, an innovation platform outside Linköping. Students presented their findings to other students, the course director and not least practitioners. The practitioners from the farming industry became an "authentic test platform" for the ideas that the students had developed. Some of these practitioners worked with trading tractors, so the students got the opportunity to bring their results into operation. By operation (in CDIO language) this was not only student operation but also a potential for practitioners operation.

CONCLUDING DISCUSSION

The cases described above show how the CDIO-approach can be elaborated on so that it fits both single exercises, (e.g. the coloring book factory) and can be integrated within the frame of a thesis-writing course. The third case shows upon that the “operate” phase can benefit from benchmarking with actors outside the university. Our preliminary conclusion is that the CDIO approach can successfully be adapted to the micro-level, and this can bring a lot of benefits to engineering students.

The examples, upon which we have applied the CDIO-framework, is not typical engineering applications - rather it is examples coupled to management issues. This rise the question of whether CDIO could also be useful outside an immediate engineering context. We think so. To us the framework is almost as universal as the initially referred work of Biggs, i.e. the knowledge pyramid, in which theoretical and practical knowledge, through application and experience, can create the type of knowledge we want our engineers to have - i.e. that we want them to be able to engineer. If we assume that engineering abilities consist of more than construction, e.g. creativity, entrepreneurship and new ways of thinking and combining knowledge and skills, into new and innovative items, it is of great importance to apply the framework also on management related subjects. Just inventing is not enough to become an innovator, the latter requires diffusion, and diffusion requires management.

As teachers, we find the CDIO approach useful when planning both course modules and single activities. We would like to highlight that it can be challenging to go from traditional teaching and learning methods to a CDIO-based approach - both for students and teachers. Introduction of new types of learning requires communication and support throughout the process, especially when the students meet this concept for the first time. Nonetheless, the leaps in development that we observe in our students make it very rewarding and motivating for us to continue to use and develop the framework and its applications.

We also want to highlight that the CDIO can gain ground also in managerial courses e.g. those focusing on marketing and entrepreneurship. But in such courses especially the implementation phase will put more focus on verification of customer needs and benefits and on verification of the business model, than on the technology used or the technological solution. This means that in such courses CDIO needs a more extrovert focus. Such processes are also highly iterative, which means that the students need to use agile approaches.

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CDIO AS BLUEPRINT FOR COMMUNITY SERVICE ENGINEERING EDUCATION

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ABSTRACT

This paper is a case report of why and how CDIO became a shared framework for Community Service Engineering (CSE) education. CSE can be defined as the engineering of products, product-service combinations or services that fulfill well-being and health needs in the social domain, specifically for vulnerable groups in society. The vulnerable groups in society are growing, while fewer people work in health care. Finding technical, interdisciplinary solutions for their unmet needs is the territory of the Community Service Engineer. These unmet needs arise in local niche markets as well as in the global community, which makes it an interesting area for innovation and collaboration in an international setting. Therefore, five universities from Belgium, Portugal, the Netherlands, and Sweden decided to work together as hubs in local innovation networks to create international innovation power. The aim of the project is to develop education on undergraduate, graduate and post-graduate levels. The partners are not aiming at a joined degree or diploma, but offer a shared short track blended course (3EC), which each partner can supplement with their own courses or projects (up to 30EC). The blended curriculum in CSE is based on design thinking principles. Resources are shared and collaboration between students and staff is organized at different levels. CDIO was chosen as the common framework and the syllabus 2.0 was used as a blueprint for the CSE learning goals in each university. CSE projects are characterized by an interdisciplinary, human centered approach leading to inter-faculty collaboration. At the university of Porto, EUR-ACE was already used as the engineering education framework, so a translation table was used to facilitate common development. Even though Thomas More and KU Leuven are no CDIO partner, their choice for design thinking as the leading method in the post-Masters pilot course insured a good fit with the CDIO syllabus. At this point University West is applying for CDIO and they are yet to discover what the adaptation means for their programs and their emerging CSE initiatives. CDIO proved to fit well to in the authentic open innovation network context in which engineering students actively do CSE projects. CDIO became the common language and means to continuously improve the quality of the CSE curriculum.

KEYWORDS

community service engineering, interdisciplinary, blended, education, open innovation, CDIO standards: 1, 2, 6, 7, 8, 9, 10

INTRODUCTION

Technology plays an important role in facing societal challenges. Engineers can contribute to the development of solutions, provided that they are aware of the context and willing to amplify their participatory skills. In 2010 a UNESCO report (Unesco, 2010) already affirms the role of engineering as the driver of social and economic development and innovation. However, it also stresses the need to transform engineering education, both curriculum and teaching methods, to emphasize user relevance and a stronger problem-solving approach.

In Lifelong Learning Project 539642 'Community Service Engineering (CSE), ('Community Service Engineering', 2015) five Higher Education Institutions (HEIs) have teamed up with the non-governmental organization RVO Society to collaborate in engineering curriculum development focusing on the social domain. The project partners are the University of Applied Sciences Thomas More (coordinator), RVO Society and KU Leuven from Belgium, The Hague University of Applied Sciences from the Netherlands, the University of Porto from Portugal and University West from Sweden. The RVO Society aims to interest youth (aged five to twenty-five) in socially relevant technology and science, and connects businesses and clients who have unmet needs to young educational and informal learning groups who want to develop solutions. Through their Cera Award RVO Society launches a call for projects to the social sector three times a year. They do this by mailings to the Flemish social profit organizations, and via umbrella organizations in the sector. Social sector organizations can formulate any technical scientific problem from within their organization. This covers a wide rage of topics such as energy, ICT, communication, mechanical or electrical problems, design projects etc. Working with their client the young developers co-create new technological applications that fulfill the needs and thus create a sustainable and more inclusive society. Every year the most promising project receives the Cera Award. A collaboration between Thomas More and the Cera Awards showed that even very motivated engineering students often struggle to create solutions that truly fit the needs of their clients. The world of engineering students and the engineering education context surrounding them is different from the organizational structure and issues playing within the social sector. This makes it difficult for engineering students to bridge that gap with empathy and really get to the bottom of the problems and needs of the social sector. This insight was the inspiration for the European CSE project. The main goal of this project is to develop, pilot and offer an international (postgraduate) course in Community Service Engineering, worth 30 European credits, with a translation to graduate and undergraduate education.

Community Service Engineering

CSE is defined as the engineering of products, product-service combinations or services that fulfill well-being and health needs within the social domain, and specifically those of vulnerable groups in society such as elderly, intellectually-, physically- or sensory disabled, chronically ill people, people with an addiction, youth at risk, detainees, people living in poverty, and people from a different migration background (Dekelver, Vervoort, Cosemans, Van Petegem & Rombouts, 2013; Hallenga-Brink & Vervoort, 2015). The vulnerable groups in society are growing, and so are their special needs. In the EU however, policies and social institutional structures are directed towards self-sufficiency and longer independence of the population, including these vulnerable groups, as fewer people will work in health care due to the ageing population (Van den Bosch, Heij, & Volberda, 2013). Finding technical solutions for the unmet needs that result from this tendency, both for the vulnerable groups and their formal and informal caretakers, is the domain of the Community Service Engineer. Formal healthcare technology and projects for newly developing countries (international humanity programs) are not part of the core of CSE, although cross links with such projects can occur. The enterprises that CSE works with are primarily non-profit or social profit organizations. In some cases, it can be profit organizations as well, as long as the products and services are developed for improving the quality of life of vulnerable groups in an ethical way. The CSE domain covers many different sectors: sheltered workplaces, special youth care, organizations working with people with disabilities, family care, youth welfare, child & family services, centers for social and general welfare, special education and housing, rehabilitation centers, community development, socio-cultural sector, social workplaces, employment, home care services, residential and care centers etc. Engineers can work with a variety of technologies depending on the needs they are addressing.

In need of a new approach

The Unesco report (Unesco, 2010) suggests transforming engineering education, curricula and teaching methods to emphasize relevance and a problem-solving approach to engineering including challenges such as poverty reduction and social development. Young people are likely to be more attracted to make a difference in the world through an engineering career than by the challenge of mathematics and science skills (National Academy of Engineering, 2008). Young people worldwide are motivated by the prospect of getting a job that fits their attitudes and values (Sjøberg & Schreiner, 2012). The results from Sjøberg and Schreiner's Rose project confirm the importance of values, attitudes and meaning. Girls especially, in all cultures, seem to value these aspects more than boys do. Yet, the contributions engineers make to a better society do not come to mind when young people think about studying engineering. Traditional engineering education does not offer a lot of opportunities and time for engineering students to get to know the social sector. Most of their education focuses on the acquisition and development of technological, disciplinary knowledge. Even if project work is an important part of education, it is often technology-driven instead of user-need driven.

As the general image of the engineering profession does not reflect social and societal components, there is a need for a new approach. This approach should offer (future) engineering students a vision of a profession that makes a difference in people's lives and operates in a meaningful context. CSE aims to offer this context in a curriculum that is based on educational concepts that match this ambition. The question is which engineering education blueprint or framework best fits the authentic open innovation network context in which undergraduate, graduate and post-graduate engineering students can learn by doing and preferably realizing CSE projects within their HEI or even in collaboration with other HEIs, and in collaboration with stakeholders.

THE EDUCATIONAL VISION OF COMMUNITY SERVICE ENGINEERING

First of all, combining engineering with the social domain requires not just a multidisciplinary, but rather an interdisciplinary approach of education. In order to learn to understand and be able to be an actor in the social domain, engineers must learn to speak the language of its professionals, end-users, educators and fellow students of social studies, and thus interact with them. This goes further than being able to do research on the requirements of stakeholders in the design phase, and then proceed with engineering, which is the multidisciplinary approach we see more often in current (project-based) engineering education. So although CSE focuses primarily on engineering students, students from other departments are seen as co-creators, together with stakeholders from both the social and technical domain and educators.

The knowledge generated by HEIs is commonly presumed to ‘find a way to society’, but dissemination is not always timely, complete or effective (Chesbrough, 2003). In the open innovation approach that Chesbrough suggests all stakeholders involved become experts by collaborating and together they generate feasible, desirable and viable innovative design. In this set-up knowledge generated at a HEI is disseminated right when and where it is applicable and in case of the social domain, often highly needed (Amsterdam University Press, 2013; Beumer, Kips, & Mulder, 2011). Moreover, the primary role of a HEI at undergraduate and graduate level is typically considered to be ‘creating a good learning experience for students’ and ‘preparing students for a career in research or a professional position with more responsibilities’. With changes in Western society such as the shifting demographical distribution of age and the resulting decreasing size of our workforce, especially in government and healthcare (Van den Bosch et al., 2013) gaps in innovation and R&D power could be filled up by HEIs in Chesbrough’s co-creational approach. In the near future higher education needs to provide for a sustained power of innovation for the organizations they collaborate with and for society in general.

The perspective on authentic learning changes considerably in that sense. Not only is it a very stimulating environment for learning effectiveness and to enhance student creativity and empathy (Nicholl, Flutter, Hosking, & Clarkson, 2013), it will also become a necessity to solve real life problems. In the next ten to fifteen years the focus of engineering student internship or graduation projects will shift towards truly solving societal (sub)problems, even as a small contribution to a bigger and longer open innovation process the student’s HEI is involved in on the long-term. This adds transformation research and transformation design to the mix of open innovation and co-creation. The term “transformation design” is used for work within communities for socially progressive ends, introducing a human-centered design approach (Burns, Cottam, Vanstone, & Winhall, 2006). Transformation research starts with activating the agents (stakeholders), defining intervention at community scale, and building capacities and partnerships. By re-distributing power and enhancing imagination and hope, ideas can be made concrete and infrastructure and enabling platforms can be built. Success and impact should always be evaluated at the end of the cycle, and new partnerships can be formed based on the outcomes (Sangiorgi, 2011). Based on experiences at THUAS, it takes six to eight years before the fruits of such projects can be truly harvested. But plenty of learning opportunities in a real context are present within this timespan for students.

Role of the teacher

Amongst others, safeguarding the long term interests and expectations of network partners within an open innovation project and not having students reinvent the wheel year after year are stakeholder management skills that teaching and research staff must (learn to) master. There will be a new and challenging role for teachers in an international learning environment, that will function as a lifelong learning environment. Traditional teaching competences may not be enough. Teaching staff needs support to redefine their role in open innovation projects and the 21st century skills they need for it. Engineering educators and the social domain partners do not typically speak the same language either, which leaves a lot of innovation potential within student projects untouched. The HEI functions as a facilitator of the learning process for all. It can integrate long-term projects in fragments in education, making students work on in between tasks in the authentic context, while guarding the continuous learning of the overall process for all the stakeholders (client, users, researchers, students). In this way the client (and user!) will not be left without a tangible result. The teachers’ role will thus have different dimensions: facilitators of lifelong/network learning environments, connectors between the social profit sector, businesses and students, coaching students in their self-directed learning, supporting students in the acquirement of international-intercultural and transversal competences, providing insights or inspiration (technologies, case studies, needs of social profit sector) at pivotal, just-in-time moments, and formulating cases out of the students' projects and making learning material out of it. Much more reciprocal learning will take place. Teachers could have an additional role to link the different fields of study and faculties within the HEI, providing insights in recurring needs in the social profit sector (and thus having market potential), and providing insights in existing technology in the market and companies looking for market potential in the social profit sector (and thus providing possible solutions for formulated needs).

Design Thinking

In the CSE project this demand-driven, authentic educational vision is applied, and unmet needs are actively searched for in the social domain, via the networks around the participating HEIs and in collaboration with the RVO Society in Belgium. Students that follow a CSE course develop solutions in co-creation for the unmet needs in the social domain: they learn to interact with clients and users in a human-centered, design thinking approach and let them participate in the creative process. To structure this process, design thinking methods are used from IDEO (IDEO, 2015), including blended materials such as online templates.

Razzouk and Shute (2012) list a number of characteristics of a design thinker: human- and environment-centered, able to visualize, predisposed towards multi-functionality and multiple angles, systemic approach, able to use language as a tool, a team player, and able to deal with the uncertainty of delaying choices and combining new configurations first. These characteristics give insight into the nature of design thinking. An innovative design process is iterative, exploratory, and sometimes chaotic. It starts from a certain need or problem, captured in the first stages in a design brief, and results in the description of a product while gradually refining its sometimes conflicting, changing specifications. Innovative design follows cycles of mutual adjustment between specifications and solutions until a final solution is reached (Hatchuel & Weil, 2009). At all times the user and stakeholders are involved.

Design thinking is key to the community service engineers to prepare them to deal with difficult situations and solve the complex problems in the social domain, without losing overview. Enhancing students' design thinking skills may be achieved through incorporating authentic and intriguing tasks (Razzouk & Shute, 2012) and providing them with many opportunities to apply design processes.

International context in undergraduate, graduate and post-graduate CSE education

It is a challenge within the CSE project to set up such an interdisciplinary, open innovation, human-centered, design-thinking approach in an international context. The benefit of an international setting is that it can help to enlarge the sometimes small, local markets within the social domain. The actual implementation of the CSE curriculum differs per partner, depending on the existing institutional and education constraints. An online platforms can be of support by offering project databases, online course elements and social interaction between students (Hallenga-Brink & Vervoort, 2015). It is not the aim to form one joined degree or diploma. Instead Community Service Engineering will be an element of engineering education programs at the partner universities. Resources will be shared and collaboration between students and staff is organized at different levels. CSE is offered on post-graduate, graduate and undergraduate level within the partners, but this does not mean cross-fertilization cannot take place when students are dealing with similar design challenges. Other options are to implement elements of shared resources and educational concepts into the existing curricula of engineering education at the different partner institutions. The option to translate the post-master's curriculum into undergraduate curricula are implemented at Thomas More, The Hague University of Applied Sciences and University West. At Thomas More, students receive a diploma supplement "Socially Ingenious" at the end or their 3 years of study if: (1) they take an extra course "socially ingenious" (3 additional credits); (2) choose during the 1st or 2nd phase of their studies assignments that carry the label 'socially ingenious' and (3) add to that a bachelor thesis project with a clear social dimension ('Socially Ingenious | Thomas More', 2015). At the University of Porto Community Service Engineering is integrated into the master program of engineering education. At KU Leuven (Belgium) the 30 credit post-graduate course "Community Service Engineering" is open to all international (life long learning) students with a Master's degree in Engineering.

In this light an experiment with a joint database of projects is being carried out, which provides information on possible collaborations and types of projects done at the partner universities. Different tools and technologies are selected for effective blended learning, including (pedagogical) models and scenarios for multi-campus education and successful e-coaching methods. For the international transfer and sharing of knowledge, experiences and results within the CSE projects, a virtual learning context has been set up in FeedbackFruits, where co-creation networks can be in digital dialogue with each other during projects, share documents and movie clips, have access to the CSE repository of knowledge clips and sources that are built up, and share experiences and good practices with each other and students. This virtual context is by no means a replacement for the authentic learning environment in which the CSE students will truly learn how to work in the social domain and find solutions. But it is a valuable support system, fit for the 21st century, making it easier to obtain still scant knowledge in socially engaged engineering's niche markets.

DRIVERS FOR ADOPTING CDIO IN CSE

In order to fit the different courses in CSE at the partner universities to one another in a way that exchange is possible, an educational framework was sought to function as a blueprint. The KU Leuven offered a competence set for international exchange students, which could fill in part of the framework. The University of Porto uses EUR-ACE as the framework for all their engineering education, and cannot abandon it. The engineering programs at The Hague University of Applied Sciences are all CDIO member. University West is in the middle of applying for CDIO. Thomas More suggested to look into these last two frameworks. CDIO is described to be flexible and adaptable (Crawley, Brodeur, Malmqvist, Östlund, & Edström, 2007), able to respond to forces in education and society such as described above. It also emphasizes the importance of fitting education to the needs of industry. Multiple cases can be found where CDIO is used as a blueprint outside the direct context of an existing engineering program or department (Malmqvist, Kohn, & Lindquist, 2015). EUR-ACE is a widely spread authorized quality label for engineering programs in Europe. First a combination of the two was considered. However, a complete conversion between EUR-ACE and CDIO is not possible (Falcao, 2011). EUR-ACE and CDIO have a different approach, and four of the CDIO standards (4, 5, 7, and 8) define educational elements which are not explicitly discussed in the EUR-ACE accreditation requirements (Malmqvist, 2009). The CDIO syllabus reflects a more encompassing view of engineering than EUR-ACE's, by considering the full product/system/process lifecycle, including the implementing and operating life phases, which is important for the open innovation. Also, an evaluation process based on a rating scale, such as the CDIO self-evaluation model, was considered more useful for guiding the continuous improvement processes for CSE than a threshold value scale, such as used in the EUR-ACE accreditation.

The University of Porto adopted the CDIO scales for the 12 standards for the CSE course for communication purposes with the other partners. At Thomas More and KU Leuven the comparison exercise led to the decision to reformulate the existing CSE syllabus for the post-masters course in CDIO terms by next semester, see figure 1.

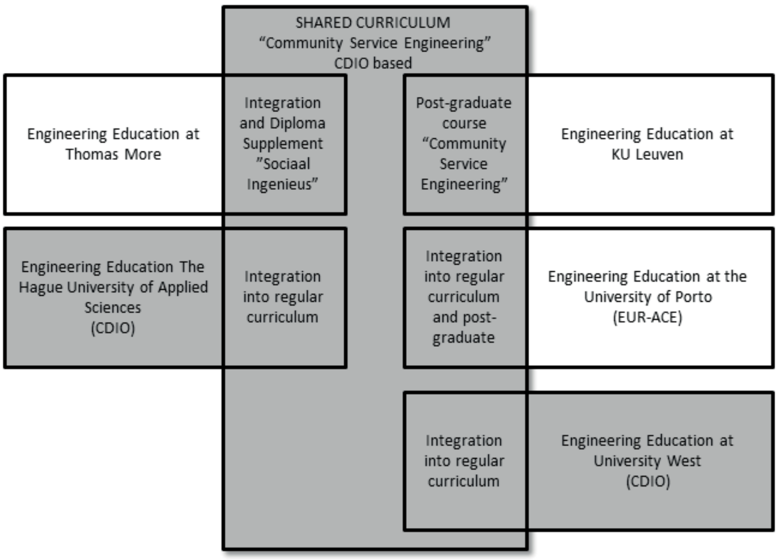

Figure 1. The shared CSE curriculum and use of CDIO, adapted to the local situations.

The area in gray indicates how CDIO is adopted. The areas in white do not implement CDIO. For instance: at Thomas More, CDIO is only implemented in the courses that lead to the diploma supplement "socially ingenious" (gray area) and that is a part of the shared curriculum of the 5 partners involved. The rest of engineering education at Thomas More does not use CDIO. At The Hague University of applied Sciences, CDIO is adopted throughout the curriculum already, as well as in the CSE curriculum, and in the near future this is expected to be the case at University West as well.

Given the aims of the CSE curriculum and the existing differences between the partners' approaches, the CDIO framework proves to fit well as a basis for the curriculum of CSE. First of all, in standard 1 CDIO (Crawley et al., 2007) describes the context of engineering education in the same professional setting as the open innovation approach of CSE: a focus on the needs of customers (the human-centered approach mentioned in the CSE vision above), delivery of products processes and systems and meaningful incorporation of new inventions and technologies (delivering real products and innovative power), focus on the solution instead of disciplines (interdisciplinary approach), working and effectively communicating with others (co-creation), and dealing with the available resources (feasibility, viability, desirability). In standard 2 the personal, professional and interpersonal skills are as important as the disciplinary knowledge and reasoning, and the possible learning goals within CSE courses cover most of the CDIO syllabus list, see table 2. The first column shows the main CDIO syllabus learning goals or competences, including the added competences 4.7 and 4.8. of the 2014 version of the CDIO book. Each competence is divided into several sub-competencies, and the table shows if all or some of these are covered in the CSE education provided by the different partners of CSE. The table makes clear none of the main categories in the syllabus are left uncovered. Communications in foreign languages seems least represented, but for all programs English counts as a second language (3.3.1), so a foreign language is taken into account. It is interesting that both personal and interpersonal skills are within the core of CSE education, as is the integrated project line of box 4. And also for each CSE program entrepreneurship is an important element of the projects. In that sense CDIO is clearly a good fit. Not all CSE programs deal with operating (4.6) in the education equally, only the applied sciences programs do.

Table 2: Use of the CDIO Syllabus in CSE education: which sub-sub competences are included per partner university.

CDIO Syllabus (Crawley et al, 2014)	THUAS	Thomas More	U Porto	KU Leuven
1 Disciplinary Knowledge And Reasoning	All	All	All	All
2 Personal And Professional Skills And Attributes				
2.1 Analytical Reasoning And Problem Solving	All	All Minus 2.1.4	All	All Minus 2.1.4
2.2 Experimentation, Investigation And Knowledge Discovery	all	All	All	All
2.3 System Thinking	All	All Minus 2.3.4	All	All
2.4 Attitudes, Thought And Learning	All	All	All	All
2.5 Ethics, Equity And Other Responsibilities	All	All	All	All
3 Interpersonal Skills: Teamwork And Communication				
3.1 Teamwork	All	All	All	All
3.2 Communications	All	All	All	All
3.3 Communications In Foreign Languages	Only 3.3.1	Only 3.3.1	All	Only 3.3.1
4 Conceiving, Designing, Implementing &Operating Systems in Enterprise, Societal, and Environmental Context – The Innovation Process				
4.1 External, Societal, And Environmental Context	All Minus 4.1.3 and 4.1.6	All	All	All
4.2 Enterprise And Business Context	4.2.1, 4.2.2 and 4.2.7	4.2.1, 4.2.2 and 4.2.7	All	All
4.3 Conceiving, Systems Engineering And Management	All	All	All	All
4.4 Designing	All	All Minus 4.4.6	All	All
4.5 Implementing	4.5.1 and 4.5.6	Only 4.5.1	All	All
4.6 Operating	4.6.1, 4.6.3 and 4.6.5	none	All	none
4.7 Leading Engineering Endeavors	All minus 4.7.5	All minus 4.7.10	All	All
4.8 Entrepreneurship	4.8.2, 4.8.5, 4.8.6, 4.8.8	4.8.5, 4.8.6, 4.8.8	All	4.8.5, 4.8.6, 4.8.8

The integrated, active approach of learning the CSE profession coincides with standards 3 and 8. Requirements for the learning workspaces mentioned in standard 7 such as collaborative design projects, extracurricular design projects, test and operate possibilities, and linked projects between departments have to be both physically and digitally covered in CSE. And last but not least standards 9 and 10 about staff (teaching) competence development are certainly important factors of success for real CSE innovation to become reality.

CONCLUSIONS AND RECOMMENDATIONS

To get a better understanding of the quality and characteristics of CSE education at the four partner universities, a template document was prepared upholding the twelve CDIO standards. All partners described their implementation status and current situation with regards to these standards in their CSE endeavors, in a mini-self-evaluation. Table 3 shows the status of CDIO implementation in CSE per partner, using the rubric of CSIO. The scale from 1-5 builds up from 'knowing it's important (1)' to 'doing it and checking it regularly with important stakeholders' (5). A score of 3 means a start has been made. At the time of this writing, information about University West was not yet known, because they are in the process of applying for CDIO membership. This exercise gave insights into the strengths and weaknesses. The difference between implementation status among partners can be explained to some extend in relation to figure 1, and to the direct link of CSE to CDIO principles or other principles. From the table it can be concluded that the implementation scores are solid and close to one another in standards 5, 7 and 8. This means that all partners support the design-implement experience in the social domain, by means of an integrated learning experience, scaffolded by active learning didactics is seen as the core of the CSE curriculum.

Table 3: implementation levels of CDIO standards for CSE partners in their CSE curricula or courses.

Standard	Thomas More – post masters CSE course	University of Porto – CSE integrated in current graduate curriculum	The Hague University of Applied Sciences – CSE integrated in current undergraduate curriculum
1: The Context	3	1	4
2: Learning Outcomes	2	3	4
3: Integrated Curriculum	3	NA	NA
4: Introduction to Engineering (CSE)	3	1	2
5: Design-Implement Experiences	3	4	4
6: Engineering Workspaces	4	2	4
7: Integrated Learning Experiences	3	4	4
8: Active Learning	4	3	3
9: Enhancement of Faculty CDIO Competence	0	2	3
10: Enhancement of Faculty Teaching Competence	0	1	2
11: Learning Assessment	3	2	3

12: Program Evaluation	1	0	5, but not 4

It can also be concluded that, as one of the work packages of the project deals with the role of the teacher, standards 9 and 10 certainly need attention. As discussed the role of the teacher changes considerably in an open innovation set-up. Guidelines and approaches are discussed and auxiliary tools experimented with. Also the introduction to (Community Service) Engineering, especially the social domain, is an important priority. For this purpose, online knowledge and experience clips are made at the time of writing to fill the CSE repository and the project database is being revised.

One thing that did not come out of the CDIO self evaluation was how CSE was doing on international collaboration. It comes back in the CDIO syllabus as one of the learning goals for students, but not as an organizational aim. This is the third priority for the project. None the less, the CDIO framework offers all partners a common understanding in defining the content of their CSE curricula, and offers insights for the quality cycle for continuous improvement for the future of this project.

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BIOGRAPHICAL INFORMATION

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ADOPTING CDIO TO INTEGRATE ENGINEERING WITH BUSINESS

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ABSTRACT

The Diploma in Engineering with Business (DEB) is a three-year multidisciplinary diploma programme offered by the Singapore Polytechnic (SP) to students who have just completed their secondary school education. Students take courses in Engineering and Business that are taught by teaching staff of the engineering and business schools. The programme aims to produce graduates who are conversant and versatile in the practical application of both engineering and business concepts, hence becoming "business-savvy engineers". This broad-based curriculum also provides graduates with more flexible educational options, post the diploma, in either an engineering or business undergraduate programme. First introduced in 2009, DEB students undertake business courses, though somewhat standalone, from those of the engineering courses. Between 2010 and 2012, the DEB management team did a review of the programme using the CDIO framework. As a result, the team enhanced the curriculum in 2013 to integrate the learning of the engineering and business disciplines with mutually supporting disciplinary subjects based on the CDIO standards. This paper will describe how the DEB curriculum is designed to make explicit connections between the related engineering and business subjects, incorporating CDIO skills that include personal, interpersonal, and product and system building skills (Standards 2 and 3). The paper will also outline how the integration of CDIO learning outcomes and disciplinary skills in both engineering and business is translated into meaningful real world learning experiences (Standard 7) in this programme. The results of a survey conducted amongst the students who experienced the revised curriculum are also shared.

KEYWORDS

Integrated curriculum, engineering, business, Standards: 2,3,7

INTRODUCTION

The Diploma in Engineering with Business (DEB) is a three-year multidisciplinary diploma programme offered by Singapore Polytechnic (SP) to students who have just completed their secondary school education.

The programme offers courses conducted by teaching staff of the Schools of Electrical and Electronic Engineering, and Mechanical and Aeronautical Engineering and SP's Business School. Introduced in 2009, this programme aims to produce graduates who are conversant and versatile in the practical application of both engineering and business concepts, hence becoming "business-savvy engineers". This broad-based curriculum also provides graduates with more flexible educational options post the diploma in either an engineering or business undergraduate programme.

As with other diploma programmes offered by SP, the diploma adopts the SP education model of being broad-based and with a multidisciplinary approach. Students will also be equipped with specialised knowledge and skills to prepare them for work as well as with life-long learning skills and ability to pursue further academic studies.

The DEB programme aims to, amongst others, equip students with fundamental engineering knowledge and technologies, fundamental business skills and the knowledge to link engineering with business and also with life skills such as analytical skills, problem solving skills, communication skills and creative and critical thinking skills.

Although SP as an institution of higher learning started the adoption of CDIO engineering education framework in 2004, as outlined in Pee and Leong (2006), this was carried out in phases across the various engineering-related diploma programmes. Between 2010 and 2012, the DEB programme management team conducted a review of the DEB curriculum using the CDIO framework.

Akers and Radson (2013) provides four broad categories of engineering and business joint academic programmes, with varying degrees of integration between the two disciplines. These include joint business and engineering degree programmes, programmes which offer business courses within the engineering curriculum, engineering programmes with entrepreneurial experience, and engineering programmes with either minor or certificate in business courses. Examples of such programmes are described in Speckhart et al (2005), Schar et al (2013) and Burke (2013). These are however offered at the undergraduate and master's level. The approach that has been undertaken for DEB is based on the CDIO framework.

As a result, the curriculum was enhanced to integrate the learning of the engineering and business disciplines more strongly. This was done by integrating the learning activities of a first year engineering project, Engineering Design and Business Project I, with those of a business course, Principles of Marketing. In the second year, the learning activities of another engineering project, Engineering Design and Business Project II, were integrated with Professional Selling, a business course.

This paper describes how the DEB curriculum is designed to make explicit connections between these related engineering and business courses, and how CDIO skills like personal, interpersonal, and product and system building skills are incorporated and assessed (Standards 2 and 3). The paper will also outline the integration of CDIO learning outcomes and disciplinary skills in both engineering and business is translated into learning experiences (Standard 7) in this programme. The learning activities carried out in the relevant courses have been designed along the lines of the broad design model described by Sales (2014) which incorporates integration of technical content and other thinking and process skills.

IMPLEMENTATION

Year 1 Curriculum – Integrating engineering with business

One of the main business courses offered since the start of the DEB diploma programme is the course on Principles of Marketing (POM). This is offered as a course in the first-year of the Diploma Programme. This course introduces students to the basic principles and concepts of marketing and teaches them to develop a simple marketing plan to launch a product or service. The topics that are covered include an overview of the marketing process and the marketing environment, an understanding of target market selection, as well as the management of the marketing mix elements that include the 4P's namely: Product, Price, Place and Promotion.

The course is taught by teaching members from SP's Business School. It is delivered through lectures, tutorials and project discussions. Key concepts and theoretical aspects of marketing are introduced in the lectures and reinforced in the tutorials and projects through discussion questions, individual and group market research, individual presentations and group reports.

Students undertaking Principles of Marketing are also required to complete two assignments. For both assignments, students work in teams of four, and up to six, students.

The first assignment requires each student team to prepare a market situation analysis for a particular industry and product or service. The market situation analysis include carrying out an industry analysis and highlighting industry trends and identifying major industry players. The student teams are also required to carry out a company analysis, including detailing the company's weaknesses and strengths relevant to achieving its mission and goals, SWOT (Strengths, Weaknesses, Opportunities and Threats), competitor analysis including identifying major competitors and their marketing mix strategies, and lastly a customer analysis through demonstrating a deep understanding of potential customers.

The second assignment requires the team to create a new and viable product/service for the company to launch. This can either be on a local, regional or global basis. The team is also required to structure a marketing plan (involving the 4 P's) for the company to launch the new product to the identified target market(s). At the end of the assignment, the team will need to deliver a comprehensive report detailing their findings, analyses and a marketing plan, carry out a formal oral presentation, and also to complete a reflective journal.

Previously students took this course independently of what they have studied in the engineering strands of the curriculum. There was no requirement for them to apply their knowledge in marketing within an engineering context. This situation reflects what is described in Heim and Erickson (1996) of how students are taught specialised knowledge but with hardly any synthesis. Most of the students tended to do a market situation analysis and marketing plan on non-engineering product or services from sectors such as finance, food and beverage, lifestyle and retail. There was usually little or no attempt to work on the engineering or technology sectors.

In 2013, the first year curriculum was enhanced with the introduction of a new engineering course called Engineering Design and Business Project I (EDBP I) to serve as a platform to make explicit, connections between engineering and business. Students have to take this course in conjunction with Principles of Marketing (POM) in the same semester.

EDBP I is designed as an introductory course that provides a framework for engineering practice in the building of an engineering product (CDIO Standard 4). In this course, students are introduced to the concepts of Conceive-Design-Implement-Operate (CDIO) in the context of the life cycle of an engineering product. Exposure to the Design-Build Experience (CDIO Standard 5) is also provided in this course through a project which the students need to conceive, design and build a prototype. To prepare students for this project, the concepts and techniques of design thinking are taught so that these can be applied during the conceive and design phases of the project. Training of students on fabrication and teamwork and communications skills are also included in this course. Most important of all, the learning activities are designed so that there are integrated learning experiences where the students can link and apply their disciplinary knowledge in the Principles of Marketing to the engineering product they designed in Engineering Design and Business Project I. In carrying this out, students are also expected to put into practice their product building as well as teamwork and communications skills (Standard 7).

Figure 1 shows the integrated learning experience that is designed to explicitly link Engineering Design and Business Project I course with that of Principles of Marketing.

The integrated experience begins with an activity in Principles of Marketing to prepare a market situation analysis. For this assignment, students work in teams of 4 and up to 6 students as was previously done prior to implementing the revised curriculum. However, with the revised curriculum, the project brief specifies that students must choose from one of six possible industries as follows:

- Consumer Electronics
- Telecom & Information Technology
- Automobile
- Healthcare Products
- Safety & Security, and
- Toys & Games.

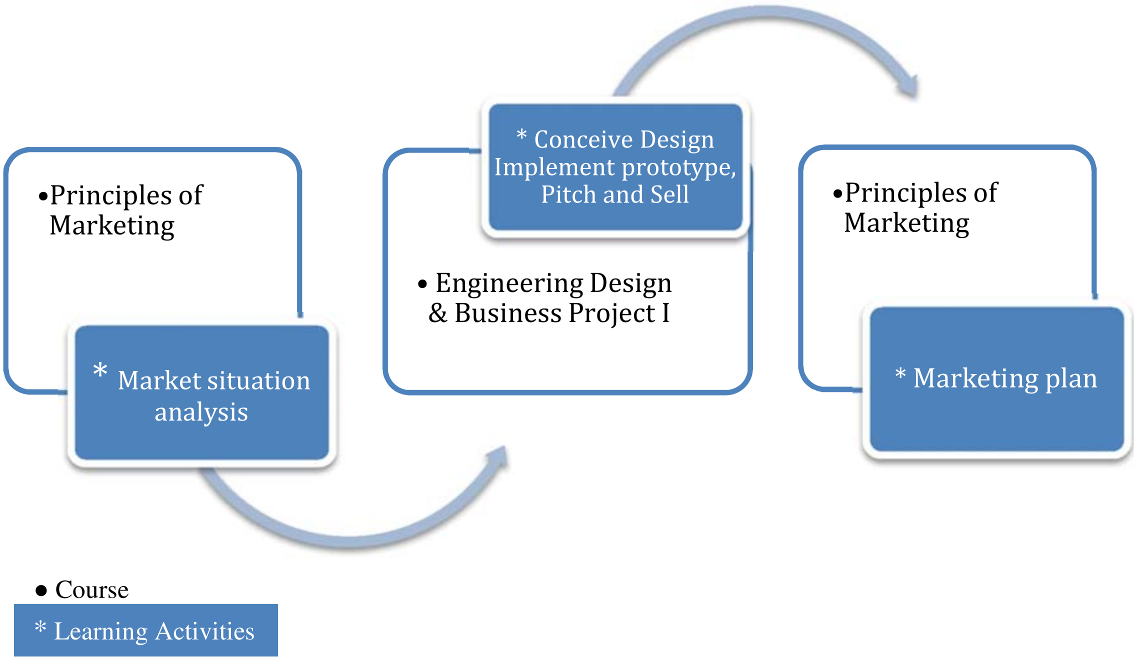

Figure 1: Integrated Learning Experience in EDBP I and POM

While working on the market situation analysis, the same team of students will embark on another activity that is incorporated in Engineering Design and Business Project I. In this activity, students will apply design thinking concepts and techniques to conceive a new product or service from the market sector that the team has identified in the market situation analysis done in Principles of Marketing. The team will then need to propose with justifications, the product or service that the team has selected.

Once the above activities are completed, the next activity requires the team to apply their basic knowledge in electrical and mechanical engineering acquired in other courses and their fabrication skills, to construct a simple prototype of the product or service. Upon completion of the prototype, they will do an oral presentation of their work, as if they are trying to pitch and sell the product or service as a possible business to the client.

This integrated experience ends with an activity in Principles of Marketing to prepare a marketing plan. This marketing plan is to cover the product strategy, price strategy, place strategy and promotion strategy for the product or service that was conceived, designed and built in

Engineering Design and Business Project I. An oral presentation of the marketing plan is to be made, as if they are presenting it to their client.

To summarise, the teaching of Engineering and Business in the first year of DEB is integrated with a curriculum that is designed to make explicit connections between the two very different disciplinary knowledge through the learning activities in Engineering Design and Business Project I and Principles of Marketing. At the same time, skills like personal, interpersonal, and product and system building skills are also incorporated in these two courses and translated into learning experiences through the activities as described above. With this integrated learning experience, students will be able to apply their business knowledge in an engineering context and vice versa. Skills like teamwork and communication skills, reflective and critical thinking skills, conceive, design and product building skills are also put into practice in these learning experiences.

Year 2 Curriculum – Integrating engineering with business

In the second year curriculum, an engineering project-based course called Engineering Design and Business Project II is used as a platform to anchor the integrated curriculum and also to provide the connections between engineering and business. This is summarised in Figure 2.

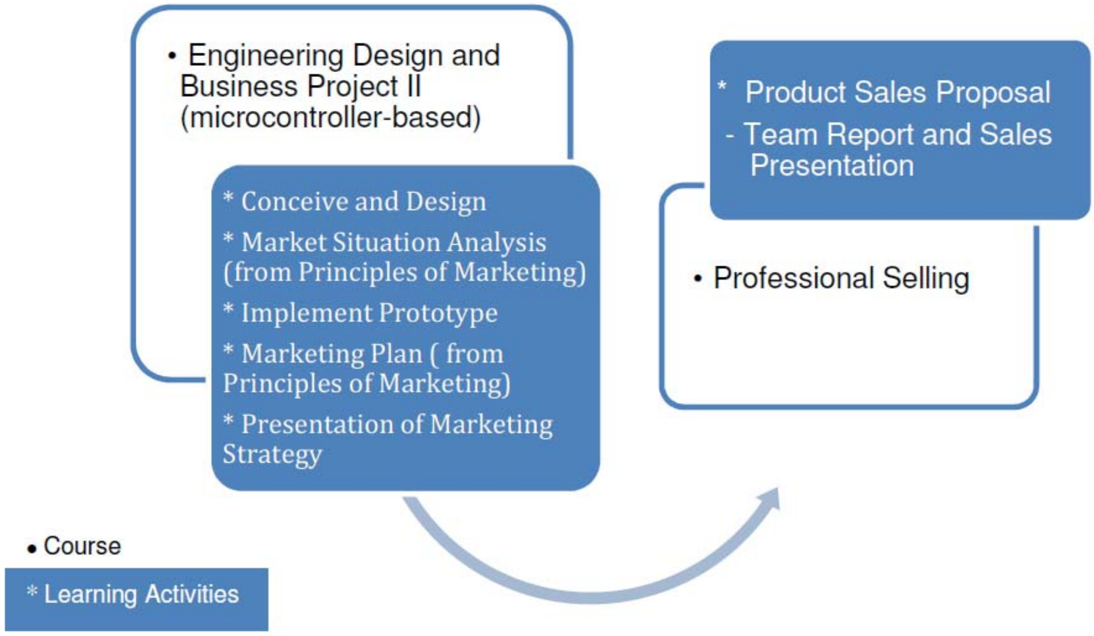

Figure 2: Integrated Learning Experience in EDBP II and Professional Selling

Engineering Design and Business Project II is a course that teaches the concepts of Microcontroller and its applications. Students learn how a microcontroller works, how to program it, as well as basic analogue and digital support circuitries, sensors, actuators and displays required for a microcontroller based application. This domain knowledge is taught in a series of lectures and tutorials with worked examples and discussions on applications. The theory learnt will be put into practice during the laboratory lessons where the students will perform a standard set of experiments.

Students will then apply what they have learnt to develop a microcontroller-based project. They are also restricted to propose their microcontroller-based project in 1 to 2 market segments, such as those for the Silver Age, Aids for Physically Disabled, Health & Hygiene, Energy/Water Conservation, Green Environment, Home Automation, Productivity Improvement, Enhance Customer Experience, Education, Games & Toys, Security or any suitable market segment as identified by their team. They will work in teams to conceive ideas for the project, which they will then design and build. Students will be required to fabricate simple electronic circuits, program the microcontroller and then do circuit interfacing and perform trouble-shooting to get their projects working. They will also have to consider the business aspects of the project through developing a simple marketing plan and demonstrating how they will sell their product.

The microcontroller-based project described above is used to deliver the integrated learning experience. Besides applying the disciplinary content on microcontrollers, the project also utilises supporting contents from first year courses. This includes C-programming, which is the high level language used to programme the microcontroller, and electronics engineering which is required for the students to design the interface circuits. Design thinking techniques and system building skills taught in Engineering Design and Business Project I in the first year curriculum are also utilised to conceive, design and implement the project. Students also need to apply personal skills, such as engineering reason and problem solving skills, critical thinking skills throughout their project, especially in testing and troubleshooting their project, They also have to demonstrate their self-learning skills as the selection of the appropriate sensors for their project, and how to use them are left to students to research and learn on their own. Students are also expected to demonstrate good team work and communication skills which form part of the assessment of the project.

The technical and learning activities described for Engineering Design and Business Project II here are similar to those of the design-build project as described by Chong et al (2010), but with the additional business-related components built into it as well.

The integration of engineering with business is also effected through this project. Students have to apply what they have learnt in their first year course, Principles of Marketing, to prepare a marketing plan for their project. Through this activity, students will have the opportunity to consider the business aspects of what they have built and apply their business knowledge in an engineering context. Explicit connection between engineering and business is also made through linking Engineering Design and Business Project II with another business course called “Professional Selling” which students have to take in the same semester.

Professional Selling provides students with practical knowledge of the art and science of effective personal selling. It encompasses the learning of the comprehensive process of personal selling to consumers and businesses, and putting into practice under realistic scenarios and assessments. The coverage of the course includes the following:

- Understand basic principles, various techniques and process of personal and relationship selling,
- Understand the critical role of pre-call preparation in sales success and be able to apply the sales techniques.
- Understand and apply questioning techniques in recognizing prospect’s problem during a sales presentation.
- Understand and apply the various methods in handling customers’ objections and closing a sales presentation.

To provide an explicit connection between engineering and business, the students will have to prepare a product sales proposal (that includes sales brochures, product pictures, charts and/or other sales materials) and make a sales presentation of the product that they have built in Engineering Design and Business Project II. This will allow students to put into practice their knowledge in Professional Selling to sell an engineering product.

To summarise, in the second year of DEB, integration of the disciplinary knowledge in engineering and business is achieved through the learning activities in Engineering Design and Business Project II and Professional Selling. In Engineering Design and Business Project II, students conceive, design & build a microcontroller-based product and then develop a simple marketing plan for their product and demonstrate how they will sell it. In Professional Selling, students will prepare a product sales proposal and conduct a sales presentation of the product that they have built in Engineering Design and Business Project II. This integrated learning activity will allow students to experience the real-life scenario of how an engineer would need to take into consideration the business aspects (such as marketing and sales) of an engineering product.

Moreover, while acquiring the respective disciplinary knowledge of these 2 courses, the learning activities also allows the disciplinary knowledge from supporting courses as well as CDIO skills like personal, interpersonal, and product and system building skills to be utilised and assessed simultaneously, thereby meeting the requirements of an integrated curriculum.

RESULTS

A survey was conducted for the first cohort of students who have undergone the revised curriculum. The response rate of the survey was about 85%. The results of the survey is summarised in Table 1.

Table 1. Summary of survey results for the first cohort of students

SA= Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree					
	SA	**A**	**N**	**D**	**SD**
1. The learning experiences in the DEB curriculum have helped me to apply knowledge from one course to another.	36%	53%	8%	0	3%
2. The learning experiences in the DEB curriculum have helped me to make connections and see the larger picture of engineering.	25%	61%	11%	0	3%
3. The learning experiences in the DEB curriculum have helped me to apply and integrate what I have learnt in my engineering courses with those in my business courses and vice versa.	19%	67%	11%	0	3%

The results showed that more than 80% of the respondents agreed that the learning experiences in the DEB curriculum have helped them to
(i) apply knowledge from one course to another
(ii) make connections and see the larger picture of engineering
(iii) apply and integrate what the students have learnt in their engineering courses with those in their business courses and vice versa.

This shows that the integrated curriculum implemented has achieved its aim of making connections between disciplinary knowledge and CDIO skills in an integrated manner, especially in integrating the learning and applying of the knowledge in the engineering and business disciplines.

CONCLUSION

In the first year curriculum, the learning activities in Principles of Marketing and Engineering Design and Business Project I are integrated. Students worked in teams to perform a market situation analysis and then proceed to conceive, design and build a prototype of a product from the target market that the team had identified in the market situation analysis. This is then followed by the final activity where the team prepares a marketing plan to launch the product to the target market.

In the second year curriculum, the learning activities in Engineering Design and Business Project II and Professional Selling are integrated. Students worked in teams to conceive, design and build a microcontroller-based product. They will then prepare a marketing plan and a product sales proposal as well as conduct a sales presentation of the product that they have built.

These learning activities have allowed students to apply and integrate what they have learnt in their engineering courses with those in their business courses and vice versa. The activities also provide a setting for students to experience the real-life scenario of how an engineer would need to take into consideration the business aspects (such as marketing and sales) of an engineering product. Besides the disciplinary knowledge, these activities also utilises disciplinary knowledge from supporting courses as well as allow CDIO skills like teamwork and communication skills, reflective and critical thinking skills, conceive, design and product building skills to be put into practice.

Feedback from students showed that most agree that the learning experiences have helped them to apply knowledge from one course to another, make connections and see the larger picture of engineering as well as apply and integrate what they have learnt in their engineering courses with those in their business courses and vice versa.

In implementing the integration of the engineering and business courses, the student curriculum hours remains the same with the use of resources such as facilities remaining the same prior to the integration. However, to implement the integration, the teaching staff of the Engineering Schools and the Business School certainly needed to work much closer together and on the same context for the courses.This echoes the kind of significant collaboration needed amongst teaching staff of different schools in order to bring about successful implementation of integrated programmes as described by Froyd and Ohland (2005).

In sum, we have adopted CDIO to design the DEB programme with an integrated curriculum that makes explicit connections between related engineering and business subjects as well as fosters the learning of disciplinary knowledge together with personal, interpersonal and product and systems building skills (Standard 2 and 3). Learning experiences built into the courses have also led to the integration of CDIO learning outcomes and the disciplinary knowledge in both engineering and business (Standard 7).

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BIOGRAPHICAL INFORMATION

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EXPERIENCES IN INTEGRATING ETHICS FOR ENGINEERS IN MSC PROGRAMMES

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ABSTRACT

Engineering ethics is an important part of education since it helps students to deal with issues they can face in their profession. A project was started at Chalmers University of Technology in 2013 with the aim to improve integration of ethics in the Master's programmes in the educational area: "electrical and computer science engineering, software engineering, and industrial engineering and management". In this paper, experiences are shared from this project. The aim is to support and stimulate to similar activities at other universities. The objectives are to describe:

- the *change process* for integrating ethics into Master's programmes at Chalmers,
- *results* of this work, such as amount and type of ethics integrated into the programmes, and differences in content and intended depth of learning,
- *challenges* to accomplish a successful integration of ethics into the programmes.

There has been a successful integration of ethics in the Masters' programmes, and all of the 13 programs now include some ethics. The most important driver has been that the project has been assigned by the dean of education who can put some pressure on the programme directors. Another important reason for a successful result is that the project has continued over several years as long as there has been a need of improvements. Support has been offered to the programme directors and teachers, and there has been a regular follow up of the progress and encouragement of programmes directors. A main challenge has been that many of the programme directors and teachers are unsure about what ethics is all about and how to include it in education. Thus, it has been a good idea to have short term goals that were not that demanding. It has been important that the actual changes are done by the programme directors and teachers themselves, and that no one else has been telling them how to do.

KEYWORDS

Engineering ethics, research ethics, curriculum development, change process, learning outcomes, faculty competence, CDIO standards: 2, 3, 9

INTRODUCTION

Ethics is an important part of education since it helps students to deal with issues they can face in their profession (in line with Standard 2 in the CDIO Initiative, 2010). An effective way to teach ethics is to use cases, and then not only emergency cases that make the news, but more appropriate cases that an engineer more likely is to encounter (Harris et al., 1997; Lynch and Kline, 2000). To make these cases effective, they should be formulated to re-sail the complex and open conditions applicable in engineering practice (Lynch and Kline, 2000). Thus, there are strong arguments for integrating ethics into courses on engineering topics instead of giving ethics only as separate courses (in line with Standard 3 in the CDIO Initiative, 2010; Harris et al., 1997; Herkert, 2002). However, this may pose challenges for teachers, who may feel unsure of how this type of learning can be implemented and how values can be handled. Teachers may need support or competence development to become comfortable with integrating ethics in their courses (in line with Standard 9 in the CDIO Initiative, 2010; Herkert, 2002).

The Swedish System of Qualifications for engineers includes learning outcomes for research and engineering ethics (Ministry of Education, 2006). There is a long tradition at Chalmers University of Technology to include sustainable development in the study programmes. However, the focus is on the environmental dimension of sustainable development, and the social dimension and ethics are not included to the same extent. Hence, a project was started in 2013 with the aim to improve the integration of ethics in the Master's programmes in the educational area: "electrical and computer science engineering, software engineering, and industrial engineering and management". The project has been successful and resulted in extensive programme and course development but is still running since there is still need of improvements.

In this paper, experiences are shared from the project mentioned above to improve ethics in Master's programmes at Chalmers. The aim is to support and stimulate to similar activities at other universities. The objectives are to describe:

- the *change process* for integrating ethics into Master's programmes at Chalmers,
- *results* of this work, such as amount and type of ethics integrated into the programmes, and differences in content and intended depth of learning,
- *challenges* to accomplish a successful integration of ethics into the programmes.

Lessons learnt and recommendations for how to support programme directors and teachers to accomplish such a change are included in the discussion. In this paper, the focus in on the change process and intended learning outcomes, and it does not include descriptions of teaching and learning situations and assessment in ethics.

METHOD

Methods for change processes

The change process to integrate ethics in the Master's programmes has been inspired and used element from change processes described in the literature by Kotter (1995) and Holmberg et al. (2012).

Kotter (1995) suggests that a successful change process goes through a series of eight distinct stages: establishing a sense of urgency; forming a powerful guiding coalition; creating a vision; communicating the vision; empowering others to act on the vision; planning for and creating short-term wins; consolidating improvements and producing still more change; and institutionalizing new approaches.

Holmberg et al. (2012) have experience of three important components for successful change processes at Chalmers: 1) a neutral arena, 2) commitment from the management, and 3) individual engagement and involvement:

1. Organizational bodies that are placed outside the research departments can work as *neutral arenas* and platforms for cooperation and information exchange, and can function as engines for issues that otherwise often become everyone's interest but no-one's responsibility. Neutral arenas can be used to avoid lock-in effects and make teachers from all departments feel welcome to take part in their activities.
2. A clear *commitment from the management* can definitely facilitate a change process and can sometimes be necessary. The role of the management can be to clearly motivate the change process and systematically create incentives and other structures that correlate with the change process.
3. A change process must build on *individual engagement and involvement*. At universities, programme directors and teachers have a high degree of autonomy, which must be respected and dealt with. The *individual interaction method*, developed and used at TU Delft (Peet et al., 2004), is an effective method in a change process at a university. By interviewing individual programme directors or teachers about their programmes and courses and discuss how the topics relate to sustainable development (or in our case *ethics*) and how this can be further improved, they are still in control of their programmes and courses and the experience is that they will open up for change and embedding of sustainable development (or ethics) in a much better way.

Method to identify and analyze integration of ethics in the Master's programmes

The integration of ethics in the Master's programmes have been identified and analyzed based on the *course descriptions in the Chalmers Study Portal* (Chalmers University of Technology, 2016a). The courses that have *intended learning outcomes* in which *ethics* is explicit are considered to be courses in which ethics is integrated.

The *topics for ethics* have been divided first into *engineering* and *research* ethics, and then further into topics mainly based on the formulation of the intended learning outcomes but also on the other parts of the course descriptions.

The *intended depth of learning* in the courses has been analyzed by comparing formulations of the intended learning outcomes with the six levels in *Bloom's taxonomy* for the cognitive domain (Bloom et al., 1956):

- *Knowledge*: Recall previously learned information.
- *Comprehension*: Demonstrate an understanding of the meaning or purpose of previously learned information.
- *Application*: Use previously learned information in novel and concrete situations.
- *Analysis*: Examine the underlying components of learned information and gain an understanding of their organizational structure. This level also includes making inferences and using the information to support broader generalizations.
- *Synthesis*: Integrate previously learned information and its components into new concepts.
- *Evaluation*: Use definite criteria (either provided or self-created) to judge the value of other material and information.

In the next step, the intended depth of learning in the courses has been compared to the *required depth of learning according to the Swedish System of Qualifications for a Master's degree* (Ministry of Education, 2006). The required learning for *engineering ethics* is "ability to *make judgments*, within the field of study, with respect to relevant ethical issues", which corresponds to the level *evaluation* in Bloom's taxonomy. The required learning for *research* *ethics* is “ability to *demonstrate an awareness* of ethical aspects of research and development”, which corresponds to the level *comprehension* in Bloom’s taxonomy.

Finally, the intended depth of learning in the courses has been used to identify potential *progression in learning* in the programmes that include more than one course in which either engineering or research ethics is integrated.

Method to identify challenges

The identification of challenges is based on the results for how well the integration of ethics has succeeded in the Master’s programmes in combination with comments from Master’s programmes directors and teachers in individual meetings and at seminars.

RESULTS

Change process for integrating ethics into Master’s programmes at Chalmers

A project to improve integration of ethics into the Master’s programmes in the educational area for “electrical and computer science engineering, software engineering, and industrial engineering and management” (EDIT-I), was started in early 2013. The continuation of the project has been decided on an annual basis, and the project is still running since there is still a need of improvement. The project was initiated by dean of education, and is led by a collegial pedagogical developer at Chalmers (who is the author of this paper). At the time, the Swedish Agency for Higher Education was reviewing all engineering degrees in Sweden, and there was a fear at Chalmers that some of the educational programmes would not pass the requirements in ethics. At the end, Chalmers got a very good result in the evaluation, but two of the Master’s programmes did not pass, and lack of ethics was part of the reason for one of them. During the project, the importance of competence in ethics among engineers has got some attention in media, e.g. due to the “emission scandal” involving Volkswagen, which has given additional motivation for the project.

Table 1. Master’s programmes (two year-long) and associated MSc in engineering programmes (five year-long) in the educational area EDIT-I at Chalmers.

Master’s programme	**Code**	**Associated MSc in engineering programme**
Computer science: algorithms, language and logic	MPALG	Computer science and engineering
Computer systems and networks	MPCSN	
Biomedical engineering	MPBME	Electrical engineering
Communication engineering	MPCOM	
Electric power engineering	MPEPO	
Embedded electronic system design	MPEES	
Wireless, photonics and space engineering	MPWPS	
Entrepreneurship and Business Design	MPBDP	Industrial engineering and management
Management and economics of innovation	MPMEI	
Quality and operations management	MPQOM	
Supply chain management	MPSCM	
Interaction design and technologies	MPIDE	Software engineering
Software engineering	MPSOF	

There are 13 two year-long Master's programmes in the educational area of EDIT-I, see Table 1. There are variations in their curricula but a typical programme consists of one fourth of compulsory courses, one fourth of semi-compulsory courses, which means that the students have to choose some courses among a limited set of courses, one fourth of elective courses, and finally one fourth of Master's thesis. All courses in a Master's programme (with just a few exceptions) are on 7.5 higher educational credits (ECTS). Each Master's programme is associated to a five year-long MSs in engineering programme, and belong to one of four educational areas. The heads of programmes and directors of Master's programmes have got their assignments from the educational areas, and order courses to their programmes from the research departments where the teachers are employed who deliver the courses.

The aim of the project is to fulfil the learning outcomes for ethics in the Swedish System of Qualifications for Master's degrees (Ministry of Education, 2006), i.e. "to have the ability to make judgments, within the field of study, with respect to relevant ethical issues, and to demonstrate an awareness of ethical aspects of research and development". Since this aim was a large step for the programmes to take in the beginning of the project, there has been some short term goals during the project. The first goal was to have at least one intended learning outcome in (any) ethics in at least one of the compulsory courses in each programme. Even though not all of the programmes had fulfilled this goal, there was a second goal introduced to have intended learning outcomes for both engineering and research ethics in compulsory courses in each programme. The next goal is to formulate intended learning outcomes that fulfil the depth of learning that is required in the System of Qualifications.

The strategy that is used for integrating ethics in the programmes is to include ethics as part of courses in which it can be integrated in a relevant way with the engineering field (in line with standard 3 in the CDIO Initiative, 2010). It would not be a good strategy to have a whole course in ethics in the Master's programmes, since all courses are on 7.5 credits, which is a lot, and there is just a few compulsory courses in a programme. Another important reason is that it can be easier to connect ethics to the engineering field when it is integrated in courses rather than in a separate course.

A requirement in the project is that ethics should be *explicit in the intended learning outcomes* (in line with standard 2 in the CDIO Initiative, 2010), and that teaching and assessment in courses should be *constructively aligned* with these intended learning outcomes (Biggs & Tang, 2007). Another requirement is that ethics should be integrated in *compulsory courses* to make sure that all students in a programme take this course.

The change process in the project started by informing Master's programme directors and vice head of departments responsible for education about the project, including motivation and long and short term goals. The Master's programme directors were asked to identify courses in their programmes in which ethics were already included but could be enhanced with explicit intended learning outcomes, and courses in which ethics could be relevant to include. The Master's programme directors were then encouraged to talk to the teachers in the identified courses about possibilities to make appropriate changes. During the project, there has been an annual follow up of the progress in the programmes and continued encouragement of programmes directors and teachers to make improvements.

The Master's programmes directors and teachers have been offered different types of *support* during the project. The collegial pedagogical developer, who is leading the project, has offered *individual support* to programme directors and teachers and has given support to the ones who have asked for it, e.g. to identify relevant courses in dialogue with programme directors and to give feed-back on suggestions from teachers of intended learning outcomes, teaching and learning situations, and assessment. The teachers have also been offered some *financial support* for course development from the educational area.

The challenges that were faced and the need of different types of support became clearer as the project went on. As a consequence, Chalmers Learning Centre organized two *seminars* on ethics to which programme directors and teachers were invited (in line with standard 9 in the CDIO Initiative, 2010). Both seminars included a presentation by an invited guest followed by allocated time for discussion. The first seminar in spring 2015 was about engineering ethics, and Sven Ove Hansson who is professor in philosophy at the Royal Institute of Technology in Stockholm was invited to have a presentation. The second seminar in autumn 2015 was about integrating ethics in education, and Ibo van de Poel, who is professor in philosophy at Delft University of Technology, was invited to have a presentation. In contrast to Chalmers, both these universities have departments with philosophers who do research and teaching in ethics. Both these professors have written books on ethics and engineering (Hansson, 2009; van de Poel & Royakkers, 2011).

Requests of support from teachers and programme directors during individual meetings and at the seminars resulted in a *webpage* (Chalmers University of Technology, 2016b) that includes different types of recourses for ethics, either directly or indirectly through links to other webpages, with the purposes:

- *for teachers and programme directors to learn about ethics:* such as a short description of ethics theory and references to books that include more thorough descriptions.
- *to learn about how to integrate ethics in education*: such as an example of strategy for how to integrate ethics in programmes, examples of intended learning outcomes, and examples of rubrics;
- *to be a source of materials that could be used in education*: examples of real cases in engineering, codes of conducts, examples of course literature, and methods to analyse ethical problems.

Ethics integrated into the programmes

There has been a large improvement since the academic year 2012/13, and the *number of courses* that include ethics has increased from only two courses in 2012/13 to in total 29 courses in 2016/17 (four of the courses include both engineering and research ethics), see Table 2. It is seven of the 13 programmes that include courses in both engineering and research ethics that the students take independent on which courses they choose. A comparison between the number of compulsory courses that include ethics and the share of Master's programmes that include ethics between the EDIT-I educational area and the three other educational areas shows a large difference, see Table 3.

There is a variation between the *engineering fields* in how many courses that include ethics. The field of *industrial engineering and management* has the largest number of courses both in absolute terms as well as in relation to the number of Master's programmes (eleven courses in four programmes). The field of *electrical engineering* has the lowest number in relation to the number of Master's programmes (nine courses in five Master's programmes). Table 4 includes the topics for engineering and research ethics that are covered in the programmes.

Table 2. Number of courses that include ethics that the students take in a programme. The reason for the range in some programmes is that the number of courses depends on which courses that the students choose to take. Source: (Chalmers University of Technology, 2016a)

Associated MSc in engineering programme	Master's programme	Number of courses that include ethics			
		Engineering ethics		Research ethics	
		2012/13	2016/17	2012/13	2016/17
Computer science and engineering (5 courses)	MPALG	0	1	0	1
	MPCSN	0	1-3	0	1
Electrical engineering (9 courses)	MPBME	0	1	0	1
	MPCOM	0	1	0	1
	MPEPO	0	3	0	1
	MPEES	0	1	0	1
	MPWPS	0	1	0	0
Industrial engineering and management (11 courses)	MPBDP	0	3-5	0	0
	MPMEI	0	0	1	1
	MPQOM	0	0-1	0	2-3
	MPSCM	1	1	0	0
Software engineering (4 courses)	MPIDE	0	2-3	0	1
	MPSOF	0	0	0	1

Table 3. The number of compulsory courses that include ethics and the share of Master's programmes that include ethics in the educational areas at Chalmers.

Educational area	Number of courses	Share of Master's programmes
EDIT-I	21	13/13 = 100%
The three other educational areas	8	5/27 = 19%

The results for the analysis of the *intended depth of learning* in the courses in the Master's programmes in relation to the six levels in Bloom's taxonomy are presented in Table 5. According to the intended learning outcomes, seven (ALG, BDP, COM, CSN, EPO, IDE, WPS) of the 13 programmes fulfil the requirement for intended depth of learning for *engineering ethics* according to the Swedish System of Qualifications for Master's degrees, which is *evaluation,* independent on which courses that the students choose. Some examples of intended learning outcomes that fulfil this requirement are:

- *Discuss and* ***value*** *the social and ethical aspects of distributed systems and their applications.*
- ***Make*** *ethically responsible* ***choices*** *when packaging or visualizing intellectual assets into physical, virtual, or intellectual properties or services.*
- ***Make an informed evaluation*** *of the ethical and societal impact of a design.*

According to the intended learning outcomes in courses that all students take, ten of the 13 programmes fulfil the requirement for intended depth of learning for *research ethics* according to the Swedish System of Qualifications for Master's degrees, which is *comprehension*. Some examples of intended learning outcomes that fulfil the requirement are:

- ***Make and defend*** *ethical judgement within the area of scientific writing, e.g. related to plagiarism and authorship.*
- ***Take into account*** *different ethical aspects when* ***doing*** *interviews.*

- ***Apply*** *ethical principles to data collection, analysis and presentation of research and investigations.*
- ***Explain*** *the importance of research ethics.*

Table 4. Topics for engineering and research ethics that are covered in the Master's programmes. The topics are sorted to the MSc in engineering programmes that the Master's programmes are associated to. Source: (Chalmers University of Technology, 2016a)

Associated MSc in engineering programme	**Topics in the Master's programmes**	
	Engineering ethics	**Research ethics**
Computer science and engineering	- Computer science; - Research in computer systems and networks; - Distributed systems and their applications; - Computer security; - Data integrity	- Academic/ scientific writing, e.g. plagiarism, authorship, proper citation and use of statistics
Electrical engineering	- eHealth and medical technology; - Embedded electronic system design; - Electric power systems and engineering; - Electric drive systems - Photonics - Design in communication engineering	- Biomedical instrumentation systems; - Scientific writing, e.g., plagiarism and authorship; - Data collection, analysis and presentation of results - Dual use
Industrial engineering and management	- Intellectual assets and property in relation to innovation and business strategy; - Entrepreneurship; - Supply chain management: purchasing and social responsibility; - Change management in industry - Role of patents in strategic business development; - Idea evaluations, including how to relate professionally to different stakeholders in the idea evaluation process, such as idea providers, in the role of consultant/analyst; - Packaging or visualizing intellectual assets into physical, virtual, or intellectual properties or services	- Business research; - Academic writing, including referencing and quoting; - Interviews; - Data collection, analysis and presentation of research, investigations

Software engineering	- Design process and final design;
	- Gameplay design;
	- Interaction design and technologies:
	    - Involvement of users in design;
	    - Impact and consequences of design on different levels (man – society), e.g. ”critical design”
		- Conducting research in software engineering;
		- Interaction design research

Table 5. Intended depth of learning based on the intended learning outcomes in the courses in the Master's programmes in relation to the six levels in Bloom's taxonomy for the cognitive domain. E and R stands for courses that include engineering or research ethics, respectively. The numbers stand for the study period in which the course is given: 1-4 in year one and 5-6 in the autumn semester in year two. Courses in parentheses are not compulsory.

Master's programme	Know-ledge	Compre-hension	Appli-cation	Analysis	Synthesis	Evaluating
MPALG			R6			E6
MPCSN		(E3)				R5, (E3), (E2/6)
MPBME	E4	R1-2				
MPCOM		R3				E1
MPEPO		E1, E1	R5/6			E5/6
MPEES			E2, R2			
MPWPS						E3
MPBDP			E1	E1-2		(E3), (E3), (E5)
MPMEI		R4				
MPQOM		(E5)	R2, R4, (R3-4)			
MPSCM				E1		
MPIDE		R1				E1, (E4), E5
MPSOF						R2

Five of the programmes include more than one course in either engineering or research ethics (CSN, EPO, BDP, QOM, IDE), see Table 5. There is a potential *progression* of learning in three of them (CSN, EPO, BDP) since they have courses in their curricula with lower intended depth of learning (*comprehension* or *application*) that come before courses with higher intended depth of learning (*evaluation*).

Challenges

It has been a huge challenge to integrate ethics in some programmes for different reasons. Many of the programme directors and teachers do not have deep knowledge in ethics and feel unsure about how to design teaching and learning situations and how to perform assessment. The first improvements were made in programmes that had programme directors and teacher with good knowledge in ethics, which was mainly the case for programmes in the field of *industrial engineering and management*. However, there have been hardly no improvements in some programmes until just recently, and unsure programme directors and teachers could be one reason. Another reason may be that it is more or less easy to integrate ethics in different engineering fields.

Another main challenge has been to find philosophers who have good knowledge in engineering and who could have the possibility to work as guest lecturers at Chalmers. Programme directors for programmes that do not have teachers with good knowledge in ethics have expressed a need of such guest lecturers. However, due to the lack of such philosophers, there has been an increasing awareness among programme directors that improvements have to be made by our own teachers in engineering.

Other challenges are about *teaching and assessment* of ethics. Teachers who have not been teaching in ethics before can be unsure in how to design appropriate teaching and learning situations as well as assessments, including rubrics for assessment, which are constructively aligned to the intended learning outcomes.

Another challenge that has been expressed by some programme directors is that ethics takes place from other content in the programme. It has also been difficult to get programme directors and teachers to prioritize this work. Money has not been a problem since there are some funding available for course development but it has rather been time and lack of priority.

DISCUSSION AND CONCLUSIONS

It has taken time to integrate ethics in the Master's programmes in the educational area EDIT-I at Chalmers, and there is still a need of improvements. However, a comparison of the integration of ethics in the Master's programmes to the other educational areas at Chalmers shows that the project has been successful. One reason for a successful result could be that the project has continued over several years as long as there has been a need of improvements. There has been a regular follow up of the progress and encouragement of programmes directors. Additionally, the project has tried to be sensitive to the need of support and has given the support that has been possible to give.

The evaluation of all engineering degrees in Sweden performed by the Swedish Agency for Higher Education has worked as an important driver for the change process, as well as media attention about the need of competences in ethics among engineers. However, the most important driver has been that the project has been assigned by the dean of education who can put some pressure on the programme directors.

It has been a good idea to have short term goals that were not that demanding compared to the requirements in the Swedish System of Qualification. It has made it possible for programme directors and teachers to develop their own competence in ethics during the project in a pace that has still made it possible for them to make some improvements in their programmes. However, some programmes directors and teachers already had good knowledge in ethics and for those programmes there could have been higher demands and the improvements could have been done faster.

It has been important that the actual changes are done by the programme directors and teachers themselves, and that no one else has been telling them how to do. They have to own the change process for their own programmes and courses to create commitment and long lasting changes, and they are also the ones who have best knowledge to make good connections between ethics and their engineering fields.

It is not obvious whether it is best to have teachers in engineering who has learnt about ethics who do the teaching in ethics or to have philosophers who have learnt about engineering who work as guest lecturers in ethics. Different solutions are probably best for different programmes and courses. It can be a strength if teachers in engineering can improve their competence in ethics to make it possible for themselves to do the teaching in ethics, but it can take time and be a large effort. Alternatively, it can be a strength to have philosophers who have good knowledge in engineering who could work as guest lecturers at Chalmers. However, this can also require large effort for teachers at Chalmers who would have to work in close collaboration with the philosophers to make sure that the ethics content is well integrated in the courses and relevant for engineers. An advantage to have such philosophers at Chalmers could be that they potentially could give advice to teachers and to secure good quality of ethics integrated in other courses.

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VALIDITY ASSESSMENT OF THE P-B-P MODEL ACROSS VARIOUS ENGINEERING DISCIPLINES FOR BETTER TEAM LEARNING RESULTS

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ABSTRACT

Promoting and enhancing team learning is one of the essential tasks in improving the quality of education using the CDIO framework. The Pull-Balance-Push (P-B-P) model, which was first presented at the 10th Annual International CDIO Conference at Universitat Politècnica de Catalunya, Barcelona, Spain (June 16 - 19, 2014), has been deployed at Duy Tan University in various CDIO projects at the senior level of different majors, including Software Engineering, Information Systems, Civil Engineering, and Electrical Engineering. The model is basically a set of approaches to bring about better team learning by improving students' communication skills, learning capability and in-class participation as well as emphasizing the instructor's role in guiding teamwork efforts. However, while the advantages of this model have become widely-appreciated by the Faculty of Electrical & Electronics Engineering and its students, other faculties like Civil Engineering and Information Technology are still cautious in their adoption of the model, partly because of their own CDIO-project structures, which were designed and adopted a long time ago. In addition, to effectively carry out the P-B-P model, students and instructors would need to spend extra time and effort for reports, meetings and other documentation work, which raised concern about the already heavy workload during the final year. Through a series of in-person interviews and surveys, this paper will help analyze and benchmark the pros and cons of the P-B-P model across the four disciplines of Electrical Engineering, Software Engineering, Information Systems, and Civil Engineering in order to assess the validity and sustainability of this model under different learning settings.

KEYWORDS

Active learning, CDIO Framework, CDIO Standard 7-8, FSNPA model, individual learning, team learning

INTRODUCTION

Team learning is the process of sharing knowledge and complementing for each other amongst members of a team, who are working collectively to achieve some common goal (Decuyper et al, 2010). Under such settings, in “Team-Based Learning: A Transformative Use of Small Groups”, Michaelsen said there are always dependencies between the work and roles of team members, hence, a high level of commitment toward the common goal, reasonable work distribution among the members and effective responsibility delegation by the team leader are some of the key factors to a team’s success (Michaelsen, 2002). Successful team learning usually helps with the learning capability of its members in various areas. As a result, team learning is now widely adopted by many universities and institutions in the teaching of many subjects (Tran, 2014). Applying and enhancing team learning is one of the important activities in improving the quality of education within the CDIO framework.

At Duy Tan University (DTU), team learning is at the heart of our CDIO deployment, but many times, we observed that our engineering students did not realize the benefits of team learning because of various break-downs in the process of team development. Therefore, in an effort to improve team learning and teamwork efficiency, our instructors from the Faculty of Electrical & Electronics Engineering and Civil Engineering have created a better way for teamwork approach in their CDIO projects. It is the Pull-Balance-Push model, which is called the “P-B-P” model in short, and which includes a series of tactics focusing on improving students’ communication skills, individual learning and participation as well as the instructor’s role in guiding teamwork effort (Tran et al, 2014). In Figure 1, the Push, Balance and Pull tactics is applied to the Forming, Storming, Norming, Performing, and Adjourning stages of the FSNPA model. The FSNPA model for team development of Bruce Tuckman also provides the big picture about what stages of team development is of the most focus for Pull or Balance or Push tactics (Tuckman, 1965).

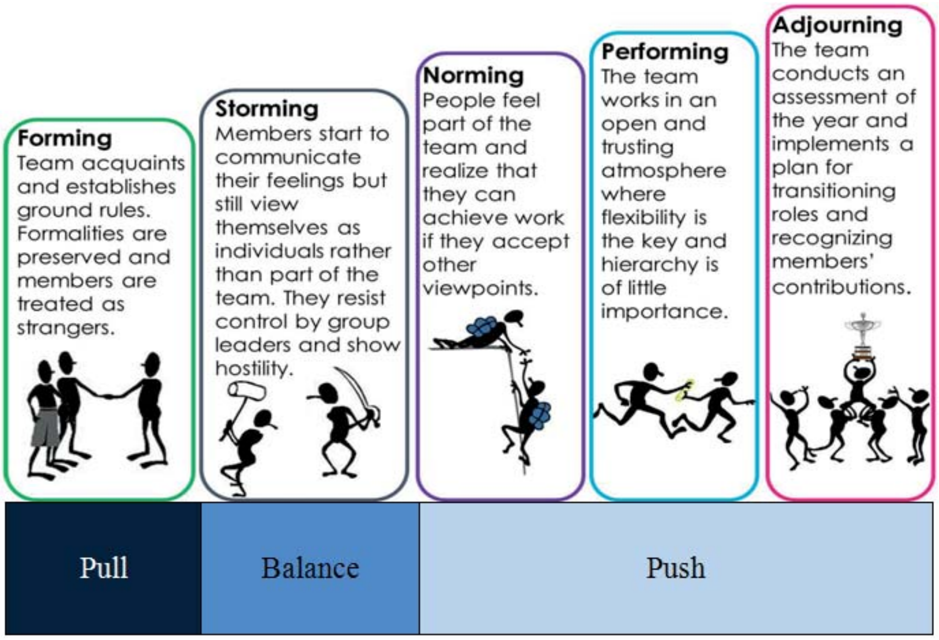

Figure 1. The FSNPA Model of Team Development

Up to this point, our P-B-P model has been adopted for four engineering tracks of Software Engineering, Information System, Electrical & Electronics Engineering and Civil Engineering at DTU and has received various feedbacks from both students and instructors. However, besides the good results recognized by the Faculty of Electrical & Electronics Engineering, the P-B-P model is not completely accepted at other faculties such as Information Technology or Civil Engineering, which have their own CDIO project structures designed long ago or proprietary models, forms and checklists (e.g., “imported” from Carnegie Mellon University - CMU) already being used. In addition, many students signified the shortcomings of the P-B-P model as they have to spend extra time to write up reports or to hold additional meetings with their instructors or mentors. Given those problems, this paper will build on our previous work to carry out additional analysis of the pros and cons of the P-B-P model as seen in reality, and to propose a number of changes which will help enhance the validity and sustainability of the P-B-P model across various engineering disciplines.

This paper has an introduction in the first section, an overview of our previous work in the second section, and then, in the third section an analysis about the pros and cons of the P-B-P model will be carried out before the proposed improvement model to help enhance the validity and sustainability of the model. The last section of conclusion will draw upon comments and directions for future studies.

PREVIOUS WORKS

In our previous paper of “Improvement of Individual learning and Instructor’s role for better Team learning” at the 10th Annual International CDIO Conference at Universitat Politècnica de Catalunya, Barcelona 2014, we looked into various inadequacies of team learning at DTU and found that the most number of teamwork breakdowns were due to communication problems. To arrive at such a finding, we carried out a series of interviews with the questions as listed in Table 1 below:

Table 1. Interview Questions for Team Learning Shortcomings at DTU

No.	Questions
1	What do you think about team learning?
2	Do you think team learning is important?
3	How many members do you usually have in your project team? How many males and females?
4	What is the biggest obstacle of team learning in your experience?
5	Do you usually have problems with your team leader? Does he/she have a good management style?
6	Do you usually have “free riders” in your teams?
7	What kind of arguments do you usually run into in your teams? Explain.
8	Do you and your team members share the same goals and vision during the course of the project?
9	Did your instructors help facilitate and support good teamwork practices?
10	What was the biggest shortcoming of your instructors when it comes to team learning effort?

The results obtained in previous study highlighted the following points:

- Responses to the importance and effectiveness of team learning were usually at the two extremes: either Very Satisfied or Very Dissatisfied.
- The percentiles of males and females in many engineering project teams at DTU are usually uneven and the opinions of the minority in the teams are mostly ignored.

- The biggest obstacles in team formation which hinders team learning at DTU include:
    - Team members are usually too busy trying to protect their ideas that the team wastes a lot of time and effort in heated discussions and arguments.
    - Some team members have to do everything while others do nothing.
    - The team leaders are usually chosen because they are good students, not necessarily because they have experience or training in team management.
    - Outstanding team members usually try to impose their ideas on other members.
    - Team members mostly focus on "getting the project done" that they usually lose track of the shared vision and goals, which require regular discussion and revision.
- While most students refused to recognize themselves as "free riders", some complained that they could not catch up with other team members, and became passive in teamwork, as a result.
- Instructors at DTU tried hard to help with teamwork activities, but they still believed that there are many aspects that they could improve on to better support team learning.
- Instructors focused so much on the outcomes and quality of the projects that more than often, they ignored team learning.
- Instructors usually paid extra attention and time with outstanding team members while ignoring other team members.

Given the problems above, we had proposed a series of changes in which the tactics of Pull, Balance and Push will be emphasized at different stages of the FSNPA model (Tuckman, 1965):

- Pull tactics are to be emphasized in the Forming stage to help improve the instructor's role in helping team members get along with each other and in enhancing participation in interactive team activities.
- Balance tactics are to be focused on in the Storming stage to help improve the communication between team members, enhance individual learning, and provide an equal opportunity for every team member to present himself or herself as well as his or her ideas. Communication incentives and conflict-resolution methods will be the focus of the instructor in this stage.
- Push tactics are to be spread out in the remaining stages of FSNPA model, including Norming, Performing and Adjourning, in order to push the team's efforts toward their goals. Specific tactics include checking on the overall progress of the teams, moving up the due dates for certain teams if they are doing well, or extending the due dates again for some teams that cannot keep up with the deadlines.

PROPOSED IMPROVEMENT MODEL TO ENHANCE THE VALIDITY AND SUSTAINABILITY OF THE P-B-P MODEL

In order to assess the effectiveness of the changes proposed in our last study, within the scope of this paper, we will carry out another survey with students coming from different engineering disciplines to assess their experiences of the P-B-P tactics being used in their CDIO projects under the context of the FSNPA model of team development. The questionnaire for this survey can be found in Table 2 in the Appendix.

A. Analysis of Survey Results:

Our survey was carried out on a sample of 100 students, spreading equally across 4 classes of Civil Engineering, Electrical & Electronics Engineering, Information Systems and Software Engineering with 25 students for each class. The same number of students for each class would allow us to easily compare and contrast on different feedbacks of students for some specific issue.

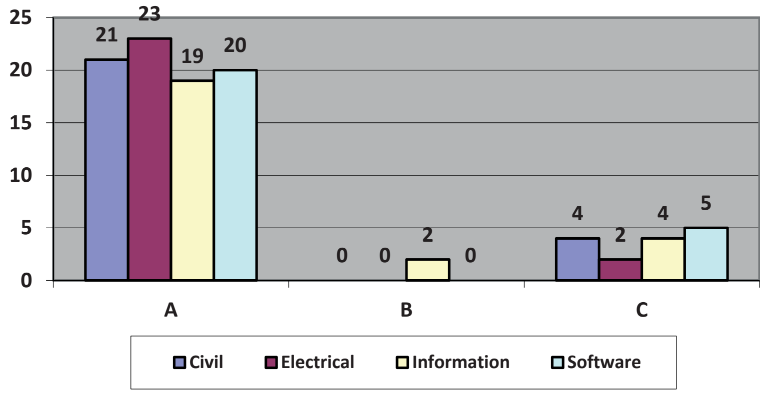

Figure 2. Survey Result for Question 1

In Figure 2, there are up to 83 responses of “Yes” on the question of whether students notice of any improvement in the CDIO project course; only 2 responses are “No”. The similarity in the responses of students from four classes signified the fact that our proposed changes have been well adopted in different engineering tracks.

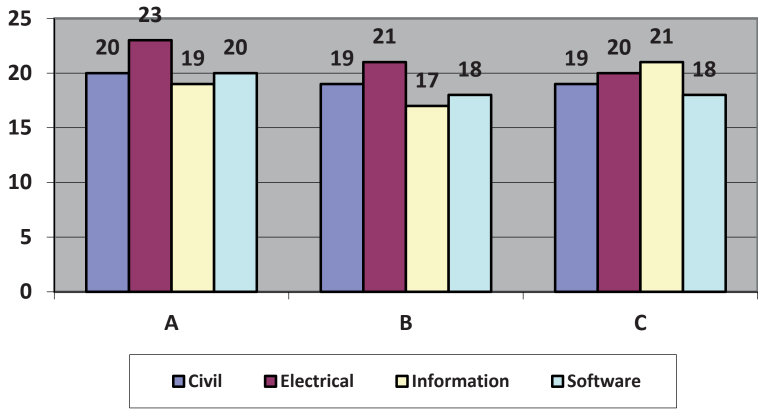

Figure 3. Survey Result for Question 2

Figure 3 demonstrates students’ satisfaction and enjoyment with the new settings for our CDIO project with a fairly equal selection for all 3 options in their responses. While most students agreed that there were more teamwork interaction, group games/activities, and instructor’s support, the benefit of teamwork interaction was slightly greater than the other two. Some students also indicated that they felt more comfortable with the new atmosphere and excitement of the CDIO project.

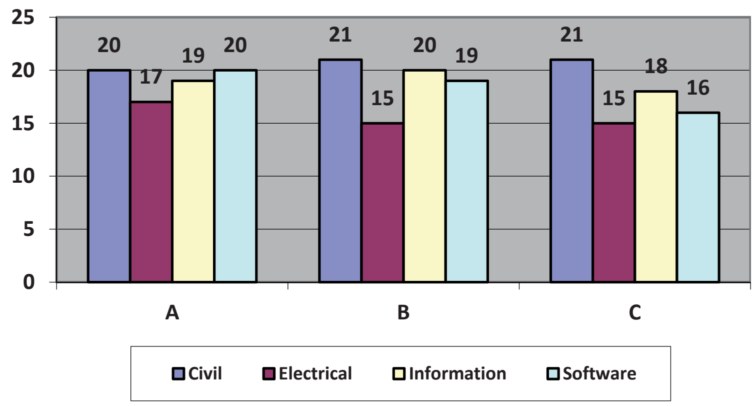

Figure 4. Survey Result for Question 3

In Figure 4, we can see many students complained that they could not manage their schedules well because of additional requirement in time and effort for the project (75/100). This is the biggest shortcoming given the significant extra amount of time students now have to spend for weekly checklists, reports and additional meetings with the instructors or mentors. In addition, up to 70 out of 100 students are not that open to conflict resolution practices, which is most apparent in the Civil Engineering class at a ratio of 21 out of 25 students, who complained about this problem. Since the field of Civil Engineering is very much project-oriented, it seems the new project settings simply add more to the already heavy workload of this discipline. And as a result of the increased requirement in the time and effort spent, most students did not keep good record of their work to support other members (76/100). This may hinder our measurement of support efforts in the new teamwork settings, which calls for some better mechanism, e.g., a software utility, to help keep track of this.

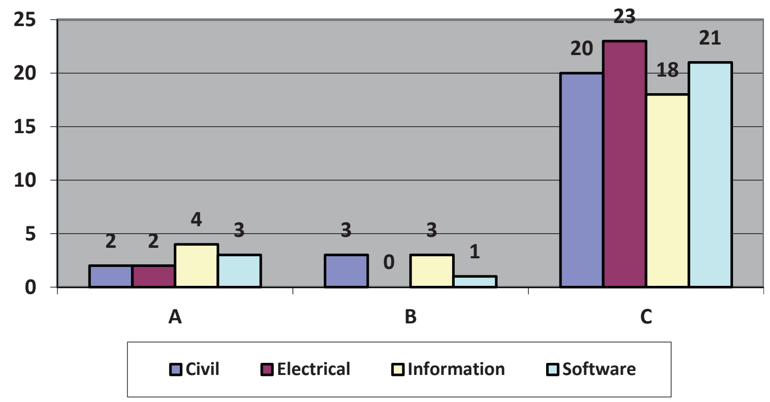

Figure 5. Survey Result for Question 4

The new class organization appears to help instructors significantly improve their role of support for students in their projects. Up to 82 out of 100 students said that their instructors seemed to understand ahead of time the team's problems and offered help as a result rather than stopping at showing their willingness to help or offering help only when asked. This is a major lift from the traditional approach, which requires a great deal of instructors' involvement with their team projects. Again, the instructors of the Faculty of Electrical & Electronics Engineering were perceived (23/25) to have done better than those of other faculties.

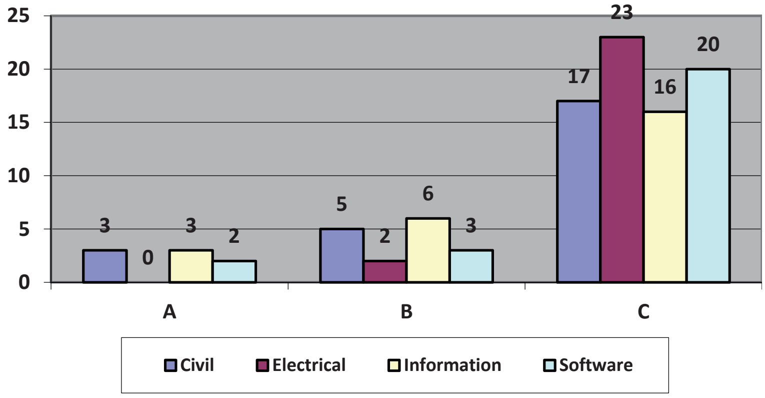

Figure 6. Survey Result for Question 5

The adoption of the P-B-P model has brought about a more proactive manner on the part of students in their offer to support other team members. Up to 76/100 students commented that their team members were willing to offer help anytime they were available and/or noticed of the need for help and support. This means team members are now more concerned about the overall outcome of the whole project rather than only trying to finish what was assigned to them, individually. Still, there were 16/100 students who believed they need to offer help in order to get help in return when needed.

With respect to the analysis of the validity and sustainability of the P-B-P model, feedbacks from Questions 6 to 10 are to be accounted for. For this analysis, we also switch to the line charts so as to clearly compare and contrast on the feedbacks of students of different engineering majors.

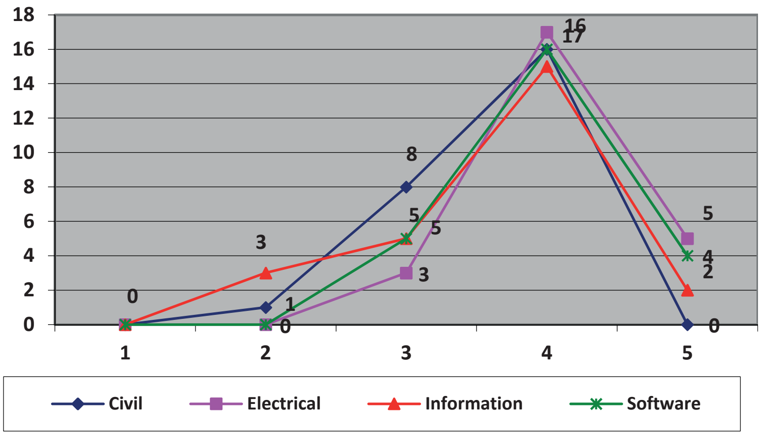

Figure 7. Survey Result for Question 6

In question 6, we asked students about their perceived level of respect from other team members. The question aims to assess whether the working environment in our CDIO projects is healthy and whether each team member is confident of their own capability. Unexpectedly, we received very positive feedbacks from this question with most students in different engineering tracks agreeing that they received good respect from other team members. This shows that the P-B-L model has brought about a more collaborative atmosphere for our CDIO teamwork. Amongst students of different disciplines, Civil Engineering students again showed most indifference about this matter, possibly due to the significant specialization in the role of each team member in the project.

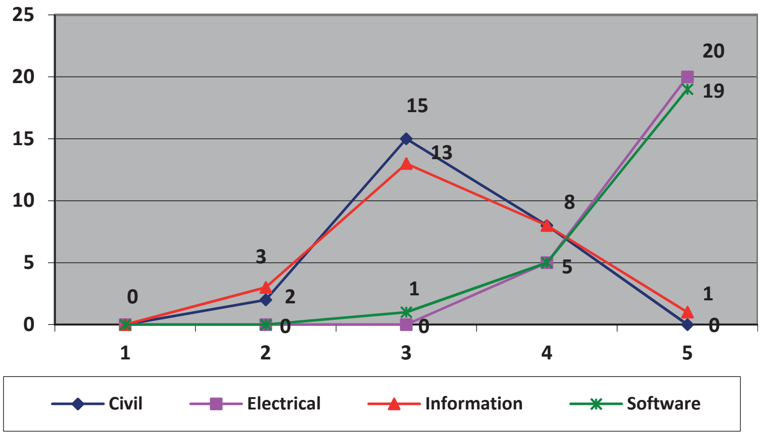

Figure 8. Survey Result for Question 7

When asked about students' commitment and engagement in the CDIO project, results in Figure 8 show that most of the Electrical & Electronics Engineering and Software Engineering students are highly committed with 20/25 and 19/25 showing their full commitment while contrary to that, most students in Civil Engineering and Information Systems are quite neutral. The complex nature and difficult grading standards of Civil Engineering projects may have been one of the reasons which discouraged Civil Engineering students from their full commitment while not all Information Systems students are prepared to be well-disciplined in engineering projects because they come from a mix of both IT and business students.

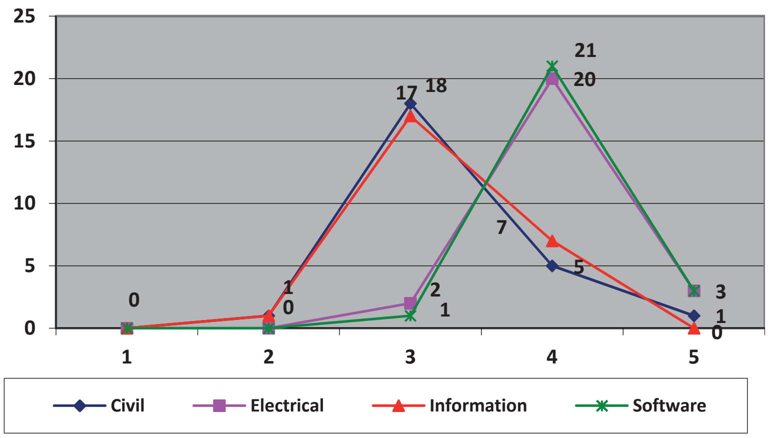

Figure 9. Survey Result for Question 8

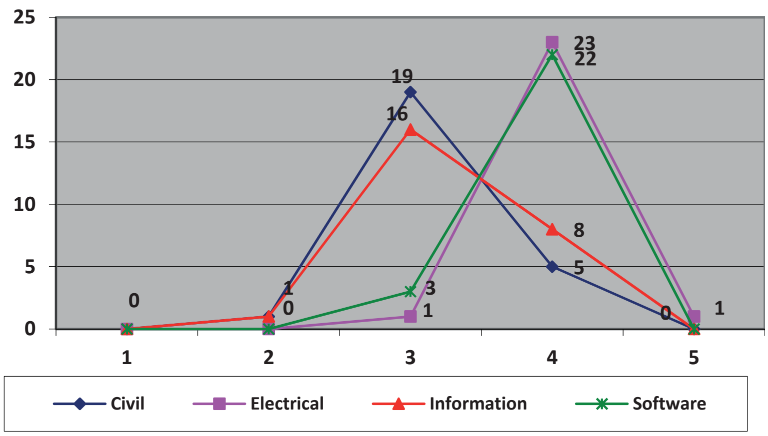

Figure 10. Survey Result for Question 9

Figures 9 and 10 show similar patterns in the feedbacks of Civil Engineering and Information Systems students versus of Electrical & Electronics Engineering and Software Engineering students. Civil Engineering and Information Systems found the P-B-P model to be useful for individual and team learning but not as much as Electrical & Electronics Engineering and Software Engineering students. Besides Software Engineering students slightly found more benefit of the model for individual learning than Electrical & Electronics Engineering students who realized more benefit of the model in team learning.

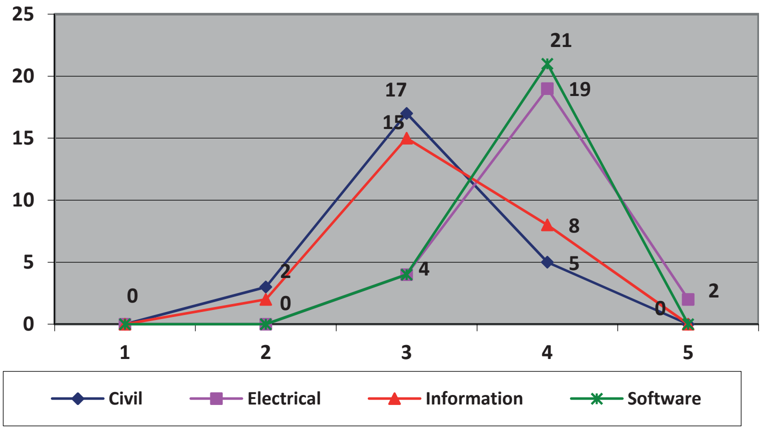

Figure 11. Survey Result for Question 10

Most of the students across different study disciplines perceived the P-B-P model to be suitable for their engineering studies. However, it seems to be more suitable for Electrical & Electronics Engineering and Software Engineering. The difference between Software Engineering and Information Systems is strange considering the closely-related nature of the two disciplines. This raised the need for further refining of the model through detailed procedures to produce more consistent deployment results.

Results from the rest of the questions provide additional information for the refining and restructuring of the P-B-P model, especially to better match up with the FSNPA model:

- Regarding Question 12 about which FSNPA stage students learned the most through the use of P-B-P tactics, interestingly enough, the Storming stage received up to 58% of the votes. On the other hand, the Norming and Performing stages received almost the same percentiles of votes at 17% and 16%, respectively. Given the fact that the CDIO projects lasted for only a semester, the P-B-P model may not have provided the full team-learning experience that it was designed for. Students instead would remember the various hassles that they had to sort out with each other during the Storming stage.
- For Question 13 about who was the key in resolving team conflicts, up to 82% of the students believed that all team members need to work together to help resolve any group conflict. This is a good sign since students had come to see themselves as the ones being responsible for any success or failure of their team and project.
- For additional comments about the P-B-P model, students suggested that the new group games should be designed to relate closely to the content of the projects being carried out. Students also requested additional support on the part of instructors to help them build essential skills for future career.

B. Proposed Improvement Model:

In so far, based on the results acquired from the survey, it seemed we have only focused on improving the instructor's role, individual learning, and team interaction (rather than team learning) at various stages of team development based on the FSNPA model. The P-B-P model was also matched up with the FSNPA model only, there has not been any match-up between the P-B-P model and different stages of the CDIO model like Conceive, Design, Implement and Operate to accurately assess the validity and sustainability of the P-B-P model in the scope of a CDIO project. The improvement model as discussed subsequently will help fix our current shortcoming.

P-B-P Validity:

The validity of the P-B-P model is its compatibility and effectiveness for various study disciplines. Since CDIO projects are at the heart of many engineering disciplines, how we match up the P-B-P model with the CDIO model will provide the basis for later tests of whether the P-B-P model is truly compatible or effective for any one specific discipline.

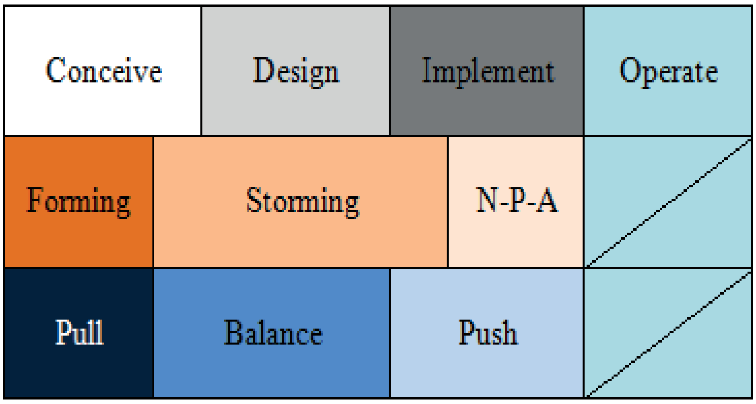

Figure 11. New Match-up between CDIO model and P-B-P tactics

With the new match-up, the P-B-P tactics are rearranged as followed:

- **Pull tactics**: Most of the Pull tactics are still applied completely for the Forming stage of the FSNPA model. On the other hand, they will be used for 2/3 of the Conceive stage of the CDIO model. The implication has to do with the fact that except for senior students who have become creative and dynamic, most junior and sophomore students need additional time and efforts to go through the team development process. As a result, by having the instructors "pull" them forward during the Forming stage, students will have more time for conceiving a project idea or solution, which in a typical CDIO project also occurs during the Forming stage.
- **Balance tactics**: Usually at the end of the Conceive stage of the CDIO model, team development will be in transition to the Storming stage of the FSNPA model, when team members are fighting to protect their ideas. As a result, Balance tactics will be necessary to keep the team focus on their goals or from falling apart. Balance tactics should help students get accustomed to structured reports and checklists so as to get them more organized and prepared for the later Design stage of the CDIO model. Past experiences have shown that team members who did not learn to get adapted usually felt overwhelmed and fell behind in later stages of the project. Even though the Storming stage of the FSNPA model will slide on to the early part of the Implement stage of the CDIO model, we will stop our Balance tactics by the end of the Design stage. At this point, with most of the major designs being already settled, students will

move back to individual learning, trying to complete their assigned tasks. Conflicts at the end of the Storming stage of the FSNPA model and the beginning of the Implement stage of the CDIO model are mostly minimal or unimportant; otherwise, it must be due to negligence of the involved stakeholders.

- **Push tactics**: Early in the Implement stage of the CDIO model, there is a strong likelihood that students will move totally back into their individual learning that they forget to regularly communicate or carry out team activities with other team members. This will lead to coordination problems later on when students try to put together their work into a comprehensive product or prototype. As a result, at the end of the Storming stage of the FSNPA model and shortly after the beginning of the Implement stage of the CDIO model, Push tactics need to be adopted to keep the team informed of their development processes and schedules. Push tactics will also help the team detect early on any shortcomings or delays as their projects progress to meet different deadlines.

P-B-P Sustainability:

The sustainability of the P-B-P model, by our definition, is its ability to deliver the same positive results across time and across different schools and universities (e.g., not only at Duy Tan University) for the same study discipline. That said, the P-B-P model can also be used for other non-engineering disciplines at Duy Tan University, which have adopted the PBL (Problem-based Learning) model, as long as it stands the test of time for a specific discipline (Dewey, 1997). Clearly enough, that sustainability can only be attained over time by the use of detailed practices and procedures. From our experience thus far, the following proposed evaluation forms, checklists and technical documents would help build that sustainability if they are adopted in the sequence described in Table 3.

Table 3. New Distribution of Evaluation Forms, Checklists and Documentation Materials in P-B-P

Documents for P-B-P Model (Detailed forms and checklists can be found online as listed in the REFERENCE section.)	**Conceive**		**Design**		**Implement**
	Pull	**Balance**			**Push**
1. Weekly Checklist for Team Leaders					
2. Knowledge Evaluation Form					
3. Relationship between Knowledge and Project Evaluation Forms					
4. Weekly Check List For Individual Team Member					
5. Project Proposal					
6. Project Plan					
7. Product Backlog Document					
8. Architecture Document					
9. Technical Design Document					
10. Test Plan					
11. Time Log					
12. Checklist for Technical Review					

Generally speaking:

- Evaluation Forms will be the focus during the Conceive stage to collect basic information about students' skills and knowledge as well as the goals and scope of the project. This piece of information will help instructors classify students into different groups and assign them to specific teams.

- Various Checklists will be utilized throughout the project to help instructors and students monitor the progress of the project besides ensuring that students are actually participate in different activities for individual and team learning.
- Technical Documentation is important in determining how well individual and team learning is going on. It also provides a series of tools for the project leader and team members to re-assess the design and organization of their project from time to time so as to make any necessary changes or improvements. The instructors should check the Technical Documentation of their students' projects on a weekly basis to give proper advice and to make in-time adjustment. Technical Documentation should be openly shared amongst team members.

CONCLUSIONS

Improving individual and team learning in CDIO projects has always been in the interest of many researchers in different engineering fields. Finding a way to deploy and measure individual and team learning practices is, however, not an easy task. The early success at Duy Tan University in applying the P-B-P model for CDIO projects under the context of the FSNPA model of team development has offered room for further research on the topic. Specifically, we need to look for ways to improve on the use of the P-B-P model for Civil Engineering projects; or else, we would need to opt for some other model for the Civil Engineering track in the long run. On the other hand, while the P-B-P model is widely successful in Electrical & Electronics Engineering and Software Engineering tracks, our research has only stopped at proving the validity of P-B-P tactics for CDIO across a number of engineering tracks. The sustainability of the model while visible through recent experiences and modifications in our approach has not been proved systematically through some statistical tests between our original adoption of P-B-P tactics and the current improvement model. Further studies should look into these aspects as well as making a more detailed analysis of how specific forms or checklists may help with the process of individual learning and team learning.

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APPENDIX: Table 2. Questionnaire for the Validity and Sustainability Test of the P-B-P Model

Student's name:		Student's ID no.:	
Student's major:			
No.	**Option**	**Weekly check list for team leaders**	**Tick √**
1	Did you notice any change or improvement in the CDIO projects of this semester? (Tick only 1 Option)		
	A	Yes	
	B	No	
	C	A little	
2	What do you enjoy the most in the new CDIO project settings and class organization? (Tick as many as applicable)		
	A	There are more interactions between team members.	
	B	There are more interactive group games & activities.	
	C	The instructor offers more support to group work.	
	List other things you enjoy:		
3	What do you dislike the most in the new CDIO project settings and class organization? (Tick as many as applicable)		
	A	Not all the team members keep good record of their work to support others.	
	B	I cannot manage my schedule well because of additional requirement in time and effort.	
	C	Not all the team members are open to conflict resolution practices.	
	List other things you dislike:		
4	How did your instructor/mentor support the work of your team? (Tick only 1 Option)		
	A	The instructor was proactive in offering help to the team.	
	B	The instructor only offered help when asked by the team.	
	C	The instructor seemed to understand ahead of time our team's problems and offered help as a result.	
	List other ways the instructor supported your team:		
5	With the adoption of the PBP (Pull-Balance-Push) model in our CDIO projects, how did you get help from your team members? (Tick only 1 Option)		
	A	I still had to seek for help from my team members when needed.	
	B	I offered help to my team members first and then got help in return.	
	C	My team members offered help to me anytime they were available or noticed that I needed help.	
	List other ways you got help or your team members offered help:		
6	Rate your perceived level of respect by other team members. (Tick only 1 Option)		
	1	No respect	
	2	Little respect	
	3	Moderate respect	
	4	Much respect	
	5	Full respect	
7	Rate your level of commitment and engagement in the CDIO project of this semester. (Tick only 1 Option)		
	1	Not at all committed and engaged	
	2	Not very committed and engaged	
	3	Moderately committed and engaged	
	4	Very committed and engaged	
	5	Fully committed and engaged	
8	Rate your perceived level of usefulness of the P-B-P model to individual learning. (Tick only 1 Option)		
	1	Not at all useful	
	2	Not very useful	
	3	Useful	
	4	Very useful	
	5	Absolutely useful	
9	Rate your perceived level of usefulness of the P-B-P model to team learning. (Tick only 1 Option)		
	1	Not at all useful	
	2	Not very useful	
	3	Useful	
	4	Very useful	
	5	Absolutely useful	
10	Rate your perceived level of suitability of the P-B-P model for your engineering major. (Tick only 1 Option)		
	1	Not at all suitable	
	2	Not very suitable	
	3	Suitable	
	4	Very suitable	
	5	Absolutely suitable	
11	Which group of tactics in the P-B-P model that was most effective for your CDIO project? (Tick only 1 Option)		
	A	Pull tactics	
	B	Balance tactics	
	C	Push tactics	
	Provide the reasons for your choice above:		
12	At which stage in the FSNPA model that you managed to learn the most knowledge and skills about your CDIO project? (Tick only 1 Option)		
	A	Forming	
	B	Storming	
	C	Norming	
	D	Performing	
	E	Adjourning	
	Provide the reasons for your choice above:		
13	Who do you think is the key in resolving group conflicts in your CDIO project?		
	A	All the team members	
	B	The team leader	
	C	The instructor	
	Other opinions:		
14	**List any shortcomings that you noticed about the P-B-P model:**		

BIOGRAPHICAL INFORMATION

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CAPSTONE PROBLEM DESIGN FOR OPTIMAL LEARNING CURVE IN ARCHITECTURE DESIGN

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Bao N Le

Board of Provosts, Duy Tan University, Vietnam

ABSTRACT

At the heart of the CDIO (Conceive-Design-Implement-Operate) model is the Capstone project, which helps link up materials from different courses in the curriculum so as to deliver the optimal learning outcomes in terms of students' knowledge, skills and attitudes. However, with respect to the architecture discipline, its Capstone projects have had an even older tradition with certain similarities and differences when compared to the CDIO approach. In any case, a Capstone project in architecture can only be effective as long as the design problems presented in those projects are relevant to the current and future real-world trends and requirements. While every architecture student would prefer working on some original problems for his or her projects, those are not always available. Most of the times, students will have to work on some age-old architecture problems, trying to refine or recreate already-available solutions. So, it is important that architecture instructors should help guide, select and/or develop the right kinds of architecture problems for students' Capstone projects. Of course, the ultimate goal would be to optimize students' learning outcomes based on available design problems and resources rather than to focus only on creating some original architecture design problems. This paper thus will introduce a number of problem design methodologies for architecture projects using the CDIO approach at Duy Tan University (DTU). In essence, it is a significant move toward open-ended and concept-oriented projects in architecture so as to provide students with additional room for creativity and innovation. This problem-design approach would require certain work settings and team synergy for participants to be successful, and we will discuss various sets of training tactics for team members to be successful in open-ended and concept-oriented architecture projects. Certain assessment measures for architecture projects are also essential in preventing students from copying from previous work of other teams or classes in the past. Given that the focus of our CDIO approach is "student-centered" and "outcome-oriented", new evaluation measures for architecture have been developed at DTU so as to ensure that the problem-design methodologies for our Capstone projects do accommodate for the evaluation of both teamwork and individual performance. Last but not least, the allocation of resources at different phases or stages in any architecture project is vital to efficiency and effectiveness in the learning experience of our students, and some of the novel practices at our institution will also be presented and assessed.

KEYWORDS

Architecture, Capstone project, CDIO, CDIO Standard 5, 6, 7 & 8, concept-oriented, student-centered, project deployment process, teamwork assessment

INTRODUCTION

How to integrate innovative values of a standard CDIO Capstone project design into those of an Architecture Capstone project design is a puzzling question to many educators in the field of architecture because Capstone projects for architecture has been around for a long period of time with many of their own defining values. Specifically, their set of goals and focus is on technical reliability, local/international usability, social acceptability, economic feasibility as well as aesthetics. These goals and focus indeed determine how architects approach any one problem and thus, their subsequent design(s) for that problem. Most of the time, great architecture designs appeared to be the work of some exceptional individuals, and for that reason, ordinary architects tend to part themselves from systematic teamwork, collective creativity and constructive argumentation, which are all the benefits of a standard CDIO Capstone project design. While we are in no position to judge what makes up an exceptional architect, we believe that an ordinary to good architect can be trained by and benefited from the CDIO model rather than from the traditional approach in architecture education, which has produced so many “by-the-book” architects with little creativity and limited proficiency in their skills (Bridges Alan, 2007). Thus, the whole purpose behind the proposal to adopt CDIO design for architecture projects is to capitalize on the Conceive features of the CDIO framework besides enhancing teamwork collaboration in architecture projects. In other words, this paper would propose that by following certain CDIO practices in architecture training and by adopting certain CDIO methodologies in project development, good architects can be “made”.

TRADITIONAL CAPSTONE PROJECT DESIGN FOR ARCHITECTURE (AT DTU) VERSUS INNOVATIVE CDIO CAPSTONE PROJECT DESIGN

An overview about the traditional approach in architecture education at Duy Tan University will provide a better idea about how academic projects in architecture have always been designed in Vietnam. It should be noted that architecture education in Vietnam was and is still strongly influenced by the French and Russian approaches:

- The design problem or task in traditional Capstone projects for architecture is usually fixed or closed-ended. The reason behind this is to facilitate for accurate assessment and/or evaluation of students’ performance on various criteria. Closed-ended projects are not necessarily bad: they can be quite helpful for low-level Capstone projects during the sophomore or junior years.

- The design problems or tasks for senior Capstone projects are usually derived from real-world problems or by local architecture-design agencies, which are more than often limited in their design concept and scope. On the other hand, more junior Capstone projects usually have their problems developed by the instructors, mostly in the format of some case studies, which again are very much similar to real-world scenarios.

- Students go through a series of separate courses on architecture theories and in-lab practices before taking on the Capstone projects. Capstone projects usually come by the end of the second year when students have built up certain basic skills and capabilities. Students develop their competency by learning from good sketches and designs, which are already available before for certain real-world projects (Bridges Alan, 2006).

- Usually, instructors with practical experience are assigned to teach Capstone-project courses. Instructors with different practical backgrounds add up to the knowledge diversity that students will get exposed to.

- For their performance in Capstone projects, students are usually evaluated based on their individual participation, project progress, and end-project outcomes, specifically, through detailed sketches and design attributes and/or features (Dang Thai Hoang, 2010).

Compared to the innovative CDIO Capstone project design, the traditional approach may be short of or inadequate in the following aspects:

- Late exposure to open-ended problem designs (only till the senior Capstone project) may hinder students' creativity because every Capstone project before that already leads students down the road of fixed problems and hence, fixed solutions. The very first standard of CDIO, Standard No. 1, emphasizes the importance of open-ended challenges, and the familiarity to such challenges is even more important in architecture education, a field which requires a great deal of creativity and out-of-the-box thinking.

- Learning through real-world projects from an early stage in architecture is not necessarily a good idea because students will immediately be tied up to end-product concepts while what they really need is to play around with abstract concepts in the beginning to be able to "think different" for future trends of design. The need to create something new is noted in CDIO Standard No. 5 "Design-Implement Experiences".

- Separate courses on architecture theories and practices will create the hassle that the students themselves have to integrate various knowledge and skills together. It would be much better if they can learn both the theoretical content and skills at the same time, as advised by CDIO Standard No. 7 "Integrated Learning Experiences".

- While team members are partially evaluated based on their team's end-project outcomes, team interaction in architecture has never been the subject of evaluation or assessment at DTU. For the CDIO approach, its Standard No. 11 "Learning Assessment" emphasizes the measure of the extent to which each student achieves specified learning outcomes, especially through collective work.

CDIO's PROPOSED IMPROVEMENTS FOR ARCHITECTURE CAPSTONE PROJECTS

For the shortcomings of the traditional approach for Capstone project design in architecture training compared to guidelines from the CDIO standards (as described above), they can be grouped into three big categories of focus for improvement, namely:

(F1) Architecture Design Problem/Task for Capstone projects
(F2) Training Approach and Deployment Process for Capstone projects
(F3) Assessment & Evaluation Measures for Capstone projects

At the heart of the problem, significant improvements can be achieved if the architecture design-problems or -tasks are remade to give students more voice and choice in their thinking and approach. By presenting students with some general design problems rather than assigning only closed-ended design tasks, we aim to force our students into analyzing and formulating their own design task for a certain problem. This actually creates a situation in which there are differences amongst the design tasks of various teams in the same class for the samed design problem, thus, giving way for more discussion and argumentation about the feasibility and rationality of any one design task. In a way, this change toward "problem-centered" orientation has indirectly helped with our active learning efforts. It also should be noted that the design problems of Capstone projects in the sophomore and junior years should focus mostly on concept designs rather than on actual architectural designs. The aim is to help students build their own style of architecture design rather than following some specific style which is already available. As for the senior Capstone projects in the fourth and fifth years, students are required to work with real-world businesses to create down-to-earth, actual design tasks. Then, no matter what year they are in, students should be required to assess the economic implications of every single one design they create. With these efforts, our students are expected to become:

(A1) more creative in every kind of architecture design, and

(A2) more confident and pro-active even in the face of unfamiliar design challenges (Graaff et al., 1997).

To realize the expected benefits from the move toward "problem-centered" Capstone projects, however, certain settings and training methodologies need to be improved. On the "surface" level, we require the Capstone teams to work on their projects in the school's workshops rather than bringing home the work like before. This change in the study settings yet required a sizeable investment on the part of Duy Tan University for more architecture workshops, and later, subsequent change in the working hours of our workshops, which started to allow for students' access to the workshops almost on a 24/7 basis. As for the project deliverables, students are asked to deliver more of wood/glass/iron/composite/… models rather than just drawings and sketches. The implication behind is that by making material models, it is more of a 3-D approach than the traditional 2-D approach through drawings alone. This also helps prevent the dilemma in which some students with good drawing skills can actually "twist" our instructors' perceptions and evaluation by drawing their designs from certain perspectives. 3-D models, on the other hand, are physically-available in shapes and can help facilitate more collective discussion of the usability, reliability, acceptability, and feasibility of the project. In addition, instead of focusing on the end-project outcome only, students are now asked to break down their project into different stages or phases for better progress management and assessment. At a "deeper" level, a series of training activities and requirements are carried out to facilitate with the change requested of our students. Those include additional training sessions on how to manage work projects and how to use equipment like laser engraving system, glass cutting machine, wood cutting tools, etc. For any one project, there are now two courses that always go in pair: one about related design theories and another about related design practices. By learning two supplemental courses for a specific project scope, students will manage to acquire the necessary skills to complete the project, and at the same time, having the time and conditions to really digest related theoretical knowledge. Also, in the process of carrying out the project, students are required to do a number of related field trips and on-site visits for the collection of relevant real-world data and materials. The requirements for change, however, are not only on the side of our students but also on the part of our instructors too. Instructors of the Architecture Faculty at DTU are now required to participate in local and international training programs and seminars for new methodologies and approaches in architecture on a semi-annual basis. In addition, once every two weeks, they meet up for academic discussion of the approved professional practices and project guidance styles in architecture. All of these efforts in training and deployment process of our Capstone projects aim:

(B1) to build students' professional skills in carrying out architecture-design projects,

(B2) to balance between students' learning of theoretical and practical contents about architecture, and

(B3) to level up instructors' capability in active teaching and CDIO project deployment.

For the evaluation and assessment of our students' performance in the Capstone projects, the changes made aim to improve on various "student-centered" aspects. In the past, our architecture students were mostly assessed based on their project participation, project progress, end-project presentation, and end-project outcomes. For the new evaluation plan, we continue to focus on our students' project participation and project progress, but at the same time, we also concentrate on the the following new items by learning from CDIO Standards No. 2, 5, 7, 8 and 11:

- Frequent evaluation of students' interaction and communication in teams,
- Frequent evaluation of off-campus activities by the teams like field trips and on-site visits,
- Cumulative evaluation of bi-weekly presentations (rather than only focusing on the end-project presentation),
- Evaluation of bi-weekly deliverables (especially on models and prototypes rather than only on drawings and sketches) based on the phase break-down of each team's project (rather than just focusing on the end-project ultimate outcomes) (Temple Stephen, 2005).

The expected improvements from our changes in the performance evaluation plan for the students' projects are that:

(C1) our architecture students will become more flexible and versatile in their project-doing capabilities,

(C2) our students will learn to appreciate the use of 3-D models and project management tools in their project, and

(C3) our students' performance in the Capstone projects will be improved in terms of creativity and effectiveness.

RESEARCH METHODOLOGY

To test whether our CDIO-oriented changes to (F1) the design of Capstone problems/tasks in architecture, (F2) the training approach and Capstone deployment process, and (F3) the assessment and evaluation measures for our architecture Capstone projects, have delivered the above expected improvements of (A1), (A2), (B1), (B2), (B3), (C1), (C2) and (C3) to our students, we need to compare the actual status and perceptions of our students before and after the application of those changes (Table 1). The problem, however, is that students generally take every course only once, so it would be almost impossible to find a set of students who learned architecture by the old standards and then, learned it all over again by new ones under CDIO adoption. The good news, however, is that we have just applied those changes to a high-quality class of students at the International School of Duy Tan University while our Faculty of Architecture still follows the traditional curriculum and methodologies. So, by carrying out a survey to test the difference in perceptions of these two groups of architecture students from the International School and the Faculty of Architecture about various settings of their current Capstone projects, we may very well determine whether our CDIO-oriented changes have done their job.

The survey included a series of statements asking for students' feedback on how much they agree or disagree with each statement. A 5-point Likert scale, with 1 as Strongly Disagree and 5 as Strongly Agree, was adopted. An initial sample of 100 architecture students with 50 from the International School and 50 students from the Faculty of Architecture was assembled for the surveyed. All students selected were junior students. To ensure the reliability and accuracy of the research, two groups of students were examined independently of each other. The students were selected randomly for the survey. Survey Form can be found in the appendix.

A major question here is whether the two groups of students may have been systematically different in the first place. By looking more into their similarities and differences, the relevance of our study may be better judged: In terms of similarities, first of all, all of these 100 students are Vietnamese students. Secondly, they originally had the same level of capability with the average grade point for national college admission at 19.2 for the group of students from the Faculty of Architecture and 18.9 for that from the International School - the difference is not significant even though the group of students from the Faculty of Architecture had slightly better academic performance. Thirdly, since they are all junior students, the differences in their training programs have been around for only one and a half years because they shared the same general education coursework. Fourthly, even though they learn from different curricula, by different methodologies and in different languages, the two groups are being taught by the same mix of architecture instructors from both the Faculty of Architecture and the International School. In terms of possible systematic differences, there are two major differences: the groups of students from the International School learned all of their architecture courses in English, not Vietnamese; and the groups of students from the International School are also more financially established because they pay higher tuition fee. Given that the major differences are in their curriculum, studying language, and financial background while their capability, instructors and other aspects are very much the same, it can be assumed that the differences may not hinder or create too much bias in our survey feedbacks and result comparisons.

Table 1. Improvement Focus/Goals and Corresponding t-Test Survey Statement

Improvement Focus	Improvement Goals	Corresponding t-Test Survey Statement
F1. Architecture Design Problem/Task for Capstone projects	A1. Students to become more creative in every kind of architecture design.	7. I feel the same motivation for creativity whether working with available architecture concepts or with new design concepts.
	A2. Students to become more confident and pro-active even in the face of different design challenge.	8. I enjoy creating new design concepts and tasks for already available architecture work or monuments in the real world.
F2. Training Approach and Deployment Process for Capstone projects	B1. To build students' professional skills in carrying out architecture-design projects.	17. I manage to utilize the school's workshops as well as different project management practices and model-making tools effectively for our project.
	B2. To balance between students' learning of theoretical and practical contents about architecture.	18. The balance between theoretical design courses and practical design ones at Duy Tan University is adequate for the development of our skills and knowledge in the field of architecture.
	B3. To level up instructors' capability in active teaching and CDIO project deployment.	19. I noticed improvements in our instructors' professional capability and guidance approach after every semester.
F3. Assessment & Evaluation Measures for Capstone projects	C1. Architecture students will become more flexible and versatile in their project-doing capabilities.	28. I do feel that I am flexible and versatile in my project-doing capabilities.
	C2. Architecture students will learn to appreciate the use of 3-D models and project management tools in their project.	29. I strongly believe that 3D models (by wood/glass/iron/composite/…) and project management tools are essential to the success of any architecture project.
	C3. Architecture students' performance in the Capstone projects will be improved in terms of creativity and effectiveness.	30. I trust that the Capstone-project format of Architecture programs at Duy Tan University helps improve my creativity and effectiveness to become a successful architect later on.

From Table 1, we can see that not all of the statements in the survey were used to test the difference between the traditional approach and the new CDIO-oriented approach for our Capstone projects; instead, only Statements 7, 8 are for that purpose with respect to the design of our Capstone design tasks or problems, Statements 17, 18, 19 with respect to our training approach and Capstone deployment process, and Statements 28, 29, 30 with respect to the effectiveness of new assessment and evaluation measures for our architecture Capstone projects.

To evaluate differences in the perceived training outcomes between the two groups of students, a series of t-tests of the corresponding statements listed in Figure 2 were carried out on the feedbacks from the two groups of architecture students from the International School and Faculty of Architecture. The t-tests were all one-tail tests with the p-value of 0.05, attempting to examine if the feedback mean value for each statement (on the 5-point scale) of architecture students from the International School was *significantly greater* than that of those from the Faculty of Architecture.

t-value Equation:

$$t = \frac{\bar{X}_{IS} - \bar{X}_{Ar}}{\sqrt{\frac{VAR_{IS}}{n_{IS}} + \frac{VAR_{Ar}}{n_{Ar}}}}$$

$\bar{X}_{IS}$: $Mean\ value\ of\ feebacks\ from\ architecture\ students\ of\ the\ International\ School$

$\bar{X}_{Ar}$: $Mean\ value\ of\ feebacks\ from\ architecture\ students\ of\ the\ Faculty\ of\ Architecture$

VAR_{IS}: $Variance\ of\ feebacks\ from\ architecture\ students\ of\ the\ International\ School$

VAR_{Ar}: $Variance\ of\ feebacks\ from\ architecture\ students\ of\ the\ Faculty\ of\ Architecture$

n_{IS}: $Number\ of\ architecture\ students\ of\ the\ International\ School, who\ gave\ feedbacks$

n_{Ar}: $Number\ of\ architecture\ students\ of\ the\ Faculty\ of\ Architecture, who\ gave\ feedbacks$

RESULTS & DISCUSSION

In this section, we will consider whether or not there are differences in the perceived outcomes between the 2 groups or students for the improvement targets in our training through the use of t-test for each survey statement. With the degrees of Freedom of around 88, p value of 0.05, the t-value will fall into the confidence interval between -2.00 to 2.00. If the t-value calculated from the equation expression above is outside the confidence interval (-2.00~2.00), we can say that the difference between the 2 groups was statistically significant. If the calculated t-value falls inside the confidence intervals, we can say that the difference between the two groups was not significant. Table 2 below depicts some of the basic information to be used in our t-tests:

Table 2. Basic t-test values

Number of Tails	1
Degrees of Freedom	88
p-value	0.05

Table 3 shows the results of t-test for Statements 7 & 8. The t-test for Statement 7 shows no significant difference in the mean values of feedbacks of architecture students from the International School compared to that of architecture students from Faculty of Architecture. So, it can be said that both groups of students were that different in terms of their motivation for creativity when working with either new or old design concepts. One thing that should be noted here is that the mean values of feedbacks from both groups are relatively high at 4.11 for students of the International School and 3.98 for those of the Faculty of Architecture, implying that the general architecture training at Duy Tan University does motivate students to be creative in their work. On the other hand, the t-test for Statement 8 shows significant difference of students of the International School from those of the Faculty of Architecture when it comes to creating new concepts for already-available architecture work and monuments, implying that students of the International School have built up their own confidence when dealing with different design challenges. Of course, this difference is only to a limited extent because its mean value is only a little greater than 3. Moreover, the big variance of feedbacks from students of the Faculty of Architecture suggests that some of its students may share the same kind of confidence.

Table 3. T-test Results for Statement 7 and 8

Statement	$\bar{X}_{IS}$	$\bar{X}_{Ar}$	VAR_{IS}	VAR_{Ar}	SD_{IS}*	SD_{Ar}*	t-value	Significant or Not
7. I feel the same motivation for creativity whether working with available architecture concepts or with new design concepts.	4.11	3.98	0.828	0.749	0.910	0.866	**0.712**	*Not Significant*
8. I enjoy creating new design concepts and tasks for already available architecture work or monuments in the real world.	3.37	2.93	0.649	1.1545	0.806	1.074	**2.219**	**Significant**

* - *SD_{IS}, SD_{Ar}: standard deviation of feebacks from architecture students of the International School and those of the Faculty of Architecture, respectively. SD=SQRT(VAR)*

When it comes to the utilization of the school's workshops as well as model-making tools and equipment, given the clear-cut opportunity and advantage, architecture students of the International School did make significantly better use of these facilities for their Capstone projects. Data from Table 4 shows that the standard deviation of each group was consistently much lower than its mean value, which implies that the input data was normally-distributed (Gaussian distribution), confirming the reliability of the input data for our t-test calculations. Also shown by significant statistical difference is the better use of project management skills and practices by students of the International School in their Capstone projects. In addition, the combo of two courses for a Capstone project with one for theories and another for practices seemed to achieve a high point with most architecture students of the International School agreed to the balance between theory and practice training in their curriculum (compared to that of the traditional program of the Faculty of Architecture), which significantly helped develop their professional skills and knowledge. As for students' perception about the improvements of our Architecture instructors over the semesters, there was no clear difference in the perceptions of the two groups of students. However, the relatively high mean values of 3.96 and 3.84 for Statement 19 again implies that our students did believe that our instructors' professional capability and guidance approach improved over the semesters. The only unusual thing here is students from the Faculty of Architecture, rather than those of the International School, noticed more improvements in the instructors' quality and capability even though they have the same mix of instructors. This may have to do with the fact that our instructors could have had more problems giving their instruction and guidance in English.

Table 4. T-test Results for Statement 17, 18 and 19

Statement	$\bar{X}_{IS}$	$\bar{X}_{Ar}$	VAR_{IS}	VAR_{Ar}	SD_{IS}	SD_{Ar}	t-value	Significant or Not
17. I manage to utilize the school's workshops as well as different project management practices and model-making tools effectively for our project.	3.51	2.89	1.1191	0.8737	1.058	0.935	**2.9566**	**Significant**
18. The balance between theoretical design courses and practical design ones at Duy Tan University is adequate for the development of our skills and knowledge in the field of architecture.	3.31	2.89	1.2191	0.6464	1.104	0.804	**2.0736**	**Significant**
19. I noticed improvements in our instructors' professional capability and guidance approach after every semester.	3.96	3.84	0.7252	0.8161	0.852	0.903	**0.6003**	*Not Significant*

As it turned out in Table 5, the new assessment and evaluation plan did help with the knowledge and skill-building of our architecture students. Architecture students of the International School significantly found themselves more flexible and versatile in their project-doing capabilities compared to students of the Faculty of Architecture. The t-value was up to 3.0411 and there was also a big gap between the mean values of 4.04 compared to 3.42, respectively, as shown in Table 5. Students of the International School also came to realize the significant importance of assessment and evaluation based on 3D material models and and project-management tools utilization in their Capstone projects. But still, most students believed that the Capstone format for the architecture programs of both the International School and the Faculty of Architecture did not, to a good extent, help with their creativity or effectiveness as a future architect. The low mean values here, of little more than 3 (i.e., 3.42 and 3.20, respectively) suggest that more work should be done on our part.

Table 5. T-test Results for Statement 28, 29 and 30

Statement	$\bar{X}_{IS}$	$\bar{X}_{Ar}$	VAR_{IS}	VAR_{Ar}	SD_{IS}	SD_{Ar}	t-value	Significant or Not
28. I do feel that I am flexible and versatile in my project-doing capabilities.	4.04	3.42	0.8616	1.0222	0.928	1.011	3.0411	**Significant**
29. I strongly believe that 3D models (by wood/glass/iron/	4.07	3.60	0.7454	0.7000	0.863	0.837	2.6038	**Significant**

composite/…) and project management tools are essential to the success of any architecture project.								
30. I trust that the Capstone-project format of Architecture programs at Duy Tan University helps improve my creativity and effectiveness to become a successful architect later on.	3.42	3.20	0.6586	0.8454	0.812	0.919	1.2155	*Not Significant*

CONCLUSION

In conclusion, it is not easy to recognize to what extent an integration of effective features from the CDIO Capstone project may help elevate the quality of current architecture Capstone projects because Capstone projects in architecture have also been around for a long period of time. Our study has shown that by remaking the design of project tasks and problems toward more of a "problem-centered" structure, we will help improve our students' confidence even in the face of difficult design challenges. Also, by reorganizing our training and Capstone deployment process toward more collective work in the school's workshops, more use of project-management tools as well as model-making equipment, and more integration of theoretical and practical training for Capstone projects, we will effectively help our students develop their professional skills and knowledge in the field. Last but not least, the move toward assessment and evaluation of more on students' interaction and teamwork, more on frequently-scheduled field trips and presentations, and more on frequent deliverables at different stages of the project definitely will make our students become more flexible and versatile in their approach. Even so, many times, our CDIO-oriented improvement efforts did not work out as expected, and additional work does not necessarily imply any future success, but that should be understandable as architecture is not only a discipline of science but also a field of art.

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APPENDIX

DUY TAN UNIVERSITY Architecture						
Student ID:	Student 's Name:	Date:				
Student's Program:		Tick One				
1: Strongly Disagree - 2: Disagree - 3: Neutral - 4: Agree - 5: Strongly Agree						
No.	Design Problem/Task	1	2	3	4	5
1	Our team has to formulate the design tasks for the Capstone projects.					
2	The design tasks for our Capstone projects are given by the instructors.					
3	The design tasks of most teams in our Capstone-project classes are different.					
4	Most teams in our Capstone-project classes are working on the same end-project design tasks.					
5	Our Capstone projects in the first couple of years were mostly on concept design while those for later years are more on real-world projects.					
6	We have the opportunity to work with real-world projects from a very early stage through our Capstone projects.					
7	I feel the same motivation for creativity whether working with available architecture concepts or with new design concepts.					
8	I enjoy creating new design concepts and tasks for already available architecture work or monuments in the real world.					
No.	Training Approach and Deployment Process	1	2	3	4	5
9	Our teams work on the Capstone projects mostly in the workshops rather than at home.					
10	Our teams are still used to working on the Capstone projects at home.					
11	I am used to making my designs through wood/glass/iron/composite /… models.					
12	I am used to making my designs through drawings and sketches.					
13	Our team breaks down our project into different phases and focus closely on the outcomes/deliverables of each phase.					
14	Our team mostly focuses on the end-project outcome because that ultimately determines the success or failure of the project.					

15	Our team does quite a number of related field trips and on-site visits to collect relevant data and materials for our project.					
16	Related field trips and on-site visits are not available or essential to the completion of our project.					
17	I manage to utilize the school's workshops as well as different project management practices and model-making tools effectively for our project.					
18	The balance between theoretical design courses and practical design ones at Duy Tan University is adequate for the development of our skills and knowledge in the field of architecture.					
19	I noticed improvements in our instructors' professional capability and guidance approach after every semester.					
No.	Assessment & Evaluation Measures	1	2	3	4	5
20	Our Capstone-project instructors take time to frequently evaluate our team's interaction and communication.					
21	Evaluation of the team's interaction and communication may not be that important if the end-project outcome is eventually a failure.					
22	Our Capstone-project instructors usually inquire about our off-campus activities like field trips and on-site visits for the project.					
23	Evaluation of our team's field trips and on-site visits (if any) for the project are not always available in our class.					
24	Our Capstone-project instructors require frequent presentations of our project progress, on either a weekly or bi-weekly basis.					
25	Our Capstone-project instructors focus mostly on the end-project presentation.					
26	Our Capstone-project instructors require us to frequently report on our project progress through weekly or bi-weekly deliverables of 3D models/prototypes and drawings.					
27	Our Capstone-project instructors put most of the grading percentile on the end-project deliverable/outcome.					
28	I do feel that I am flexible and versatile in my project-doing capabilities.					
29	I strongly believe that 3D models (by wood/glass/iron/composite/…) and project management tools are essential to the success of any architecture project.					
30	I trust that the Capstone-project format of Architecture programs at Duy Tan University helps improve my creativity and effectiveness to become a successful architect later on.					

BIOGRAPHICAL INFORMATION

Hieu X Luong is the Vice Dean of International School, Duy Tan University. His interest is in green architecture.

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USING FACEBOOK AS A SUPPLEMENTARY COMMUNICATION CHANNEL FOR ACTIVE LEARNING

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ABSTRACT

Active Learning as CDIO Standard No. 8 is all about engaging students in discussion, argumentation, interaction, and eventually, the creation of new ideas and concepts. Through Active Learning, students will not only learn about the materials at hand but also manage to figure out how they should structure their learning approach and what topics they should focus on to enhance their own personal skills and knowledge. A key element to successful Active Learning, however, is the interaction channel between students, instructors and other stakeholders, who are involved in the overall teaching and learning process. While online communication channels are increasingly promoted at many universities and colleges as the best way to enhance Active Learning, the effectiveness of those channels for Active Learning, are usually left unmeasured or ignored in most studies. This paper, as a result, will attempt to measure the pros and cons of using one specific online channel of Facebook for CDIO study groups. In particular, Facebook sites have been set up for CDIO projects at Duy Tan University with the purpose of:

(1) Fostering neat and timely communication and interaction amongst CDIO team members,

(2) Facilitating different brainstorming and design-thinking tactics for the conceiving of new ideas,

(3) Collecting and comparing data on students’ postings and participation so as to propose an appropriate approach in the use of Facebook for CDIO teamwork,

(4) Developing a data pool on Facebook about different Active Learning tactics to be used in specific CDIO-based courses.

Different measurements and comparisons between teams which facilitate Facebook and teams that do not will be carried out to compare and contrast the strengths and weaknesses of our new Facebook approach versus other communication channels. This study is supposed to be of interest to schools which are looking for ways to smoothen and fasten their Active Learning approach in the overall CDIO adoption.

KEYWORDS

Active Learning, brainstorming tactics, CDIO Standard No. 8, CDIO Project, communication channel, design-thinking social network, Facebook

INTRODUCTION

As of late 2015, there are up 1.6 billion users on Facebook, of which the majority are youngsters and college students (Stutzman, 2006; Roblyer et al, 2010), who spend an average amount of 30 minutes or more on Facebook on a daily basis (Pempek, Yermolayeva and Calvert, 2009). This is a significant difference when compared to earlier generations of Internet users who tend to use email for online communication (Roblyer et al, 2010). So, the question becomes whether Facebook may help foster a productive learning environment? This is very much possible given the fact that Facebook also include other software utilities like email, chat rooms, and bulletin boards. College instructors can easily make announcements, assign tests and exams, or carry out class activities through Facebook. It also helps keep parents well-informed about what is going on in school with their college kids (Uzun et al, 2014). Moreover, research results have shown that students who use Facebook for their study tend to be more active, positive, and motivated in their approach (Mazer, Murphy and Simonds, 2007), part of the reason has to with the fact that most students have used Facebook for a long period of time before, with many friends and fans to recognize and support their online identity and participation (Bosch, 2009). Hence, would it be great if Facebook is to be used for the deployment of CDIO projects so as to enhance various benefits of Active Learning tactics? And how great would those benefits be in reality?

In the first part of this paper, we will present the purpose, structures, and settings of the CDIO projects designed for IT disciplines at Duy Tan University (DTU) using the guidelines and advice from the CDIO Framework. Issues concerning communication will be highlighted at different points to signify the importance of an appropriate communication channel. In the next part, we will attempt to measure the pros and cons of using one specific channel of Facebook for CDIO project teams. As a matter of fact, during the last two to three years, Facebook has been used for CDIO projects in IT at Duy Tan University with the original purpose of:

(1) Fostering neat and timely communication and interaction amongst CDIO team members,

(2) Facilitating different brainstorming and design-thinking tactics for the conceiving of new ideas,

(3) Collecting and comparing data on students' postings and participation so as to propose an appropriate approach in the use of Facebook for CDIO teamwork,

(4) Developing a data pool on Facebook about different Active Learning tactics to be used in specific CDIO-based courses.

CDIO PROJECTS IN SOFTWARE ENGINEERING & IT-RELATED DISCIPLINES AT DTU

In this section, we will describe the deployment of the CDIO projects in Software Engineering, Network Security and Information Systems at the Faculty of Information Technology (IT) of Duy Tan University in a university-wide effort to foster quality engineering training.

A. CDIO Projects and their Implications:

CDIO projects are set up for students to solve some practical problems through the integration of many learned skills and knowledge (IEEE Computing Society and Association for

Computing Machinery, 2004). For DTU, the main purpose of its CDIO projects is to provide students with some sense of "real-world", "on-the-job", teamwork activities. Using the CDIO Framework, the CDIO projects at DTU utilize typical teaching/learning methodologies like active learning, team learning, experimental learning, design-implement experiences, etc. (CDIO™ Initiative, 2016). Another motivation behind the adoption of CDIO projects is to support the ABET accreditation effort for different engineering programs of the Faculty of Information Technology (IT Faculty), the International School of DTU and other engineering faculties.

B. CDIO Project Structures and Timeframes:

At DTU, there are three CDIO projects for students majoring in Software Engineering, Information Systems and Network Security. These courses are usually held in the second semester of each academic year, starting from the sophomore year. Since the CDIO projects of the sophomore and junior years mostly provide some introductory hands-on experience of IT projects, we will focus on the CDIO project for the senior year. For this final-year CDIO project, students in each team will have to work with a real-world client to design, develop, and implement an IT product or solution, for a period of 6 to 8 months. Communication is usually a big issue here because many students do not have experience working with real-world clients before. Finding the right communication channel for in-time and regular contact with clients may take time and effort. As a result, mentors are assigned to each CDIO team project to ensure smooth communication with business clients and to support the students whenever needed (Todd & Magleby, 2005).

For the final-year CDIO project, students are assigned into teams of 3 to 5 members. Following the guidelines of ACM/IEEE, team member assignment is done by the Faculty of Information Technology of DTU so as to ensure that the skills and capabilities of any one team member will supplement for those of others (ACM, 2001). Because of the many “soft-skill” courses at DTU, students usually have no problem getting along with each other in the beginning even though they were not allowed to choose their friends for their projects. Problems actually emerge when the team has to bid for one of the real-world projects from several IT-business clients of Duy Tan University. Disagreement over role assignment, project selection and idea development is usually the source for conflict between team members. The role of assigned mentors for each project team at this point is to help maintain the relationship with the business clients. Most IT-business clients of DTU are software and IT companies from Da Nang, Hanoi, and Ho Chi Minh City.

Out of the 6 to 8-month time period of the final CDIO project, there are two stages with each lasting for a period of 3 to 4 months. For Stage 1, each student will need to spend a minimum of 16 hours per week for team interaction, regulation formulation, conflict resolution, software process selection, and proposal write-up. It is expected that Stage 1 will take up to 192 hours (i.e., 16 hours x 12 weeks) per student in every team, not including extra interpersonal interaction. However, as soon as the project proposal is approved by the IT-business client, the team will move on the next stage, which means teams with excellent communication skills may cut down Stage 1 to three months or even less. In Stage 2, students will have to spend time on requirement engineering, product architecture, system design, coding, testing, product implementation and maintenance. At least 40 hours of work per week or a total of around 480 hours will be expected from every student for this stage. In short, students will experience every step of the complete software development life cycle. As a result, a well-structured communication channel that goes along with each software development process is essential to the success of the project within the allowed timeframe. On the other hand, there may be deviations from the projected schedules depending on the software development methodology the team selects, for example, the actual schedules will be quite different between an AGILE approach (i.e., small software development team format) and a plan-driven structure (i.e., well-organized, enterprise-wide software-development approach) (Sliger & Broderick, 2008).

C. Detailed Implementation Tasks in the IT CDIO Project:

Team Formulation:

One of the first activities in the final CDIO project is the skills-review session in which each team member will identify how he or she may best contribute to the project. Together, the team must define the roles and responsibilities of each team member (IEEE Computing Society and Association for Computing Machinery, 2004). All kinds of communication conflict may arise during this session depending on the approach and personality of team members: some may try to dominate the team, some only want to focus on what they are good at, and yet some may just want to get a free ride. Faculty members from the Faculty of Information Technology will attend the role identification meeting, and may give direction or guidance as well as mediation when needed.

It is important to remind team members that the CDIO project helps them learn and no one member is "the Boss" of the project, but it is also essential for them to recognize that the project management/leadership role is needed to help coordinate, plan, and track the team's activities and efforts. The Project Manager (PM) role is to keep the team focused and makes sure that various tasks get done on time. The PM will also review each member's work contributions to make sure that they meet the proposed technical and quality requirements. The PM is the most important role in any IT CDIO project, as a result, the team needs to select the best member for this role. Communication skills should be the top requirement for the PM position.

Beside the PM roles, there are other roles that team members must also identify and assign such as Software Configuration Manager, Software Quality-Assurance Manager, Testing Manager, etc. Since there are several development phases in an IT product life cycle, team members can take turn switching roles with each other in each phase (Moe, Dingsøyr & Røyrvik, 2009). Role switching can be sometimes damaging to the team's performance if the communication structure is not effective and clear-cut.

Conceiving of Product Ideas and Creation of Project Structures:

In this step, IT-business clients will hold a series of presentations to introduce their projects and related problems and/or solution suggestions with all the CDIO teams at DTU. Each team will then prepare initial proposals for at least three projects so as to bid for the most suitable one. This is usually the time when team members may run into significant communication conflict over their preferences for different projects, time allocation for proposal write-ups, lack of certain capabilities, etc. Based on the team's capacity and capability, DTU IT faculty members will work the IT-business clients to assign the right project to the right team. Together with the bidding result, each team will also be assigned one or two mentors for their project. There is a potential for conflict again here when role re-assignment may take place due to the nature and requirements of the assigned project. Subsequently, the team needs to actively plan for meetings to design, develop and implement the selected project. Even though the project problem may not be original because it has been presented by the business clients from the first place, students are encouraged to discuss with each other to develop original solutions in their team formation and/or technology application for the project at hand.

Design & Implementation:

Before any actual design and implementation activities start, successful team formation and continuous maintenance of the team's communication and workflow are arguably the biggest challenge to most students in their CDIO projects. From the beginning, team members do not have the right to select one another. Then, they have to join force together for the most important project before graduation. Hence, team members need to put aside their differences, their interests, and their ego in the team communication so as to develop a successful solution for the project. It is important for students to understand that the CDIO team is "larger" than themselves and every team member must jointly contribute to the success of the project (ACM, 2001). It is at the same time important to have a communication channel for mentors and business clients to continuously provide students with inputs about the expectations and goals of project so that they may adjust themselves and their project, accordingly.

Once the team and its project structures are in place, team members need to actively assess their capabilities and the feasibility of the project in order to set up an effective project plan. Even though the project plan is usually put together by the PM, it is important that the plan be discussed and agreed upon by all the team members to ensure their commitment for the project (Lingard, 2010). Depending on the software development process methodology being selected, the PM will build a detailed plan which are consistent with all the criteria and requirements of that software development process. The choice of tools and systems for idea sharing and project management will be very important here for in-depth communication and discussion between team members. In addition, later on, especially before each development phase of the software development process, the PM will need to share all the information about the actual number of hours that each team member will have to put forth for their tasks. This will create a sense of equality and fairness, plus team members can also plan for their next tasks based on that.

As the project design work goes on, the team needs to discuss with its business clients from time to time about the desired scope of the project. When the project scope is finally approved upon, the team will need to revise its Software Requirements Specification (SRS) to fit with the approved scope. They may also have to revise the use cases and use-case diagrams and narratives designed previously as well as to fill in the missing details and to indicate all the preconditions, post-conditions and triggers for each use case. Project management tools and dashboard utilities to share information amongst team members and with business clients are essential here. Once all of the design details are put together, the Design phase is basically completed. Design work, however, does not stop here: depending on the problems and risks encountered later, the PM may decide to go back and revise the design accordingly later on.

In the following phase of project implementation, many tasks of coding, testing and redesigning will be carried out in sequence or at the same time in a complex arrangement. As a result, the team will need to foster clear communication, to identify dependencies among their tasks, and to jointly sort out any problem that they may run into so as to ensure the quality and success of the end product or prototype. Besides the end product or product prototype, CDIO teams at DTU are also required to write up an overall report of their accomplishments, conclusions, recommendations and lessons from the CDIO project. This report must be clear, complete, well-written, and delivered on time. It will serve as the basis for the final assessment of the project outcomes.

USING FACEBOOK AS A SUPLEMANETARY COMMUNICATION CHANEL

Of all the communication requirements for the final CDIO project mentioned above, over the years, students and mentors from the Faculty of Information Technology (IT) as well as IT-business clients have referred to a number of different channels for their communication. Faculty members, like in other courses, tend to use email and e-learning platforms such as Moodle or SAKAI to communicate with students. However, while email continues to be an essential tool for private communication between students, project mentors and business clients, most e-learning platforms appear to be more of a one-way communication channel with the faculty members or mentors making announcements, focusing students' attention on certain topics, assigning tasks and tests, etc. Most features in the bulletin board or chat box of e-learning platforms are yet so limited that they usually do not attract students to join in and raise their questions or concerns. On the other hand, IT-business clients mostly use email and paper-based communication to deliver and exchange their materials with students and mentors of the IT Faculty. Paper-based communication is still utilized because it has legal implications between the sender and receiver. It is, however, very slow and does not foster discussion and participation.

With the exception of certain features like making quizzes and tests or maintaining a schoolwork drop-box, Facebook actually has almost all of the other features of a typical e-learning platform with much more attractive, easy-to-use interfaces and functions. Indeed, the fact that many students have already had Facebook accounts long before makes it easy for them to join in another Facebook site designed for their CDIO project. The very first benefit of using Facebook for CDIO projects is that students may learn about other team members' skills and background by accessing the Facebook site of those members. This actually helps save a great deal of time and effort for initial exchange and communication between the team members. The availability of personal information from each Facebook user, however, calls for professional behaviour and conduct on Facebook regarding the CDIO project. The administrator account of the CDIO Facebook site is assigned to the project mentor, and students are asked not to discuss personal or political issues.

In addition, Facebook appears to be very effective in the interaction between students and IT-business clients. Instead of spending time for some formal presentations of the business problems or system requirements of the project, companies and businesses may send in the e-copy of their formal materials through Facebook. Some businesses even come to the point where they make video presentations of their business problem so that students may watch those many times before making the bid for their project or for revising their codes and designs. The Facebook templates allow students to actively interact with business clients on any of their questions or concerns. One point that should be noted here is that the Faculty of Information Technology of DTU needs to require each IT-business client to assign at least one specific staff member to regularly observe the Facebook site and promptly answer any question raised by the students. Many times business clients may send in many staff members during the initial exchange for the setup of the project, but fail to participate throughout the whole process of project development with our students.

As for the use of Facebook amongst the project team members, it is important that clear-cut rules and regulations are established to set firm foundations for smooth and sustainable communication throughout the project development process. Specifically, the project mentor needs to closely monitor all the communication on the Facebook site for the project. Should there be any hostile or personal communication, he or she should ease off the tension or divert the communication to a different topic or put an end to a negative discussion in an outright disciplinary manner. At the same time, the project mentor needs to motivate constant contribution of ideas and suggestions from each team member by posting related readings, raising certain questions or problems, requesting comments on different feedbacks among the team members, etc. for at least a few times a day. On the other hand, students are encouraged to regularly express their opinions and be responsible for responding to questions and feedbacks on their opinions. This requires students' active involvement in the discussion through a series of push-and-pull tactics. For example, in a number of CDIO projects at DTU, the mentor usually requires the PM to lead the discussion on any immediate or current problems of their projects. If the problems put forth are relevant, the project will usually make visible progress over time. Some mentors even come to the point of replacing the PM of the project if he or she fails to lead the discussion in the right direction. Others switch the role of the discussion champion among the team members on the basis of every one or two weeks. In addition, besides the Facebook site for every CDIO project, three general Facebook sites for three respective aspects of design structures, coding tactics, and testing methodologies are also set up so that team members with their roles closely related to those fields may come together for Q&A on different problems and issues. At times, it is also important that the mentors post certain guidelines, experiences or lessons learned from each CDIO project on those general Facebook sites for teams to learn from each other. Another incentive mechanism established by our mentors is that at the end of each week, 5 top postings with the most number of Likes and responses will be awarded with bonus points toward their eventual project grades. Students are also ranked and graded based on their participation according to the number of (fruitful) postings they made throughout the project. Last but not least, students, mentors and business clients alike are free to discuss and revise on the rules and regulations for their interaction and communication over Facebook whenever needed.

In order to assess the effectiveness of using Facebook as the major communication channel for IT CDIO projects, a survey is carried out at the end of each CDIO project. The questionnaire used in the survey has two parts of (I) Personal Information and (II) Opinions on (using) Facebook for CDIO projects. A Likert scale of 1 to 5, with 1 as Strongly Disagree, 3 as Neutral and 5 as Strongly Agree, is used for the rating in the second part. The time amount allowed for students to finish the questionnaire is relatively short for only 10 minutes so as to ensure that students will provide their most immediate, direct and honest reflections on the use of Facebook for their CDIO projects. Additional details of the survey questionnaire can be found in the Appendix of this paper.

RESULTS & DISCUSSION

A total of 184 students have participated in the survey with their age ranging from 20 to 26 years old with the average age of 22.5, meaning that most of them are senior students. The percentage of males is 73% and that of females is 17%. Most of these students are very much familiar with Facebook, spending an average amount of 86 minutes on Facebook per day. As for the second part of the questionnaire, the mean value of feedbacks to each question, out of the Likert scale of 1 to 5 as mentioned in the previous section, is calculated to determine how much on average students agree about the benefit of Facebook for certain aspect of carrying the CDIO project. Respective standard deviations are also calculated: a low standard deviation will indicate a firm level of agreement around the mean value while a high standard deviation presents a loose level of agreement.

As the results shown in Table 1, except for responses to Question 10, all the mean values of responses to other questions are higher than 3 (i.e., above neutral) indicating that on average students agree about all the benefits of Facebook for CDIO projects to certain degree. With the mean value of 3.76 for answers to Question 1, it can be said that students strongly believe in the overall benefit of using Facebook for CDIO projects. Questions 2, 3 and 4 have to do with whether Facebook helps improve on the traditional skills used for CDIO projects. While a mean value of 3.22 for answers to Question 2 signifies that Facebook relatively helps improve on the design-thinking skills of students, most students are quite neutral about whether Facebook indeed improves their brainstorming and problem-solving skills with a mean value of only 3.12 with respect to Question 3. In addition, most students do not believe that their attitudes toward carrying out CDIO projects have been changed because of Facebook (with a mean of 3.04 with respect to Question 4). This is probably true not only in IT-related fields but also in other engineering fields, in which the change of the communication channel does necessarily change the ways of carrying out the projects. The high standard deviations for responses to Question 2 and 3, however, indicate that some students very much perceive the benefits of Facebook for their CDIO projects, and some others, on the contrary, do not at all.

Table 1. Means and Standard Deviations on Survey Results (part II)

Does Facebook Site help on:	**Mean**	**Standard Deviation**
1. Doing CDIO project	3.76	0.84
2. Improving design-thinking skills	3.22	0.88
3. Brainstorming and problem-solving skills	3.12	0.91
4. Attitudes toward carrying out CDIO projects	3.04	0.63
5. Getting class-related information	4.00	0.49
6. Expressing your opinions	3.68	0.55
7. Relationship with the project mentor	3.64	0.79
8. Relationship with other team members	3.50	0.70
9. Relationship with business clients	3.84	0.70
10. Posting more on Facebook	2.22	0.73

Question 5 and 6 is directly related to the effectiveness of Facebook as a communication channel. A mean value of up to 4.00 and a low standard deviation of 0.49 proves that Facebook helps students get access to project information and materials much easier. The same situation applies to students' ability to express their opinions through Facebook with a mean value of 3.68 together with the standard deviation of only 0.55 in Question 6. As a matter of fact, the number of responses and feedbacks from students, mentors and IT business clients on any one topic has significantly increased when using Facebook, compared to the use of tools from traditional e-learning platforms. Questions 7, 8 and 9 inquire on whether Facebook helps improve the relationship between students and their mentors, team members and business clients. With the mean values of 3.64, 3.50 and 3.84 respectively, it can be said that Facebook very much helps improve the communication and relationship between students and all other stakeholders. The average standard deviations of around 0.70 for responses to Questions 7, 8 and 9, moreover, confirms this fact. As for the last question of whether the adoption of Facebook for the CDIO project helps promote additional use of Facebook on the part of the students, it appears that it has no actual influence with the mean value of only 2.22 and the standard deviation of 0.73. This probably has to do with the fact that our students already has been using Facebook a great deal on a daily basis, or that they do not see the additional use of Facebook for their CDIO projects as making any visible leap in their use of Facebook in general.

CONCLUSIONS

The purpose of this study is to validate the idea that social networking sites, as online social communication platforms, can be utilized to enhance various Active Learning tactics in CDIO projects such as teamwork collaboration, peer support, project management procedures, debates and Q&A, etc. Facebook as the top social networking site with all of its user-friendly features may help build up an informal but effective learning atmosphere amongst students, project mentors and business clients, which eventually will translate into academic performance improvement. Daily interaction on Facebook also brings all the participants closer together, and their improved interpersonal relationship will directly enrich the overall learning experience. The study also signifies the need for further studies including a detailed comparison between the benefits of specific Facebook features and those of traditional communication methods, or about the over-time increased willingness of students to communicate with the school's administrative personnel on Facebook, or about the different impacts of Facebook on students and other stakeholders under various cultures or geographical locations.

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BIOGRAPHICAL INFORMATION

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APPENDIX

Survey Questionnaire on Facebook for CDIO Projects

Personal Information:					
1. Your name:					
2. Your age					
3. Your gender	MALE / FEMALE				
4. How many hours on average do you spend on Facebook per day?					
5. How many postings do you usually make on Facebook every week?					
6. How many responses do you usually get for each posting?					
(5: Strongly Agree; 4: Agree; 3: Neutral; 2: Disagree; 1: Strongly Disagree) **Does Facebook help on:**					
1. Doing CDIO project	1	2	3	4	5
2. Improving design-thinking skills	1	2	3	4	5
3. Brainstorming and problem-solving skills	1	2	3	4	5
4. Attitudes toward carrying out CDIO projects	1	2	3	4	5
5. Getting class-related information	1	2	3	4	5
6. Expressing your opinions	1	2	3	4	5
7. Relationship with the project mentor	1	2	3	4	5
8. Relationship with other team members	1	2	3	4	5
9. Relationship with business clients	1	2	3	4	5
10. Posting more on Facebook	1	2	3	4	5

INTEGRATING CDIO SKILLS BY TEAMWORK IN A SCHOOL OF ENGINEERING- ISEP

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ABSTRACT

CDIO initiative establishes a set of learning outcomes for the students to achieve upon the completion of their engineering programmes. These learning outcomes cover several areas namely scientific knowledge, personal and interpersonal skills and product, process and system building.
Teamwork is recognized to be very important in the learning process and contributes to engineering thinking and problem solving using knowledge discovery and creative and critical thinking. Besides it enhances interpersonal development since it favours individual and group interactions using communication, conflict solving and leadership.
Engineers should acquire the essential technical knowledge and also soft skills to be able to face and solve the challenges of our modern society, which require knowledge, the ability to communicate and implement solutions many times using a multidisciplinary approach. The goal of this work was to characterize and analyse the situation related to teamwork in Instituto Superior de Engenharia do Porto (ISEP), School of Engineering.
In order to achieve these goals a review of existing teamwork tasks in every course of each engineering program in ISEP was performed. In addition a survey was designed and launched online at the end of the second semester to cover all academic year. All students have access to computers and internet at school and some them also have access at home.
For the engineering programs that used teamwork as a very common tool survey quantitative and quality analyses were performed such as frequency analysis among others, in order to characterize the main aspects of their implementation.
By performing this type of analysis it was possible to detect, for example, the advantages and disadvantages of teamwork perceived by the students.
The answers given by students indicate that most of them are happy with the teamwork developed in the courses and that the support provided is enough.

KEYWORDS

Higher education, Engineering, Teamwork, Teaching-learning process, and Learning strategies, Standards: 2, 8, 11

INTRODUCTION

Engineering graduates should have several technical knowledge and skills that contribute to enhance and improve their role in business and society and that enable them to perform their work with professionalism and success. Graduates should also have personal and interpersonal skills such as engineering reasoning and problem solving, system thinking, creative and critical thinking, working in teams and communication. These are often named “soft” as there are not considered the core subjects of an engineering graduation in opposition to the more technical subjects. All these outcomes are present in the CDIO Syllabus outcomes (standard 2) (CDIO, 2016; Zou et al., 2012). The new and global challenges/problems that exist nowadays have proven that those skills are essential to the development of an engineer’s work (Crawley et al., 2011; Woods et al., 2000). Engineering programs are challenged to create innovative ways for students to learn not only core and technical subjects but also these skills. Many methodologies to enhance learning and to provide skills for future engineers have been tested and implemented such as problem-based learning and project based learning (Ríos et al., 2010). The involvement of key stakeholders that validated the learning outcomes can be very valuable to determine what should be achieved.

Teamwork is very important to the development of an engineer’s work because many projects involve several professionals in a multidisciplinary approach and aspects such as leadership and communication are essential to achieve goals successfully. Teamwork can also be a very important and useful tool to enhance learning and the development of these skills. It is an active learning activity since students take on roles that follow the professional engineering practice (standard 8) (CDIO, 2016). Teamwork also promotes peer learning, which is considered by some authors very important to the effectiveness of many engaging methodologies, such as cooperative learning and problem-based learning (CDIO, 2016).

Teamwork and their assessment can help to evaluate the personal and interpersonal skills, since it is important to have effective assessment processes for measuring them as stated in standard 11 of CDIO Syllabus (CDIO, 2016).

Nowadays there is a generalized concern about the effectiveness of conventional models of teaching and learning. The engineering schools are seeking for more active and effective ways of learning to improve programs outcomes (Rodriguez-Donaire and Amante, 2012). In fact some institutions are already studying the importance of teamwork in the learning process of their students (Oakley et al., 2007; Kamarudin et al., 2011).

The goal of this work was to characterize and analyse the situation related to teamwork in ISEP, School of Engineering. To study this a review of existing teamwork tasks was done and an online survey was made to all students about teamwork developed at ISEP.

METHODOLOGY AND CHARACTERIZATION OF ISEP, SCHOOL OF ENGINEERING

To achieve the goals mentioned a survey was designed and launched online in ISEP. The questions and choices were meant to be brief with the least possible ambiguity. The survey was launched at the end of the second semester to cover all academic year. All students have access to computers and internet at school and some also have access at home.

Quantitative and qualitative analyses were performed such as frequency analysis. By performing this type of analysis it was possible to characterize the teamwork developed in the institution and to detect the advantages and disadvantages of teamwork.

ISEP is a School of Engineering of the Polytechnic of Porto that has 11 first cycle degrees in Engineering and 11 Masters in Engineering which covers almost all domains of engineering. In the academic year considered ISEP had 6502 students (table 1).

Table 1. Engineering degrees at ISEP

Bologna 1st cycle degree	Masters in Engineering
Chemical Engineering	Chemical Engineering
Civil Engineering	Civil Engineering
Computing Engineering and Medical Instrumentation	Computing Engineering and Medical Instrumentation
Electric and Computer Engineering	Electric and Computer Engineering
Electrical Engineering - Electrical Power Systems	Electrical Engineering - Electrical Power Systems
Geotechnical and Environmental Engineering	Geotechnical and Environmental Engineering
Informatics Engineering	Computer Science
Instrumentation and Metrology Engineering	Instrumentation and Metrology Engineering
Mechanical Engineering	Mechanical Engineering
Automotive Engineering	Sustainable Energies
Systems Engineering	Applied Mathematics to Engineering and Finances

Informatics and Mechanical Engineering are the courses with more students followed by Electric and Computing Engineering, Civil Engineering, Power Systems, Chemical Engineering, Medical Instrumentation, Geotechnical and Environmental Engineering and finally others courses with a percentage of students equal or lower than 1% (Fig.1). Fig.1 shows the first 10 cycles with more students.

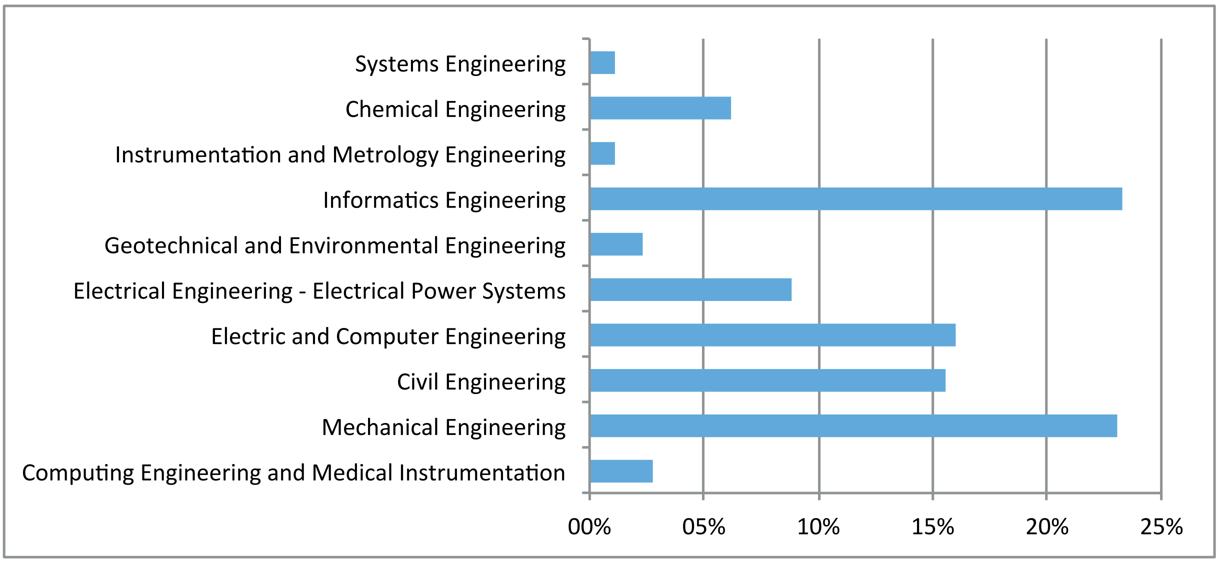


Figure 1 Percentage of students in each area of engineering at ISEP

SUBJECTS ANALYSED AND CDIO STANDARDS

The first analysis performed was to evaluate the number of courses that use teamwork as a learning tool for each engineering program. The results were compared with the integration of CDIO standards in those engineering programs. A more detail analysis was carried out for the engineering programs that used teamwork in a higher percentage.
Table 2 presents the questions asked and the corresponding CDIO standards applicable.

Table 2. Survey questions and CDIO standards

Questions	CDIO standard
1. How satisfied were you with the teamwork developed to learn the UC outcomes?	2
2. The guidance provided by the Professor was enough?	8,11
3. Is the work developed by each team member reported in any document?	11
4. Order by importance the advantages of teamwork (Maximization of the use of each member's skills, maximization of the creativity applied to the development of the project, maximization of the motivation to reach the targets, time savings considering the effort to be applied, facilitates learning, increase of the participation in the course and enrichment due to the exchange of experiences and roles)	2,8,11
5. Order by importance the disadvantages of teamwork (Decrease of personal responsibility, difficulty coordinate schedules, distraction and lack of concentration that provoke time losses, personality collisions and leadership seeking that result in conflict, lack of leadership which results in chain discouragement, confusion in responsibility attribution which results in team exhaustion and lack of productivity of some members which results in unbalanced production of the team)	2,8,11

RESULTS AND DISCUSSION

Fig. 2 shows the number of CDIO inspired/compliant courses in first cycle programs in 2008-2009 by engineering program.

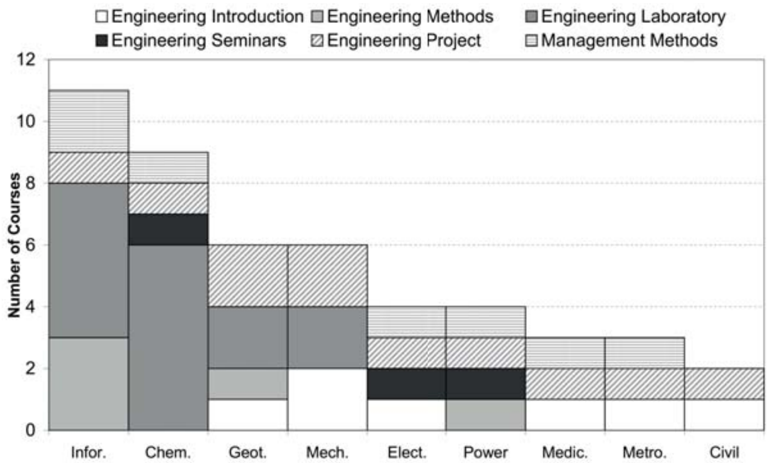


Figure 2. CDIO inspired/compliant courses in ISEP first cycle programs during 2008-2009 (Costa et al., 2010)

Comparing the results obtained with the figures available for 2008-2009 it is possible to conclude that the two engineering programs which present higher implementation of CDIO components are still Informatics Engineering (LEI) and Chemical Engineering (LEQ). It is also possible to conclude that these first cycles programs are increasing the implementation of CDIO components. For example Chemical Engineering has showed an increase approximately of 60% and LEI an increase of 36%.

In 2008-2009 System Engineering (LES) did not exist yet but it is one of the most committed engineering program in applying CDIO with 23 number of courses with teamwork besides other CDIO practices.
These three engineering programs have a capstone project/internship at the end of their cycles. They will further studied in next sections of this work.

HOW SATISFIED WERE YOU WITH THE TEAMWORK DEVELOPED TO LEARN THE UC OUTCOMES? (STANDARD 2)

Fig. 3 presents the answers given by the students, concerning the contentment with teamwork developed, of the three engineering programs that present the highest percentages of CDIO inspired courses. Comparing these 3 graphs, it is possible to conclude that almost all students seems to be satisfied with teamwork developed, because the sum of positive answers corresponds to high percentages. System Engineering and Chemical Engineering above 80% (very and reasonably satisfied) and Informatics Engineering above 55%.

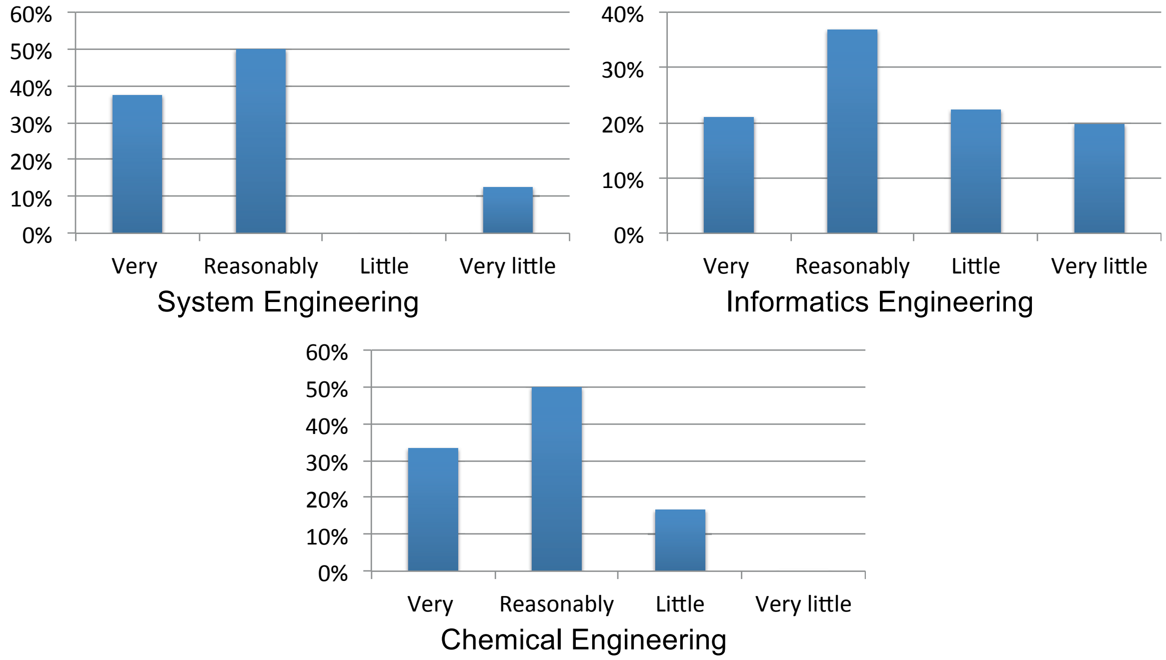
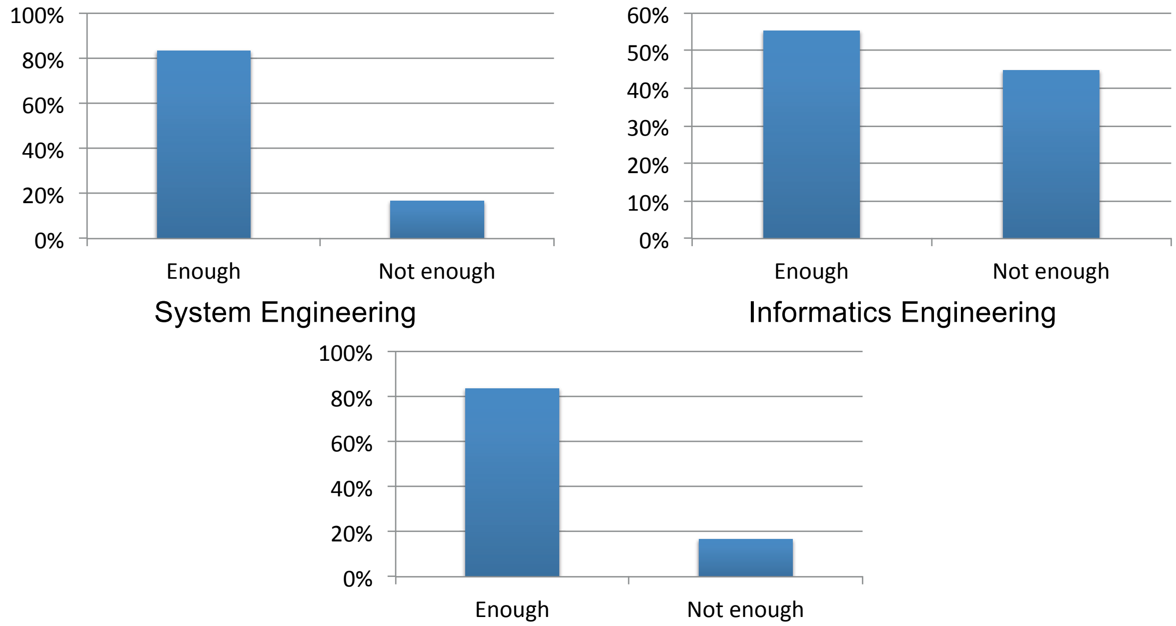


Figure 3. How satisfied were you with the teamwork developed to learn the UC outcomes?

THE GUIDANCE PROVIDED BY THE PROFESSOR (STANDARDS 8 and 11)

Fig.4 presents the answers of the students of the above mentioned engineering programs related to the guidance provided by Professors in teamwork. As can be perceived the majority of students answered that guidance was enough. System Engineering and Chemical Engineering present the highest percentages (>80%) as had happened for the previous question. In LEI only 55% of students are happy with Professor support.



System Engineering

Informatics Engineering

Chemical Engineering

Figure 4. The guidance provided by the Professor

IS THE WORK DEVELOPED BY EACH TEAM MEMBER REPORTED IN ANY DOCUMENT? (STANDARD 11)

From Fig.5 it is possible to conclude that often the work developed by each team member is not reported in any document. According to the data this happens in all the engineering programs studied. Although, it is important to note that the percentage of students that answered not applicable corresponds to 17 to 32%.

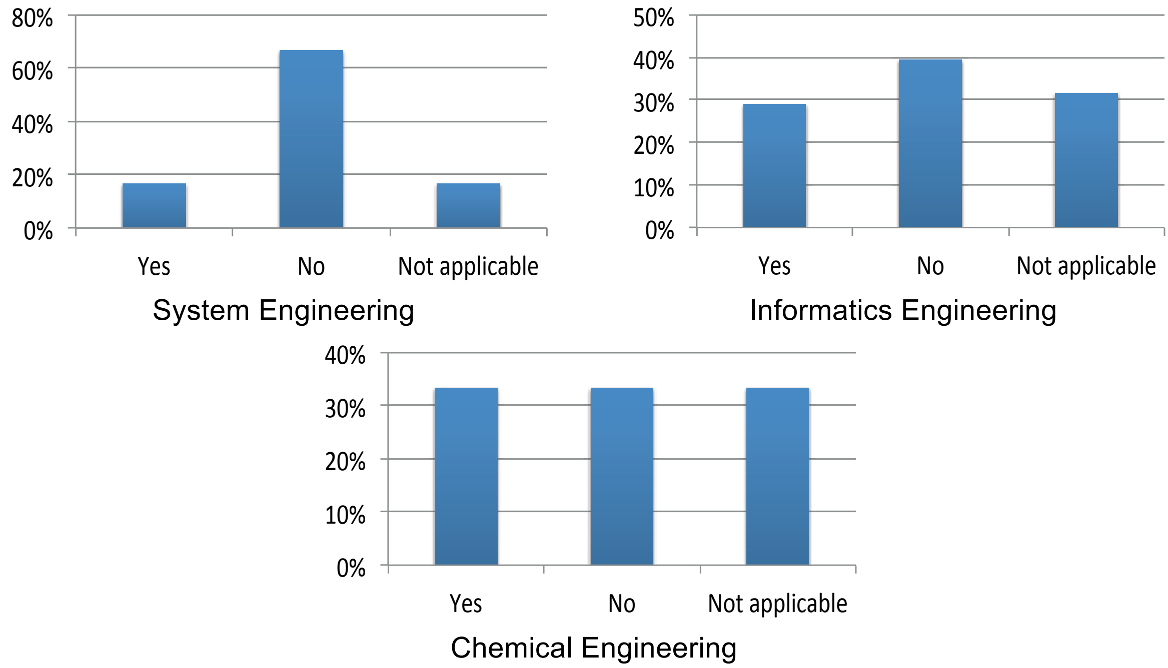


Figure 5. Is the work developed by each team member reported in any document?

ADVANTAGES AND DISADVANTAGES OF TEAMWORK (STANDARDS 2, 8 and 11)

Table 3 presents average and standard deviation for the seven advantages and Table 4 for the 7 disadvantages, the scale is between 1 (the most important) to 7 (the least important).

Table 3. Average and standard deviation for advantages of teamwork

Advantage	Average	Standard deviation
Maximization of the use of each member's skills	3.557	2.154
Maximization of the creativity applied to the development of the project	3.500	1.882
Maximization of the motivation to reach the targets	3.739	1.962
Time savings considering the effort to be applied	3.807	2.039
Facilitates learning	3.795	2.069
Increase of the participation in the course	3.886	2.065
Enrichment due to the exchange of experiences and roles	3.739	2.184

Table 4. Average and standard deviation for disadvantages of teamwork

Disadvantage	Average	Standard deviation
Decrease of personal responsibility	2.175	3.807
Difficulty in coordinate schedules	2.074	3.636
Distraction and lack of concentration that provoke time losses	2.014	3.693
Personality collisions and leadership seeking that result in conflict	1.872	3.784
Lack of leadership which results in chain discouragement	2.144	4.045
Confusion in responsibility attribution which results in team exhaustion	1.866	3.682
Lack of productivity of some members which results in unbalanced production of the team	2.171	3.000

From the analysis of data from tables 3 and 4 it is possible to conclude that most advantages and disadvantages present similar classifications, average and standard deviation. However the average values for disadvantages are slightly lower than the values for the advantages but the standard deviations are higher which indicates that for disadvantages students evaluate them more differently. Lack of leadership which results in chain discouragement, presents the highest value for standard deviation and it is followed by Decrease of personal responsibility. The advantage that presents the smallest average value is Maximization of the creativity applied to the development of the project and the disadvantage that presents the smallest average is Confusion in responsibility attribution which results in team exhaustion.

CONCLUSIONS

The results show that ISEP has engineering programs that incorporate CDIO components in the learning process in a very committed way since they have many courses with significant CDIO influence. The answers given by students indicate that most of them are happy with the teamwork developed in the courses and that the support provided is enough. Not reporting the work developed by each team member in any document seems to be a common practice. Concerning advantages of teamwork all of them present similar average values as well as the disadvantages. However the advantage that presents the smallest average value is Maximization of the creativity applied to the development of the project and the disadvantage that presents the smallest average is Confusion in responsibility attribution which results in team exhaustion.

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BIOGRAPHICAL INFORMATION

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ACTIVE LEARNING THROUGH 3D PRINTING TECHNOLOGY AND PROTOTYPING

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ABSTRACT

This paper describes our journey in using 3D printers as a pedagogical tool to implement active learning (CDIO Standard 8) in the Biomedical Project module in the School of Engineering at Nanyang Polytechnic, Singapore.

The Biomedical Project module aims to develop students' skills in designing an innovative biomedical product with business ideas to market and package it for commercial consumption. By incorporating 3D printing into the module, students are involved in an iterative and connected process that empowers them to be better able to experiment with their innovative design concepts and test their designs for fit and function. It exposes students to various facets of engineering and design disciplines, as well as promoting creative thinking among the students.

Besides the strategies used in designing and implementing the learning activities with 3D printing, our experiences in incorporating other active learning strategies in the module, like flipped classroom in lecture lessons and mini-seminar for students to pitch their business ideas, are also highlighted in the paper.

This paper ends with a discussion on the outcomes of the active learning strategies used in the module by examining students' interest in learning biomedical technologies/concepts and their perception towards this active learning approach.

KEYWORDS
Active Learning, 3D Printing, Prototyping, Biomedical Product Design, CDIO Standard 8.

Note – In the context of Nanyang Polytechnic, the term 'course' refers to a 'program' while the term 'module' refers to a 'course'. For example, *Diploma in Biomedical Engineering* is a course; *Biomedical Project* is a module.

BACKGROUND

Introduction

Polytechnic education in Singapore aims to provide industry relevant education and training for the workplace, to give Singapore a competitive edge as we move to a knowledge-based economy [1]. At Nanyang Polytechnic (NYP), we strive to provide our students with a learning and development experience that nurtures their potentials and helps them develop specific attributes to excel in work, life and learning. The education equips them to thrive in rapid economic and social changes, and contribute to Singapore's technological, economic and social development. In meeting these goals, our graduates must possess critical & transferrable skills and desirable personal values. As our graduate attributes spell out, we would like our graduate to be:

- ✓ Professional Competent – The graduate is knowledgeable and skilled in his field of study so as to apply them effectively in workplace. The graduate possesses multi-disciplinary perspectives, and has the passion for lifelong learning.
- ✓ Competent in 21st Century Skills – The graduate is ready to sustain personal and

professional development. The graduate has essential skills in civic literacy, global awareness & cross-cultural understanding; critical & inventive thinking; and information literacy, communication & collaboration.

- ✓ Innovative & Enterprising – The graduate thinks critically and is ready to recognise challenges and embrace them as opportunities. The graduate is able to generate creative ideas, exploit resources and develop practical approaches to create innovative solutions.
- ✓ Socially Responsible – The graduate recognises and upholds personal and professional ethics. The graduate is able to appreciate and respect cultural and intellectual diversities and is caring and compassionate to the community.

These graduate attributes are translated to the student learning outcomes and course educational objectives for the courses offered by the School of Engineering (SEG) at NYP, which define what our graduates are able to perform upon graduation as well as a few years after graduation, respectively.

In 2013, the SEG conducted a major course evaluation and review for the Diploma in Biomedical Engineering (DBE). The course review evaluated how the course educational objectives and student learning outcomes were able to meet the current needs of various stakeholders, including potential employers from industry and government agencies, our alumni and faculty members of SEG. There are many enhancements to the curriculum from the review, one of them was to deepen the adoption of the Active Learning (CDIO Standard 8) pedagogical approach with the objectives to further improve our engineering education, and to better prepare our graduates to be more capable of carrying out self-directed learning, problem-solving and collaborative team work. In this paper, we present in detail one of these selected modules, the Biomedical Project module, as a reference model for the implementation of active learning in the DBE course.

Challenges in Existing Practice

Before the course review, students in the Biomedical Project module would go through the processes of ideation, designing and prototyping. Typically a few problems related to healthcare and medical device were given to the students and they would form teams of two to three members to look into solving the problem with innovative solutions. They would usually come out with two to three ideas or designs and build prototypes using recyclable materials. Sometimes it was a mere paper exercise where students shared their ideas through poster presentation. This was due mainly to the time-consuming processes that students had to go through if they were to fabricate a slightly more complex prototype, given that the module was a 60-hour module. The limitations of such an approach were obvious in that the students were not able to recognize and experience the true challenges in making biomedical products. They were also not able to appreciate the process in building and testing the functionality of the products if the prototypes were not constructed fully, and hence affecting their assessment outcomes. In the CDIO terms, students experienced the ‘Conceiving’ and ‘Designing’ aspects of the product lifecycle, and partially on ‘Implementing’ and lacking on ‘Operating’, which are important aspects of the engineering education. It is through the ‘Operating’ phase that the students were able to perform the product trial, solicit feedbacks from end users, and iterate the designs to better meet their needs. Due to these constraints, students’ feedbacks were not as good as we hoped to achieve at the end of the module delivery.

Active Learning Pedagogical Approach

Since the course review, the DBE has implemented the Contextual Teaching and Learning (CTL) pedagogical approach [2] in a number of selected modules. The CTL pedagogy, which is also the approach adopted by other courses offered by SEG at NYP, encourages faculty members to relate subject content to real world situations / context and to motivate students to connect acquired knowledge to applications in real life.

In order for CTL to be deployed effectively, we have decided to exploit the additive manufacturing technology through the rapid prototyping approach. Additive manufacturing is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer [3]. Rapid prototyping is one form of additive manufacturing and it is commonly used in making engineering prototypes. 3D printing is the process of fabricating objects through the deposition of a material using a print head, a nozzle, or another printer technology in the rapid prototyping process. Institutions exploiting 3D printing technology found that it could enhance students' practice of visual spatial skills to perceive and visualize significantly more complex objects [4]. 3D printing also allows the institutions to adopt the techniques of rapid prototyping engineering and fundamentals of engineering service processes in the curriculum [5].

More importantly, by incorporating 3D printing into the ’Implementing’ and ‘Operating’ aspects of the product lifecycle, students will be involved in an iterative and connected process that empowers them to be better able to experiment with their innovative design concepts and test their designs for fit and functionality. It exposes students to various facets of engineering and design disciplines, as well as promoting creative thinking among the students.

METHODOLOGY

Strategy

To achieve CDIO active learning experiences and outcomes for this Biomedical Project module, the strategy focuses on incorporating active learning pedagogy for imparting product development and the technopreneurship skills sets. Students are expected to complete an assignment with special emphasis on biomedical engineering-related applications.

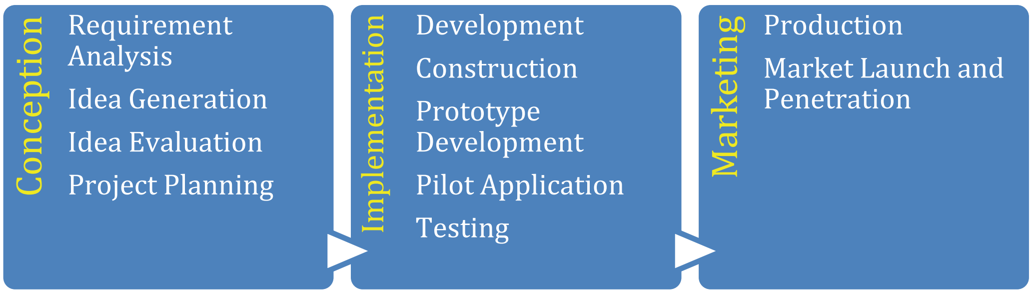

Figure 1: Product Development Cycle

Using the typical Product Development Cycle as shown in Figure 1, students will research on project engineering including emphasis on information gathering, usability, robustness of design, costing analysis, business entity and structure, business plan and its various components, and intellectual property protection. The focus is on applying the technopreneurship skills to the creation process for biomedical engineering-related applications. At the end of the module, each team of students complete a business plan to market the designed and constructed 3D printed innovative prototype.

Defining the Module Learning Outcomes

The constructive aligned curriculum mentioned in the CDIO syllabus [6] was adopted in defining the module learning outcomes. The module learning outcomes stated in the module syllabus are constructed with student learning in mind and they are consistent with and aligned to the student learning outcomes and course educational objectives articulated at the course level.

Thus, the student learning outcomes for this module are defined as follows:

The students will be able to

- *develop a business plan*
- *design an innovative product*
- *identify and analyse design constraints associated with the product*
- *interact and collaborate with others in teams to complete the design of an innovative product*

Designing Learning Activities

The learning activities are designed for students to achieve the module learning outcomes. These activities are typically carried out in the form of lecture, tutorial and practical sessions. Table 1 shows the chapter 1 to 3 of this module, as an example of the plan. The cognitive skills levels that the student would attain in these activities are classified into four levels, namely Remembering (I), Understanding (II), Applying (III), and Analysing/Evaluating/ Creating (IV).

In the instructional outcomes, the module is designed with 15 hours of lecture and 45 hours of practical. Chapter 1 and 2 are allotted only for lecture as they are intended for students to be introduced to the technopreneurship and business ownership. However, chapter 3 is allotted with the entire 45 practical hours as it is the main focus of product development cycle, in which each group of students is to deliver an innovative product by the end of the module. The CDIO approach is applied to provide integrated, active and collaborative learning with the aims to develop skills in problem formulation, estimation, modelling and solution. To make more effective and efficient use of student learning time in acquisition of disciplinary knowledge concurrently with personal and interpersonal skills, and product, process, and system building skills [6], we also incorporate other active learning strategies in the module, including flipped classroom in lecture lessons and a mini-seminar at the end of the semester for students to pitch their business ideas and products.

Table 1: An excerpt of Instructional Outcomes (L-Lecture, T-Tutorial, and P-Practical)

No	Topics	Instructional Outcomes At the end of this topic, students will be able to:	L	T	P	Cognitive Skills Level*
1.0	**Introduction to Biomedical Project and Technopreneurship**		1	0	0	
1.1	Introduction to the module	• describe the objectives of the module • locate the linkage of this module to other modules in DBE course • state the relevance of this module to the industry				I
1.2	Introduction to Technopreneurship	• recognize the role of entrepreneurship in Singapore • assess one's suitability for entrepreneurship				III
2.0	**Business Ownership**		4	0	0	
2.1	Forms of business ownership	• identify different ways to start a company • identify different types of business ownership				II
2.2	Registering your business	• select an appropriate company name • write a mission statement • prepare company objectives				III
2.3	Marketing research	• identify targeted market				II
2.4	Feasibility study	• develop a SWOT analysis on one's business • prepare a feasibility study for one's business venture				III
3.0	**Product Development**		3	0	45	
3.1	Business product	• identify the product life cycle • recognize the importance of intellect property • recognize the importance of inventory management				II

No	Topics	Instructional Outcomes At the end of this topic, students will be able to:	L	T	P	Cognitive Skills Level*
		• develop a healthcare prototype				IV
3.2	Marketing plan	• examine marketing mix • recognize the need for advertising & promotion				II

Assessing Student Learning

When planning the module learning outcomes, assessments and learning activities, we use the CDIO Syllabus v2.0 as a guide for defining the skills. Table 2 shows the criteria for assessing students' business plans and prototypes, and Table 3 shows the relation of our work on module learning outcomes, assessments and learning activities with the CDIO Syllabus v2.0.

Table 2: Assessment Criteria for (a) Business Plan and (b) Prototype

(a)

Category	Scoring Criteria	Score
Format	Business plan is prepared using appropriate format specified and details duly completed	10
Content	Each topic is duly completed with appropriate and suitable content	60
Professionally Done	Professional looking and accurate representation of the data in tables, graphs, and written form; graphs and tables are appropriately labeled and titled	20
	All appendices are properly referenced, labelled and appended at the end of the report	10
	Total	100

(b)

Category	Scoring Criteria	Score
Poster Information	Indicate name of invention, pictures of referenced product, indicate 2 extra features in the product, names of inventors	5
Poster Design	Engaging, visually simulating, aesthetically appealing use of colour, diagrams and text	10
Prototype	Complete Prototype	10
	Functionality	25
	Uniqueness	10
	Prototype is professionally done	20
	CAD model is professionally done	20
	Total	100

Table 3: Mapping CDIO Syllabus to the components used in the Constructive Aligned Curriculum based on Extended Syllabus v2.0.

	CDIO Syllabus v 2.0*															
	1.1	1.2	1.3	2.1	2.3	2.4	2.5	3.1	3.2	4.1	4.2	4.3	4.4	4.5	4.6	4.8
Module Learning Outcomes	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Assessment	●	●	●	●	●	●		●	●		●	●	●	●	●	●
Learning Activities	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

* Topics in Extended CDIO Syllabus version 2.0 are mapped as follows:

1.1 Knowledge of Underlying Mathematics and Sciences (mapped to 1.1.1, 1.1.2 & 1.1.4)
1.2 Core Engineering Fundamental Knowledge
1.3 Advanced Engineering Fundamental Knowledge, Methods and Tools

2.1 Analytic Reasoning and Problem Solving (mapped to 2.1.1 - 2.1.5)
2.3 System Thinking (mapped to 2.3.1 - 2.3.4)
2.4 Attitudes, Thought and Learning (mapped to 2.4.1 – 2.4.7)
2.5 Ethics, Equity and Other Responsibilities (mapped to 2.5.1)
3.1 Teamwork (mapped to 3.1.1 - 3.1.5)
3.2 Communications (mapped to 3.2.1 – 3.2.10)
4.1 External, Societal and Environmental Context (mapped to 4.1.1 & 4.1.2)
4.2 Enterprise and Business Context (mapped to 4.2.3, 4.2.4 & 4.2.7)
4.3 Conceiving, Systems Engineering and Management (mapped to 4.3.1, 4.3.2 & 4.3.3)
4.4 Designing (mapped to 4.4.1 – 4.4.6)
4.5 Implementing (mapped to 4.5.1 – 4.5.6)
4.6 Operating (mapped to 4.6.1, 4.6.2, 4.6.4 & 4.6.6)
4.8 Engineering Entrepreneurship (mapped to 4.8.1, 4.8.2, 4.8.3, 4.8.4, 4.8.7, 4.8.8)

Delivering of Lesson

The expected deliverables of this module are students' biomedical prototypes and their business plans. To facilitate the students in achieving these outcomes, the class is organised into teams of two to three members. The teams are to plan and organise themselves for the tasks assigned. As time is an important element in the completion of the assigned tasks, lecturers need to manage the 60 hours that are spread over 15 instructional weeks (four hours per week) for best student learning experience. Based on past experiences, instead of planning one hour of lecture lesson and three hours of practical lesson every week, it is more effective to arrange these four hours of lessons in the following manner on alternate week basis over a duration of 14 weeks: two hours of lecture and two hours of practical lessons on one week, and four hours of practical lessons on another week. During the last instructional week, the four hours are combined for students to prepare and participate in the mini-seminar. The two-hour lecture session is conducted using flipped classroom approach, where students read materials provided off-campus and spend face-to-face time in-campus focusing on project discussion and construction of the biomedical prototype, and strategizing their business plans with team members. The delivery plan is shown in Table 4.

Table 4: Plan for Delivery of Learning Activities

Learning Activities	Title of Learning Activities	Lecture (Flipped Classroom)	Practical
1	Are you an entrepreneur?		√
2	Designing my techno-product	√	√
3	Get started		√
4	Know your environment	√	
5	Sizing your competitor	√	
6	Know your customer	√	
7	Financial planning	√	
8	Understanding advertisement	√	
9	Making your product known	√	
10	Financial management	√	
11	Business plan (I)	√	
12	Business plan (II)	√	

Implementation

This module requires the students to work in teams. Before each lesson, individual student is required to access the learning management system to read the module materials. The face-to-face classroom sessions consist of group discussion, presentation, and working on product ideas. The lecturer, acting as a facilitator, guides them in classroom activities and provides technical consultation on product designs. The implementation of flipped classroom and practical sessions require the students to organize their time based on the scheduled sessions.

As a team, the students need to organize themselves in carrying out their tasks as assigned and planned. Submission of progress report is monitored and the dates when the reports are received are published to the learning management system. Lecturer provides timely feedback to the students on their work submitted, allowing them to make improvements to their works.

For instance, as part of learning activity 5, the teams discuss their products' strengths and weaknesses as compared to competitors' products. Based on the findings, they review their designs to improve their products' strengths. As the students progress on their design, the lecturer monitors and participates in their design evaluation and review process. The lecturer shares his or her experiences and provides insights to various design methodologies. Once the designs are ready, the students construct their prototypes using 3D printer.

From the 3D printed prototypes, lecturer shares techniques involved in evaluating the 3D printed products, and the students review and evaluate the fit and functionality of the products. Often students are able to identify mistakes made during the design stage and make changes to their design to rectify them. The benefits of this iterative approach are many folds. First, students are able to find the right context and connection between the knowledge acquired in the module and the products that are being 3D printed. Second, students are able to acquire higher order thinking skills when they are evaluating and testing the prototypes. Third, students are more confident in marketing their works as they are able to complete a functioning prototype.

Finally, to showcase the effort of the students, a student mini-seminar is organized. The platform allows the students to 'sell' their ideas and the developed products (see Figures 2 & 3 for pictures taken at the mini-seminar). In this mini-seminar, the teams have 10 minutes to present their developed products to a panel of assessors. Following the presentation, an exhibition is organized for the teams to display their posters, business plans and developed products as well as to provide opportunity for the teams to hone their skills in seeking 'seed money' from the assessors who act as 'potential investors'.

Figure 2: Student sharing his biomedical product with a 'potential investor'

Figure 3: Students with their posters and 3D printed product

RESULTS AND DISCUSSION

Measure

To measure the effectiveness of this active learning through 3D printing approach, data was collected from an experimental group of 48 students who were enrolled in the Biomedical Project module in semester 1 of academic year 2015. First, we examined students' academic performance in this module which was mainly contributed by their ability to realize a physical and functional prototype, together with a sound business plan. Second, we examined the data collected from the end-of-semester module feedback where students provided feedback on all modules they attended in a semester, covering module content, delivery and learning environment. Finally, we examined the data collected from a survey that was specifically administered to this group of students to gauge the feasibility and effectiveness of the implementation and acceptance of the approach by students. The results are reported in the following sections.

Academic Performance

Previously, without the availability of 3D printing technology, students were unable to grasp the fit and functionality of their designs. In addition, students who conceptualized products with more complex designs were not able to produce the prototype due to time and cost constraints. Thus these students received lower scores as they were not able to demonstrate a complete product. With the availability of 3D printers, students were able to visualize and validate their designs, and make the necessary adjustments to rectify any shortcoming before producing the final prototype. It was through this iterative process that most of the students were able to demonstrate a complete and functional prototype, leading to overall improved module grades performance as shown in Figure 4.

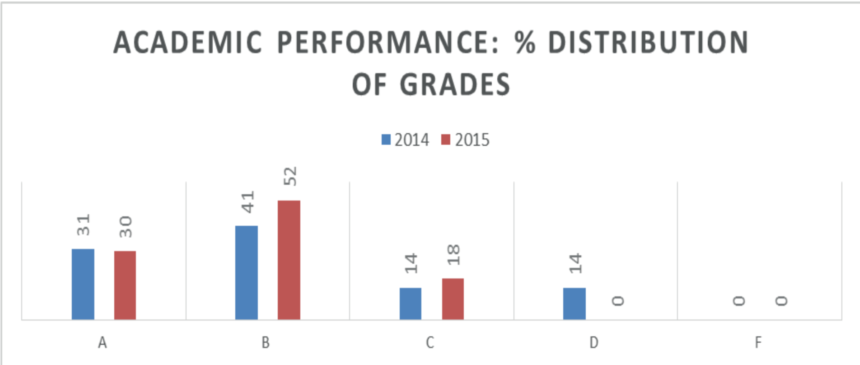

Figure 4: Comparison of students' academic performance in Biomedical Project module

In addition, based on the analysis of the submissions of the prototypes, all teams were able to avail their prototypes for assessment. Out of 20 teams, 85% of the teams submitted completed prototypes. In terms of functionality, points awarded range from 10-25 points with an average of 18.5 points. About 70% of the teams were able to score a median of 20 points for functionality. This good score reflected on the achievement for functionality as compared to about 55% of the 20 teams scoring a median of 20 points for 2014.

Student Module Feedback

There was also improvement in the module feedback provided by the students at the end of the semester for the Biomedical Project module, especially when students were asked to rate items related to the organisation and adequacy of the module. The ratings of 'Agree' and 'Strongly Agree' showed an increase of about 10 percentage points, from 85% in 2014 to 95.5% in 2015. These items included the clarity of module learning outcomes, the design and organization of module materials, the availability and quality of facilities and equipment, the e-learning components and the grading criteria. This improvement indicated a good acceptance of the active learning through 3D printing approach by the students when the approach was implemented in the module.

Surveys

Through surveys, students perceived that the flipped classroom pedagogical approach gave them an opportunity to learn in a dynamic and interactive environment. Module materials and video-recorded lectures were viewed by students before the face-to-face session in the classroom. Time in the face-to-face session was devoted to project, presentation or discussion which allowed students to have more time to interact and collaborate with their team members leading to better learning experience and teamwork spirit for the students. The survey results are shown in Figure 5.

A good 83.7% of the students responded strongly to better learning experience from flipped classroom as opposed to the traditional lecture. 86.1% of the students preferred group collaborative activities. This implied that the students had a keen interest in working in teams.

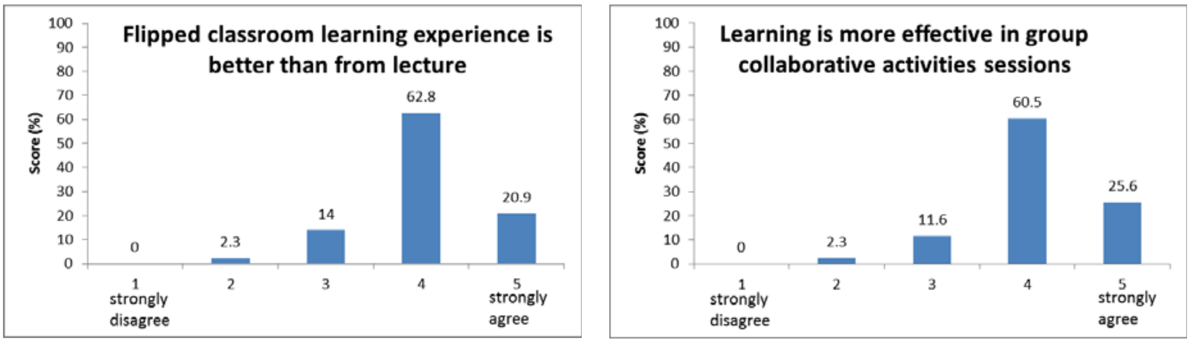

Figure 5: Results of a survey carried out after the new implementation.

CONCLUSION AND REFLECTION

The main outcome of the Biomedical Project module is for students to be able to produce an innovative, functional biomedical product with a good business plan. The successful development of these products and plans required active participation of the students. To facilitate the learning process, active learning environment needs to be created for students to participate actively in a collaborative manner within a team. The higher level of active participation from students in the experimental group was seen from the completion of their final prototypes and business plans.

It is important to ensure ownership is given to student on the development of the biomedical product. By changing lecturer's role to facilitator using the flipped classroom approach, students in the experimental group were responsible for their learning and the deliverables. It encouraged students to explore and discuss among themselves to find the best solution, with the lecturer providing the necessary facilitation.

With the use of 3D printing technology for rapid prototyping, the realisation of more complex biomedical products become achievable within the time given in the Biomedical Project module. In fact, many students in the experimental group were able to iterate their designs for more than two times to address shortcomings in their products. Through this process the students gained valuable experience in translating digital models into actual functional physical parts which they would not have if they were not able to build the complete prototypes. The students also learnt that features that they created in digital models might not be translated successfully into a functional prototype due to issues such as space, assembly, materials, and many others that they discovered in this process.

The student mini-seminar, on the other hand, provides the students an avenue to market their ideas and products. The presence of 'potential investors' at the exhibition created an exciting and real-life environment for the students in the experimental group to showcase and sell their products. The environment also required the students to be creative in using various media to promote their products and be able to respond to queries quickly and confidently. Under such situation, the students needed to demonstrate their ability to think and respond on their feet.

We conclude that the active learning using 3D printing approach undertaken by this module improves the students' learning experiences and increases their knowledge and skills in building and marketing their biomedical products. The use of 3D printing technology enhances the complexity level of the projects that students can work on. The students have also acquired employable and transferrable skills which are specified in our graduate attributes. The challenges faced are the availability of the 3D printers as well the space for development work outside students' scheduled lessons.

To further encourage active learning (CDIO Standard 8), we plan to build a maker space equipped with 3D printers, CAD tools and workstations for students to use them anytime outside their scheduled lessons. This facility will provide students with more opportunity to develop their innovative and enterprising spirits, to enhance students' skills in design and development works, to create more prototypes which could be used as project references and inspirations in the workplace, and to be future-ready.

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INDUSTRY-INSPIRED EXPERIENTIAL LEARNING AND ASSESSMENT OF TEAMWORK

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ABSTRACT

In preparing students for work, final year students studying the Diploma in Multimedia and Infocomm Technology at Nanyang Polytechnic, Singapore, are not only trained to hone their technical skills in software development, but also on how to use those skills as described in the CDIO Syllabus (2.4, 3.1 and 3.2).

This paper presents a series of industry-inspired experiential classroom activities that provide opportunities for students to work effectively in a team. These activities, accompanied by instructional scaffolding, comprise guidelines on dealing with team-based communication, setting and expecting professional behaviour from teammates, to an assessment method that uses a set of criteria commonly adopted by the industry.

Through these activities, students learn about interpersonal skills and leadership traits that are expected of them. Students also get to experience first-hand how the technical skills they have acquired such as software designing and collaboration tools can serve to augment more effective teamwork in software development. Finally, students are also given two in-class assessments, one in which they are required to work under pressure and observation, and the other requires the entire class to complete a single large-scale project which is guided by lecturers. Through self-assessments, peer assessments and feedback from the observations, students are able to reflect on how well they and their classmates have done, giving them valuable insights to how well they can perform in a team.

This paper shares the feedback received from students and their perceptions on the usefulness of the different activities towards their learning. Reflections on the strengths, areas for improvement in the approach and the future course of action to enhance students' learning are also shared.

KEYWORDS

Assessment, Experiential Learning, Rubrics, Software Engineering, Teamwork, CDIO Standards 7 and 8

Note: In the context of Nanyang Polytechnic, the term 'course' refers to a 'program' while the term 'module' refers to a 'course'. For example, Diploma in Multimedia and Infocomm Technology is a course, Java Enterprise Development is a module.

INTRODUCTION

Programming enterprise software solutions usually requires programmers to work together in teams. Students need to be armed with both hard skills and soft skills to work in real-life projects. Hence, soft skills such as teamwork and communication are also important (Figl, 2010).

A set of experiential activities to learn about communication and teamwork soft skills is designed for final year students from the Infocomm Solutions specialisation of the Diploma in Multimedia and Infocomm Technology, Nanyang Polytechnic, Singapore, who are expected to learn about programming enterprise software solution. This set of activities is described to be *“industry-inspired”*. This means that students are informed of the activities’ meaning and relation to real-life work as they undertake these activities.

This paper shares our experiences in using the industry-inspired activities in the Java Enterprise Development module to coach and assess students in personal attitude, teamwork and communication, mapping closely to the CDIO Syllabus 2.4, 3.1 and 3.2 (Crawley, et al., 2011).

This paper also shares the findings from 97 responses of an anonymous survey conducted across three semesters focusing on the small group collaborative project and interviews made with 10 students focusing on the large group collaborative project, on whether these activities are useful and meaningful from the perspectives of the students.

RUBRICS AT THE HEART OF LEARNING

In our previous study (Tio, et al., 2014), we found that instrumental usage of rubrics for both coaching and assessment could guide students towards achieving better results and train them in acquiring the module learning outcomes. Similarly, in this study, students were briefed on the interpretation and usage of the rubrics, in terms of expected personal attitude and communications they could practice for effective teamwork. Finally, students made use of this set of rubrics for both self-assessment and peer assessment for their collaborative assignments.

The rubrics used were adapted from the Capacity, Achievement and Relationship (CAR) selection criteria and appraisal framework developed by Shell[1], in the spirit of an appraisal aligned with the industry. In particular, only the Achievement and Relationship aspects of the framework were used as guideposts for the personal attitude, and teamwork and communication aspects respectively.

For the rubrics to be used easily by students in their self-assessments and peer assessments, students were asked to give an overall grading for themselves for the collaboration assignments. As Arter (2000) pointed out, a holistic rubric allowed for quick scoring and snapshot and an analytic rubric was more useful for complicated skills. Our rubrics were hence designed with an additional analytic component with behavioural

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[1] “FAQ – Students & Graduates”, Retrieved from http://www.shell.com/careers/contact-careers-and-faqs/faqs-students-graduates.html

indicators to take advantage of the benefits of using the analytic rubrics. Table 1 and Table 2 show the details of the holistic and analytic rubrics.

Table 1. Holistic rubric on level of competencies and their definitions

Level of Competencies	**Definition**
Far Exceeding	Consistently goes above and beyond his own duties – carries more than his/her fair share of the load.
Exceeding	Does what he/she is supposed to do sometimes going beyond his/her duties, very well-prepared and cooperative.
Competent	Does what he/she is supposed to do, acceptably prepared and cooperative.
Developing	Does what he/she is supposed to do to a limited extent, minimally prepared and cooperative.
Not Meeting	Consistently fails to complete his/her share of the project, unprepared.

Table 2. Analytic rubric on expected behavioural indicators

	Level of Competencies	**Competent**	**Developing**	**Not Meeting**
Behavioral Indicators	**Personal Attitude** Models the teamwork aspect of the “Achievement” indicator in the Shell CAR framework	Stays on tasks all the time without reminder Searches for solution actively Takes initiative to help others or asks others for help	Needs reminders from group members to do the work Is easily distracted Pretends to be busy Comes late for assessment	Selfish actions Works alone even when faced with difficulties that cannot be solved on his/her own Comes very late for assessment
	Teamwork and Communication Models the “Relationship” indicator in the Shell CAR framework.	Is Open Is Trusting Is Supportive Is Respectful	Disrupts the flow of discussion Communicates negative talks (eg. Complains and arguments)	Ignores or ridicules others Feuds with other team members

A key feature of this set of rubrics was the focus on individual, how one could respond, communicate and perform to contribute in a team. The scores could be assigned to an individual student based on how well he or she was able to work in a team. Indeed, interviewed students shared that individual grading was a fairer way of assessment compared to a common score assigned to the entire team. In addition, out of 97 students who participated in the survey across three semesters, 97% find the rubrics to be useful and they helped students to be aware of the expectations when working in a team-based environment (see Figure 1).

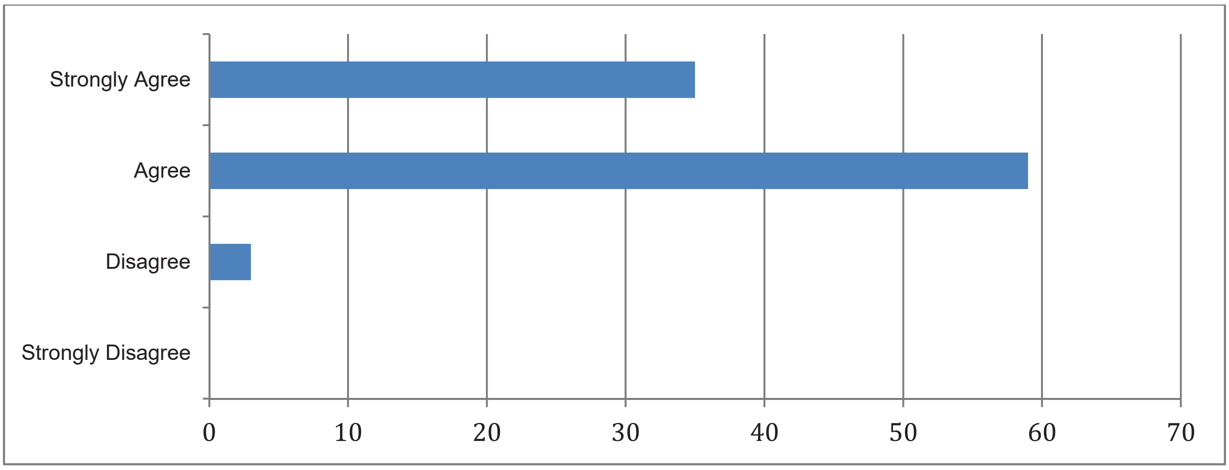

Figure 1. Student responses on the usefulness of the industry-inspired rubric developed (n=97).

INDUSTRY-INSPIRED EXPERIENTIAL LEARNING AND ASSESSMENT

In this study, students participated in three industry-inspired activities:

1. Pair Programming,
2. Small Group Collaborative Assignment, and
3. Large Group Collaborative Assignment

Pair Programming

First, students practiced how to communicate and work with each other in pairs. Pair programming, an agile software development technique where two programmers worked together on one workstation, was used for this purpose. Research (Faja, 2013) suggested that pair programming improved student engagement, student learning outcomes and perceived learning. However, these were largely related to technical learning outcomes.

For the Java Enterprise Development module, pair programming was used as an introduction to help students understand the attitude and communication required for a professional and productive working relationship. Students were given guidelines on the best practices of pair programming and they were asked explicitly to practise them during their class assignments. These best practices largely included how communication was to be carried out in a pair programming session and how to (and not to) communicate with each other. 94% of the students agreed that pair programming helped to prepare them to communicate and program effectively in a team (see Figure 2).

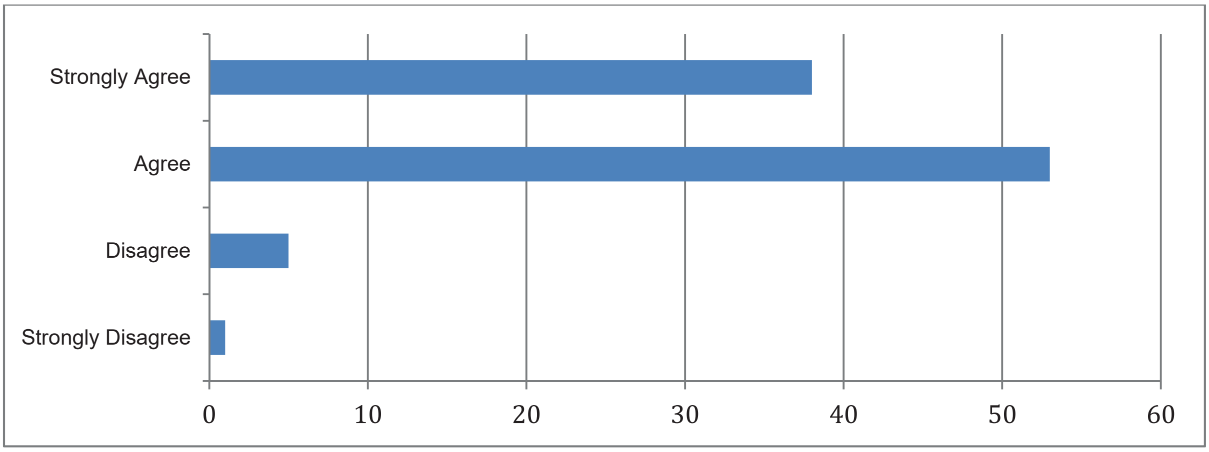

Figure 2. Student responses on the effectiveness of pair programming in learning about communication and working as a team (n=97).

Small Group Collaborative Assignment

Following the pair programming practice, students participated in a small group collaborative assignment. This comprised five phases:

1. Group Formation
2. Choice of Leadership
3. Small Group Collaborative Assignment and Observations
4. Peer Appraisal and Self Appraisal
5. Debrief and Discussion

Three weeks before the assignment, students were assigned in groups of five to seven and each group was asked to choose a technical lead. The actual small group collaborative assignment was done in-class so that the instructor could observe the students at work. At the end of the session, students were asked to reflect and give an appraisal to themselves and fellow group members. Finally, a debrief and discussion session between the instructor and the students regarding the exercise was held.

Group Formation

The assignment of students to groups was done by the instructor of the module according to two criteria. First, students who seldom worked together were placed in the same team. The main aim was to model the relationship between colleagues in real work-life, where people often did not have a choice over who they would be working with. Second, students with varying technical abilities with at least one student who was more competent in programming were placed in the same group. This was to ensure that all groups could be self-sufficient at completing the assignment.

The aim of grouping students who were not familiar with each other together in a group was to reduce friendship bias that may affect the reliability of the peer appraisal, noting that prior research showed that peer ratings could be both valid and reliable even with the presence of friendship bias (Love, 1981).

One significant difference was the decision to put five to seven students in a group, as opposed to what research suggested to keep team sizes up to four (Figl, 2010). The main aim was to allow a more complex assignment to be set for the students at a scale which students had not seen before in class, in an attempt to reflect the scale of enterprise projects. Students could also get a chance to work with more people who may have different working styles they were not familiar with. 96% of the students agreed that such grouping process was useful as they experienced what it was like to work with different types of people and some of whom they had not had a chance to work with before (see Figure 3).

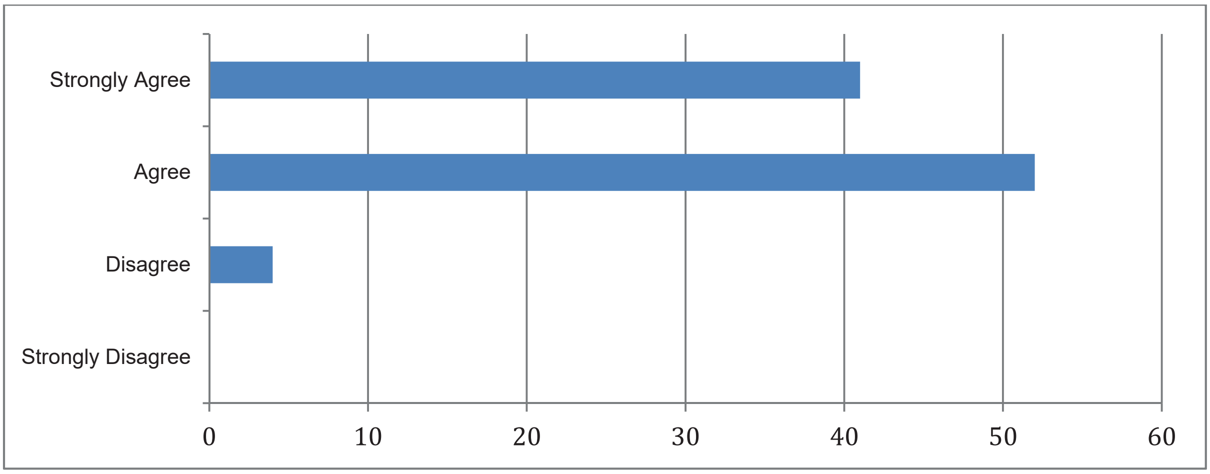

Figure 3. Student responses on the usefulness of the experience working with other students whom they seldom worked with (n=97).

Choice of Leadership

Students were also asked to select a technical lead for the group. They were first given the scope of work of the technical lead. They then individually selected a member from their group to be the technical lead with reasons for their choice. The reasons were analysed and compiled as a report presented to the class by the instructor.

This activity served two purposes. The first was to crowd source knowledge from students and let them become aware of the different reasons that their friends used to select a leader (as opposed to lecturer quoting theories on what qualities leaders should possess). The second purpose was for the students who received at least one vote as the leader to be aware of what their friends thought about them.

An observation regarding the students’ choices was that they were collectively capable of selecting a suitable leader among themselves. They were able to identify the need for the technical lead to possess both hard and soft skills in order to lead them effectively. This was despite the fact that they may not know the team members very well due to the way they were grouped. 99% of the students agreed that the activity allowed them to understand what people usually looked for in a leader and what it took to become a leader (see Figure 4).

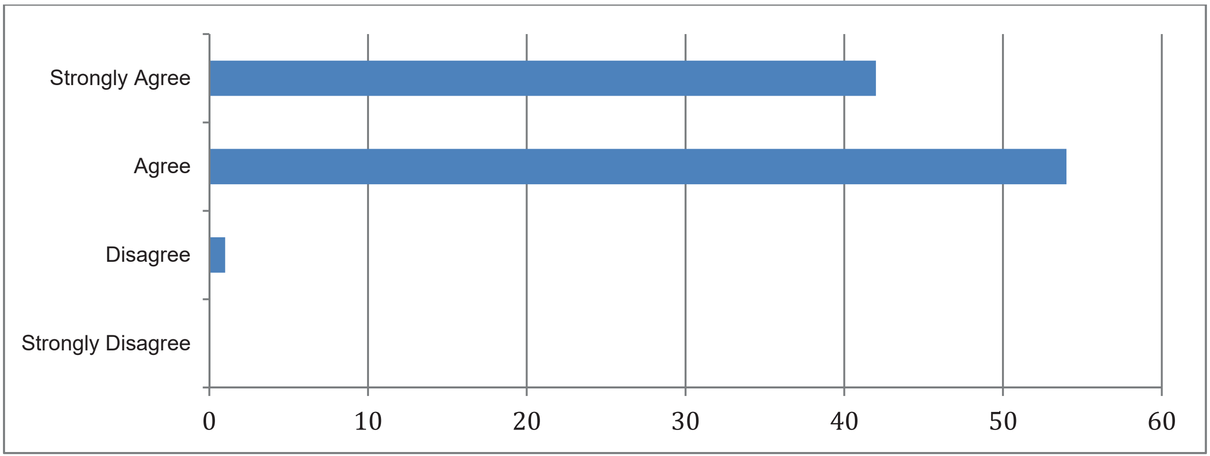

Figure 4. Student responses on the usefulness of the Choice of Leadership activity (n=97).

Small Group Collaborative Assignment and Observations

Students received their assignment on the day of the in-class observation. They were given the guidelines regarding roles assignment and time management to help them manage the assignment that was to be done within two hours. Students were expected to solve any issues they encountered along the way on their own without receiving any technical assistance from the instructor. While students worked on their in-class assignment, the instructor observed the students, gathering both positive behaviours demonstrated and areas for improvement according to the guidelines set out by the rubrics. These observations were shared with the students during the debrief session held after the completion of the small group collaborative assignment.

A member of staff who was invited to one of the sessions to observe the small group collaborative assignment in action noted that “the lab was conducted as a simulation of real-life project development” and “there were active discussion, consultation and communication among team members during coding”.

Peer Appraisal and Self Appraisal

After the completion of the in-class assignment, students were asked to do an appraisal for themselves and their peers on how they performed in terms of personal attitude and communication based on the rubrics. The word ‘appraisal’ was used in place of the word ‘assessment’ intentionally to emphasise the similarities between a work performance appraisal exercise in the industry and assessments in school.

In addition to grading each other using the rubrics as described in the earlier section of the paper, students were also asked to give reasons to the grades they assigned for themselves and their peers. These reasons could aid the instructor to review the students’ understanding of the attitude and communication required for teamwork.

Debrief and Discussion

A debrief and discussion session was conducted immediately after their appraisals, aiming to provide immediate feedback to the students. The instructor reported his observations on the students’ personal attitude, teamwork and communication displayed during the course of the assignment. This included positive points, areas for improvements as well as possible blind spots that students never noticed before. Students were also given the chance to share their thoughts and feedback through this open forum. 95% of the students found the debrief and discussion session to be useful as they not only learnt about their experiences working in a team, they also learnt about their blind spots (see Figure 5).

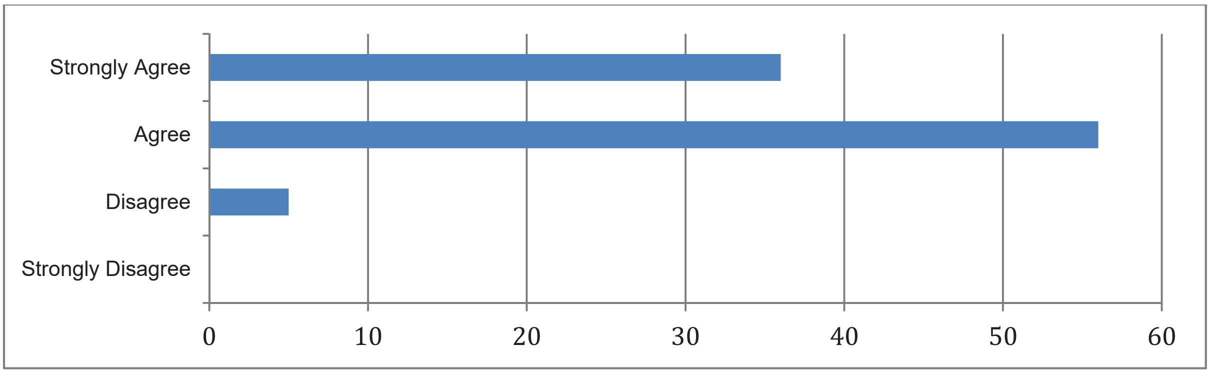

Figure 5. Student responses on whether the debrief session was useful for them (n=97).

Large Group Collaborative Assignment

The aim of the large group collaborative assignment was to give students additional experience at collaboration work, and to simulate a large scale project handled by a software development house. The assignment, involving the entire class (between 15 to 24 students), comprised several modules to be implemented in parallel by multiple sub teams. Students were given the choice of different roles such as chief technical lead, technical lead, assistant technical lead and team members and were briefed on how to communicate with each other in a large group. The Subversion system, a collaboration tool commonly used in the software engineering domain was also introduced at this point. This was to allow students to feel the difference between developing a project with and without a collaboration tool.

To ascertain if the assignment was useful and meaningful to the students, ten students from across two of the most recent batches were interviewed. There were some differences in the way the assignment was carried out between the two batches; the 2016 batch received some tweaks in the way the assignment was carried out, based on student feedback and suggestions from the 2015 batch. These differences are shown in Table 3.

Table 3. Differences in the manner in which the assignment was carried out

	2015 Batch	**2016 Batch**
Duration	3 hours	6 hours (across two weeks)
Guidance on Method of Communication	Simple Guidelines with briefing.	Comprehensive Guidelines with briefing. Printed guidelines are given for reference.
Training on Subversion System	“On the job” training with pre-briefing given during the assignment.	“On the job” training with pre-briefing given before the assignment. Tutorial sheet for reference.

Findings from the Interviews

In both batches, students understood the intention of the assignment. However, one of the major gripes experienced by the 2015 batch was insufficient time to complete the assignments. This was identified as a major cause for their lack of appreciation over other aspects that the assignment entailed as they were committed to complete the project within the short timeline that was allocated to them. Even though communication guidelines and training on the Subversion system were given to them, students from the 2015 batch felt that communication was "messy" and "haphazard", faced "difficulties in understanding" how the Subversion system worked. Eventually this also led to the "lack of sense of achievement" in the assignment which majority of the students interviewed felt was an important factor that affected their perceived learning.

Based on the suggestions made by the students from the 2015 batch, the duration of the assignment was lengthened to 6 hours and printed notes on communication guidelines and usage of the Subversion system were given to the students in the 2016 batch. With such changes implemented, students agreed that they felt a sense of achievement working through this assignment. They also felt that the earlier activities such as pair programming and the small group collaboration assignment helped them build rapport with their peers, making it easier for them to communicate with the others.

One interesting thing to highlight regarding communication was that while the students reported that they found that the communication guidelines very useful in giving them a starting point on how to communicate with one another, they were also able to develop their own style of communication in the midst of the assignment that worked better for them.

With regard to the training on using the Subversion system, the 2016 batch felt that more could be done. For instance, giving them a dry run on the usage of the Subversion system before the assignment would help them get familiar with the tool. One student also highlighted that the large group collaborative assignment was similar to the experience he had during his internship attachment period as he was asked to use a Subversion system during his stint. Hence, he felt that the Subversion system was a very important tool for all students in his specialisation to learn.

DISCUSSION

The industry-inspired experiential activities that were described in this paper showed a way to integrate teamwork into a module. Students who took the module were generally receptive and they valued the experience that was given to them.

There are a few learning points from this study. First, students find the learning activities to be useful when they see activities are strongly contextualised to the domain the students are studying, and the rationales behind undertaking of the activities and its relation to real-life work are explained to them. Second, it is possible to let students work in large groups. Given sufficient guidelines to work with and easing them through a sequence of activities that grow in complexity, students can learn about managing projects and communication meaningfully. Third, teamwork assessment is to be done at an individual level, giving more control over their performance without the fear of their grades being pulled down by their peers. Fourth, it is important to allow time for students to get a sense of achievement through their collaborative projects. While it is useful to experience what it is like working in a group and learn soft skills, a lack of sense of achievement in the technical task, on the other hand, can lower the usefulness and meaningfulness of the activities that they undertake.

Moving forward, we intend to look into how a selection of these activities can be adapted and contextualised for usage in other modules.

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DEVISING AN ELECTRIC POWER SYSTEM: A CDIO APPROACH APPLIED TO ELECTRICAL ENGINEERING

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ABSTRACT

The study of electric power systems within the field of Electrical Engineering is usually approached by computer simulations because any actual test is quite complex to be implemented. Having the aim to improve student learning about this topic, a new subject called “Devising an Electric Power System” was organized following a CDIO (Conceive-Design-Implement-Operate) approach.

The subject is programmed for one academic year and based entirely on laboratory work. The students are divided into three groups. Every group would have to work on a device that includes a solar PV generator and a pumping controlled drive, both connected to a three–phase grid.

The process followed by the students along the academic year begins with a short theoretical introduction and simulation studies where they conceive and design control strategies. These control strategies are for the solar PV generator (i.e., programing the “Maximum Power Point Tracking” MPPT) as well as for the pumping electric drive (i.e., following a V/f strategy or a vector control). The process is continued by practical implementation of the simulated algorithms previously obtained. In this step, the students implement and operate the systems until they become robust and well adjusted, and ready for the intermediate partial competition among the three groups. During this practical implementation stage, the innovative competence is better enhanced. At the moment that each group has implemented an electric generator and an electric consumption (load), they follow the third and last part of the subject that is focused on “electric utility” business strategy. The students will have to comply with the rules of the electricity market by offering energy packages to be generated and consumed at a certain price. The price and volume of energy to be generated/consumed are determined by the convergence point of supply and demand, as determined by the marginal pricing model. Once the market is cleared, the students have to realize their generation/consumption commitments by operating the real power system they have conceived and implemented.

After the first academic year of this subject, the students’ evaluation was highly acceptable. The specific technological contents of the subject were learnt by the method called “learning by doing” that allows students to improve their skills in team building, innovation and communications. In addition, a good work atmosphere among students and teachers has arisen.

KEYWORDS
CDIO as Context, Integrated Learning Experiences, Active Learning, Electrical Engineering, Solar PV Generation, Electric Drives Control, Electric Markets. (Standards: 1, 3, 5, 7, 8).

INTRODUCTION

Promoting motivation and engagement among students in a subject is considered as the key aspect that allows better and more efficient learning. For this reason, this type of practice has been introduced at the implementation of the European Higher Education Area (EHEA) in 2010. The case of technical sciences and engineering studies deserves special interest since their intrinsically complexity often requires dedicating most of the class time to theoretical description of the fundaments and working principles and rarely allows promoting students' participation.
In order to overcome this constraint, the CDIO approach provides students with an educational framework which faces the study of engineering fundamentals through "Conceiving - Designing -Implementing and Operating" (CDIO) real-world systems (Crawley, et al. 2007).
In the field of Electrical Engineering, the study of different technologies concerning "Renewable Energies", "Electric Drives" and "Electricity Markets" is usually approached by computer simulations because any practical exercise is too complex to be implemented.
In this paper, the development process of a new subject called "Devising an Electric Power System" is presented along with the results obtained after the first year of implementation in 2014-15. This new subject was regarded as an opportunity to change traditional teaching-learning procedures within the electrical engineering area in order to promote the acquisition of different competences such as "team work", "creativity" or "communication". Fully based on laboratory work, the idea of the subject was to conceive a physical platform that would allow students to learn through innovation and experimentation and to have the opportunity to test improvement at any time. The strengths of the new methodology unites laboratory work (learning by "doing" instead of only by "listening/studying") with innovation to improve the physical systems and their control.
The device developed by the electrical engineering staff includes a solar PV generator and a pumping controlled drive, both connected to a three-phase electric grid. By using this laboratory setup, the students can conceive and design control strategies, both for solar PV generator (i.e., programing the "Maximum Power Point Tracking", MPPT) and pumping electric drive (i.e., following a voltage/frequency strategy or a vector control). In addition, this platform allows the students to comply with the rules of the electric utility market by offering energy packages to be generated and consumed at a given price. Once the price is fixed according to the marginal pricing model, the group that comes up with the best offers and best follows their energy generation/consumption commitments will be chosen as the winner in the final contest at the end of the course.

CONTEXT OF THE COURSE "DEVISING AN ELECTRIC POWER SYSTEM": THE "INGENIA" INITIATIVE AT ETSII – UPM MADRID

The Master Degree in Industrial Engineering offered at ETSII-UPM Madrid is the result of the implementation of Bologna process. The academic implementation took place in the academic year 2014-15. The Master Degree at ETSII is a two year program with 120 ECTS credits, after a four-year Bachelor degree in Industrial Technologies with 240 ECTS credits, with a new subject called INGENIA, linked to the Spanish term "ingeniar" (to provide ingenious solutions) and etymologically related in Spanish with "ingeniero" (engineer).
INGENIA subjects use project-based learning methodologies following the CDIO approach. Therefore, their structure promotes learning the fundamentals and advanced disciplinary contents of engineering in a practical environment and, at the same time, improving students' motivation and engagement with their own learning process.
The principle that defines INGENIA subjects is to guide the students starting from the conception and design, up to the implementation and operation of a project, system or product in the field of engineering. All the steps previously mentioned would have to comply with a

series of requirements previously defined. Students will be given the opportunity to work in real conditions similar to the ones they could encounter in the field. Therefore, students have to work in teams, decide what information they need, find and manage the information, organize the work and communicate the results obtained, all in an efficient way.
INGENIA subjects are compulsory for all students and have 12 ECTS credits, which correspond with student workload between 300 and 360 hours, distributed along two semesters, with 14 weeks per semester. The distribution of this workload is the following: 120 hours correspond to supervised work, that is, work performed under teacher supervision, and between 180 and 240 hours which is allocated for group work.
The supervised work is divided into three categories:

- 30 hours dedicated to the explanation or adaptation of the basic theoretical knowledge to carry out the project.
- 60 hours for practical implementation in the laboratory.
- 15 hours for transversal competences. Several seminars and workshops are offered to students to acquire and improve team building, communication and creativity skills.
- 15 hours for social responsibility issues, such as, environmental impact and consequences of the project in social, political, security and health areas. All projects must include a study of this type.

Lectures, laboratory and seminars with teacher supervision are spread in 5 hours per week.
Several departments of the ETSII-UPM have carried out INGENIA proposals related with diverse disciplines such as: electronic and automation, electrical, automotive, mechanical and biomedical engineering.
INGENIA course “Devising an Electric Power System” has been developed by Electrical Engineering instructors (Electrical Machines and Electric Power systems) and Statistics instructors. Twelve teachers have participated in the subject and most of them have previous experience in CDIO activities, Veganzones et al (2011), and belong to two different Innovation Education Groups at the UPM university[1] having participated in several educational innovation projects, Veganzones et al (2009), Ramírez et al (2009), Blázquez et al (2010), Arribas et al (2011), Moreno-Torres et al (2015). The subject aims to provide an insight that integrates the most important and innovative advancement in electrical engineering and promote the capability for designing and implementing an electric power system with both generation (photovoltaic panel) and consumption (pumping electric drive), and at the same time operating under the rules of an electricity market.

DESCRIPTION OF THE COURSE

The students are divided into three groups of seven people and each group has to work on a device that includes a solar PV generator and a pumping controlled drive, both connected to a three phase electric grid. Thus, the hardware the students deal with, includes mainly a laptop connected to a DSP, two power converters (one DC/AC that connects the PV generator to the grid, and another AC/AC that feeds the pump motor from the grid), current and voltage sensors and energy measurement devices (Figure 1).

[1] http://innovacioneducativa.upm.es/informacion_grupo?grupo=276 and http://innovacioneducativa.upm.es/informacion_grupo?grupo=205

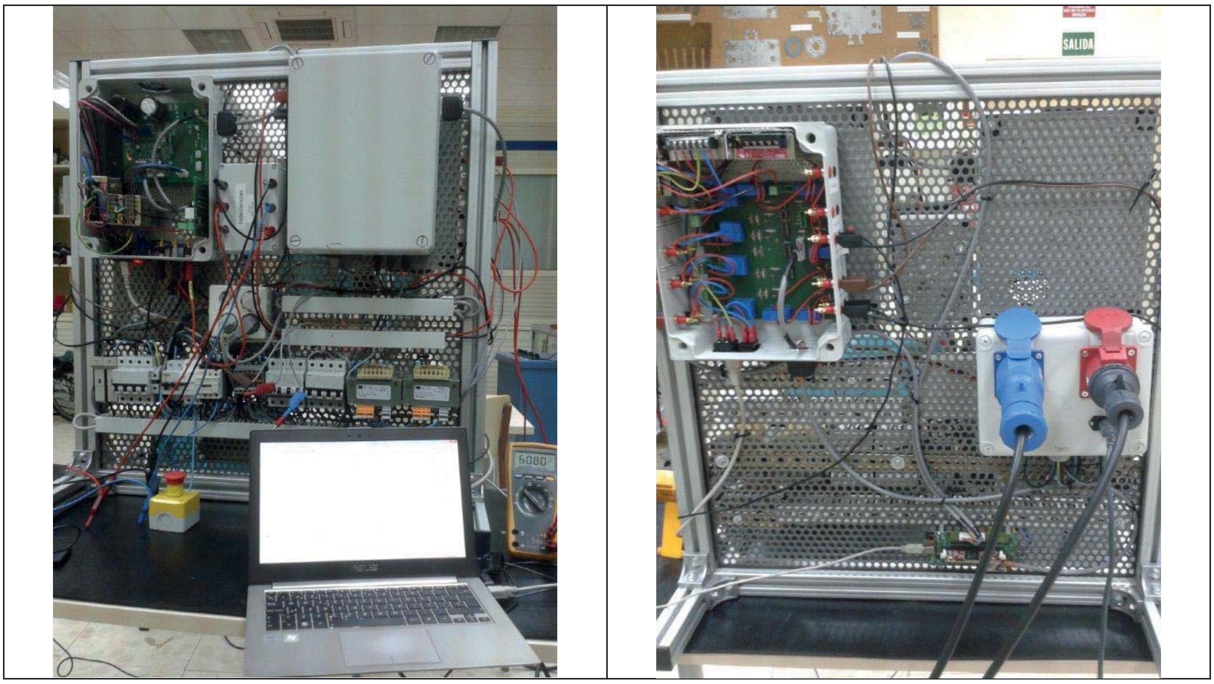

Figure 1. Frame with the lab setup including: two power converters, inductances, transformers, electric protections and laptop (left), and PV and grid connection supply, voltage/current sensors and DSP (right)

Although the subject lasts one whole course, it is divided into four two-month periods.
The first one is used to introduce the basic theoretical contents of each topic in the subject (PV generation, power electronics, pumping installations, control of electric drives and the hardware platform the students will use during the course). All these theoretical contents are faced along with the physical systems being in front of the students, so as the students can learn quickly the working principles of each device in the system.
The second two-month period is used to perform laboratory tests in each component of the system, so as to acquire a deep knowledge and characterize them in order to be able to improve them or to take into account their particular behavior for the next innovation stage.
The third period consists of different partial competitions each one concerning only one system (PV generation or pumping control). In order to prepare each event the students must face a creative practice in which innovative competences are trained. This way the subject allows the students, for example, to learn about the grid connection of a PV generator and to program the Maximum Power Point Tracking (MPPT) along the sun day, by innovating and practicing with a real installation together with the motivation of a teamwork facing a contest. In this period, predictive models of PV generation, which are prepared by the students under the supervision of experts in statistics, are also used in order to improve the success options for the competitions.
The fourth and last two-month period deals with the study of electricity market rules. The complexity of this discipline itself makes it especially difficult to be taught by using real equipment instead of only simulation models. In this way, the subject that is being described is innovative, since it allows the students to learn this matter again by practicing, being conscious, for example, of the difficulties in real life of predicting the energy demand, the renewable resource, etc.

The three main disciplines the subject deals with are the PV generation, the pumping facilities and the electric markets. Each of them with be treated separately in the next sections of this subject description.

Solar PV generation

Each group of students have a solar PV system that comprises three PV panels connected in series, with a total rated voltage of 48V, a three-phase DC/AC converter as a solar inverter, some current filters and a three-phase transformer 25/230V to connect to the grid, since the low voltage range of operation at the PV panels require a low AC voltage to work properly. The students carry out the different stages to do the starting up of the solar inverter. They previously test the inverter supplying a passive load, firstly in open loop and secondly controlling the current in closed loop. Then, they connect the DC voltage supplied by the panels to the grid, by using a voltage reference value which is obtained every moment from the algorithm of maximum power point tracking (MPPT).
The solar inverter commutations are controlled by means of space vector modulation (SVM) technique, ensuring a better harmonic distortion and the possibility of overmodulating.
Both the MPPT algorithm and the inverter commutation are implemented in the system into a commercial digital signal processor (DSP), a F28335 from Texas Instruments©. The code is introduced in C-language and there is an instrumentation environment, MATLAB GUIDE, in order to represent the different waveforms, mainly the DC-link voltage and the line currents supplied to the grid. Figure 2 shows the instrumentation environment developed with MATLAB, allowing to modify parameters and to obtain the main variables from the system.

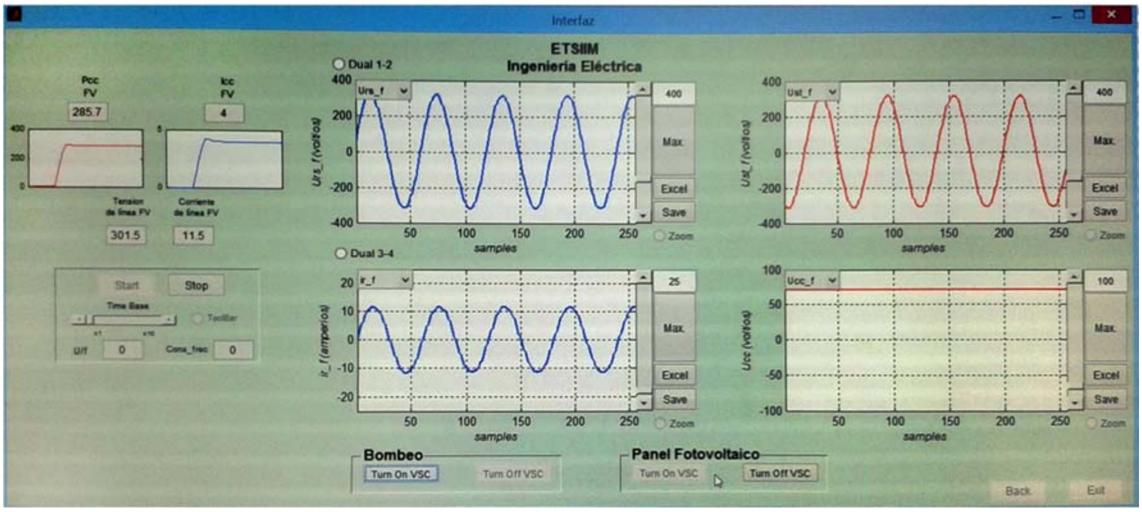

Figure 2. Screenshot of the Matlab interface showing the grid connection of the PV generator and the search for the MPPT

Pumping installation

In order to train students in the control of electric drives, a pumping installation has been chosen both to innovate around efficiency concerns and as an example to represent an electric load for each team when acting as an electric utility with generation and consume in the final contest. Three different types of pumps are available and each team should test them in advance in order to know which one would fit better the performance required in each competition. Different criteria will be used according to the water flow and the energy

consumed requirements, making each team to look for the best solution and to take strategic decisions in a short time manner. With respect to the motor control techniques the student are free to use a simple scalar control (open loop V/f) or a more sophisticated alternative (vector control with speed estimation). The inverter is controlled again through the DSP system using SVM technique.
The pumping setup includes, for each team, a water tank, flow and pressure measurement devices, and a calibrated deposit which allows to see/measure the amount of pumped water. In Figure 3, a picture of the pumping installations for the three teams is shown.

Figure 3. Three pumping installations for the three teams

Electricity markets contest

As a part for the development of the various objectives of the course, an electricity market simulation game is proposed. In this game, each of the three groups assumed the role of a utility that integrates a generation business and a large electricity consumer. The firm participates with two agents, a generator and a large consumer, in a competitive electricity market. In addition to these six participants, there is a seventh agent, the system operator, assumed by the instructor, whose role is to ensure proper operation of the power system. To do this, the system operator has an additional reserve generation or consumption, physically implemented as a connection to the external 50 Hz power supply. The market operator is also the instructor.
For each session of the competition, all the agents participate in the market with at least ten different offers or bids each. In a first step, the offers from generators are matched to the bids from consumers, using an algorithm developed in Matlab, specially design for the subject, and the clearing price is determined as the intersection point between aggregated curves. A picture of the laboratory screen taken during a session can be seen in Figure 4. According to a marginal pricing model, this price is paid to all generators with cheaper offers, which are committed to supply the corresponding energy blocks. Similarly, all consumers with higher bids pay the clearing price and are obliged to use their corresponding energy amounts.

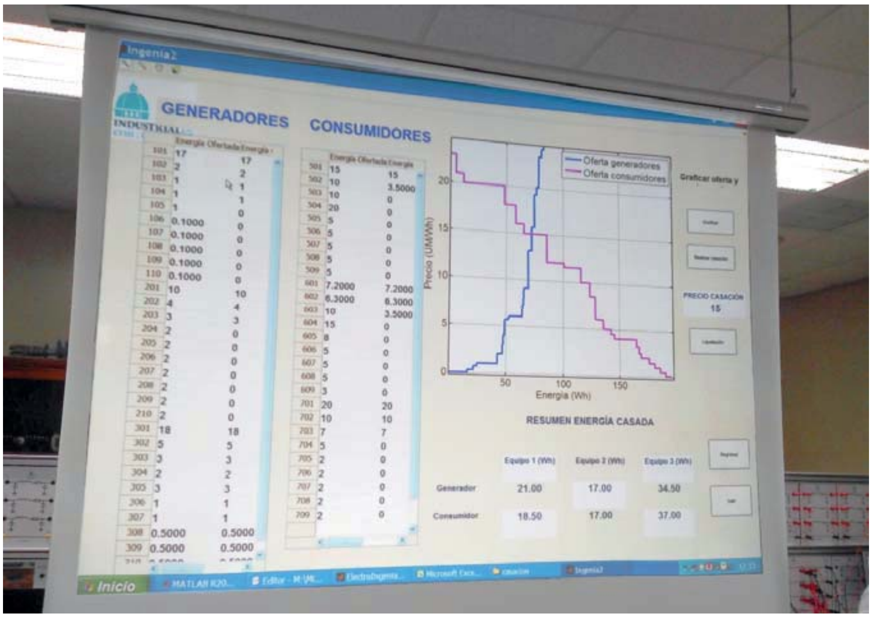

Figure 4. The price and volume of energy are determined by matching offers from generators to bids from consumers

Once the market session is cleared, the second step is the physical operation of the power system with the developed real equipment. The agents try to do their best to meet their energy commitments but, as in the real world, this is not always possible and some deviations occur. All the energy interchanges are measured and recorded.

In the final step of the session, the market operator proceeds to the liquidation of the energy blocks actually generated or consumed, taking into account the marginal pricing model and the settlement of deviations.

The goal for every company is to obtain maximum profits after a predetermined number of sessions. To do this, the groups integrate income and expenses of their generator and consumer agents. Obviously, the implementation details of the game are designed with the aim that a good result is the consequence of a good job of prior design, construction, and testing of the developed generator and consumer devices.

RESULTS

The described INGENIA course "Devising an Electric Power System", to the authors' knowledge, is the first course held in Spain that complete a CDIO cycle in the field of Electrical Engineering with laboratory and practical implementation which includes not only the generation and demand of an electric power system, but also carrying out an electric market.

The results obtained have been highly satisfactory for teachers and students. Teachers have proved that the new learning methodology carried out helps the students in understanding the theoretical principles, and the physical implementation favors their comprehension and learning. The success ratio (student completion rate) has been 100%, significantly superior to the one obtained in conventional subjects within the electrical area, which is usually between 70% and 80%.

In the case of the students, the course has provided them with the "conceive-design-implement-operate" teaching-learning activities, which include the acquisition of transversal skills such as team work, communication and creativity.

At the end of the course the students answered a questionnaire that asked them about their overall assessment of the subject, as well as about each of the modules in which it is divided. Table 1 summarizes the most relevant students' answers to this questionnaire. The consideration about their improvement in supervised work and global consideration of the course is significantly good, however, the results obtained in the part of improvement in transversal outcomes are lower than those obtained in the part of supervised work. Transversal skills acquisition modules represent an educational innovation in the electrical engineering of the ETSII experience. General courses on transversal outcomes were offered so students could learn how to work more efficiently in groups and to improve their techniques in public expositions, carrying out individual presentations. However, it has been necessary change the methodology of transversal skills acquisition. During the 2015-2016 course it has been worked individually with each INGENIA course, within the ETSII, adapting to their own peculiarities and trying to reinforce transversal skills by introducing practical sessions rather than theoretical presentations.

Table 1. Result of students' questionnaire

Question: What is your consideration about…..?		**Subject on Devising an Electric System**	**Typical deviation**
The whole course		4,48/5	0,6
Improvement in Supervised work	Conceiving	4,25/5	0,72
	Planning	4,15/5	0,59
	Designing	4,38/5	0,77
	Experimenting	4,95/5	0,22
	Implementing	4,76/5	0,44
	Continuous work	4,48/5	0,68
Improvement in Transversal outcomes	Team work	4,10/5	1,22
	Communication	3,65/5	0,93
	Creativity	3,30/5	0,98
Social responsibility Teacher contributions		3,52/5	1,12

As an overall conclusion of the results obtained in the first year implementing this new subject, it is important to highlight that the students also included personal comments in the questionnaire that pointed out their high motivation and engagement with the subject.

CONCLUSIONS

A new subject called "Devising an Electric Power System" has been presented including its conception, the development along the course and the results obtained after the first year of implementation in 2014-15. Following the CDIO concept and fully based on laboratory work, the starting point for this experience was to conceive a physical platform which would allow the students to learn through the innovation, all facilitated by the ability of testing any improvement any time is needed. The strength of the new methodology presented is putting together the laboratory work (better "doing" than only "listening/studying") and the capacity of innovation applied to improving a physical system and its control.

In the course "Devising an Electric Power System", a hybrid simulation-reality game is proposed by simulating electricity markets integrated with an actual power system, in which the emphasis is put on the conception, design, implementation, and operation of a real system and its components. The integration of this real system into the game, in addition of serving as an incentive to the student and an assessment method of the developed work, aims to provide the mere engineering tasks with an orientation towards meeting customer needs while considering resource constraints.

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WORKING DAY MODEL FOR STUDENTS IN CHEMICAL AND MATERIALS ENGINEERING

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ABSTRACT

The students' working schedule was modified as part of overall curriculum redesign work in the Chemical Engineering department. The change from a highly detailed, fragmented and classroom-orientated curriculum towards a flexible and working life connected, project-based curriculum is remarkable. The previously applied weekly schedules did not support the new curricula. Teaching was organized in a new way based on the CDIO framework and is now implemented according to a working day model. A working day was planned to include only two subjects. The first subject is studied during the morning session and the second one in the afternoon. This paper introduces the background behind the working day model and the reasons why the program decided to reorganize the studies. The design and the learning objectives as well as the working day model are described.

KEYWORDS

Working Day model, Curriculum Design, Integrated Curriculum, Standards 3, 6, 7, 8

BACKGROUND

The curriculum of the Degree Program in Chemical and Materials Engineering was redesigned to comply with the new requirements and instructions of Turku University of Applied Sciences (TUAS). The main requirement was to create a modular curriculum with entities of minimum 5 ETCS and to thus avoid a highly fragmented curriculum by integrating different subjects to form larger entities. In addition, the strategy of TUAS guided the use of innovation pedagogy (Penttilä et al 2011 and 2013). In our degree program, innovation pedagogy is implemented through the CDIO concept.

Another goal of the curriculum redesign work was to bring the teaching out of traditional classrooms and introduce more modern learning methods for the students. This goal combined with the general reduction in the number of contact teaching hours created the need to rearrange the program in a more creative way. The students were presumed to compensate for the reduction in contact teaching time by doing more independent or group work. This was, however, not the trend noted. With the reduction in the number of contact lessons in the weekly schedules, the students started to get employed outside the university to earn money instead of using the time for self-studies. This was a clear sign that a significant change in the weekly schedules was necessary.

Several other reasons in the background acted as drivers for the schedule change as well. Previous experiences gained in subjects including laboratory work had been encouraging and acted as an incentive towards a change. This previously applied concept included both theory and practical work during one day, whereby the morning started with a takeoff session, including the theory behind the laboratory assignment. The takeoff session was then directly followed by the actual hands-on session. This had turned out to be an efficient combination which resulted in good learning outcomes. Furthermore, the students tend to find this arrangement meaningful and interesting. In general, most students find project work much more motivating than classroom lessons. This concept was expanded to now apply even to the schedules of more theoretical topics such as mathematics.

SHEDULE REVISION BASED ON NEW CURRICULUM

Work according to the new curriculum started in 2014 but without any changes in the students' weekly schedule. The schedule was fragmented and did not support project-form work, which is in a central role in the CDIO model. The results from that trial showed us that the new curriculum needed a revised weekly schedule to support and achieve its full potential for enhanced learning. In accordance with the CDIO framework, students are encouraged to work in projects originating from the surrounding businesses (Sutherland et al., 1996). To enable the students to work in projects as well as to manage a project successfully within the given timetable, the working schedule needs to be flexible. Full working days were reserved for project work. Similar arrangements were made for the personnel working as project coaches. The increasing R&D participation required from the personnel needs planning and consideration in the schedules.

The schedule of the first year students in Chemical and Materials Engineering was totally rearranged during the summer of 2015. The schedule was planned to include only two topics per day and only one topic per day when laboratory, projects or other practical work was included. The revised schedule is presented in figure 1. This arrangement made the implementation of the CDIO-based projects in their full extent possible. The schedule arrangements were implemented into the older students' schedules when applicable.

Monday	Tuesday	Wednesday	Thursday	Friday
Information Manag.	Math	Project	English	Chemistry
English	Chemistry		Information Manag.	Math

Figure 1. The new layout of the revised time schedule

TEAM-BUILDING ACTIVITIES FOR EFFICIENT TEAMVORK

The new curriculum is to a large extent based on student self-studies and group assignments. The role of the teacher in the new curriculum resembles that of a coach; they help the students onto the right track and support the learning procedure. The large number of group assignments forces students to form teams with functional internal dynamics and a positive team spirit in order to avoid conflicts within the team. To be able to work in teams during studies as well as later in business life, the students need to acquire both soft and hard skills. To enhance the development of both types of skills is a central issue in the CDIO framework. Soft skills are seen as including self-confidence, self-discipline, stress resistance and interpersonal abilities such as co-operation, tolerance of diversity, willingness to do teamwork, and conflict handling and decision making skills. This important aspect was early acknowledged within the program and an effort to strengthen the team spirit among the first year students was made from the first day of studies.

At the beginning of the first semester, the entire group of first-year students together with tutor students and some teachers travelled to a summer camp, “Boostcamp”, to spend 24 hours together. The goal was to introduce the new students to each other in order to avoid conflicts based on prejudice. To leave school premises and to spend time together is an effective way to get people to know each other.

The Boostcamp program was planned in detail to train students in several critical teambuilding issues. The group was divided into smaller teams and assignments such as “the future engineer” and “my strengths and weaknesses” were worked on and the results were presented. The positive result of the camp can today be seen in the way the student teams operate. The team spirit is excellent, the mutual respect amongst group members is high, the attendance at start-off sessions and projects is high and the students know each other. These are all prerequisites for successful teamwork.

LEARNING ENVIRONMENTS AS PART OF THE EXPERIENCE

Most of the learning according to the old curriculum took place in traditional classrooms. Experiments performed in laboratories and lessons requiring computer laboratory work were the only teaching events not using regular classrooms. The new curriculum had to be implemented making use of the existing premises, but several improvements in order to achieve a better learning experience were made.

For the take-off sessions, the traditional tables and chairs in the classrooms were arranged in groups instead of the more conventional layout where the tables are arranged in lines. Small groups consisting of 6-8 students work together from the first day onwards. The idea behind these arrangements was that the students were not allowed to take the traditional position and role of a student sitting passive in lines listening to the teacher standing in front of the class. Innovative and new thinking need inspiring surroundings (Stenroos-Vuorio el al., 2012). The teacher walks between the groups and uses the several whiteboards placed on walls in the classroom for the teaching. All traditional large classrooms were updated with extra whiteboards and new table arrangements. Smaller rooms, where student teams can meet and work on their assignments, were equipped with more comfortable furniture in order to create an atmosphere where reflection, free discussion and sharing of information is encouraged. A smaller, redecorated student team room is in presented in figure 2. This new classroom layout was utilized during the fall 2015 especially by teachers in mathematics and languages.

Figure 2. An inspiring learning environment for team assignments. The pillar in the center of the room can be connected to a laptop to show the same screen to everyone.

STUDENT AND STAFF FEEDBACK ON THE WORKING DAY MODEL

The working day model was created during summer 2015 and first implemented in fall 2015. In order to evaluate the model and to further develop it, a survey was conducted. Feedback was obtained from both students and the academic staff.

The feedback from the academic staff was collected through interviews. Open questions like “your experiences about the working day model”, “has the model effects on learning results” and “what would you change or keep” were asked. As a summary of the positive feedback from the staff, it can be stated that the students were more regularly present during the contact lessons compared to the time before the revised model. The good team spirit shows and the student teams work diligently on their assignments. The students’ independent study skills are improving all the time. However, the staff still hoped for more contact hours during the courses.

Even there was positive feedback, there are, according to the staff, several issues which still require attention. The students’ attendance between 8 a.m. and 4 p.m. has improved remarkably, but is still not actualized for all students. Methods to even more deeply engage students need to be developed. Some students have still not realized their essential role in a team and the consequences the team faces when some members do not participate in the work. Another issue identified was the amount and quality of written instructions available for the students. As the students are obliged to work independently or in groups, carefully drafted instructions play a more important part in the learning procedure than when the teacher was available to answer questions. A third issue identified concerned the premises available. Even though efforts to modernize the classrooms were made, there is still more work to be done. In particular, there is dire need of smaller team rooms and a proper booking system for these needs to be developed.

The student feedback was obtained by means of a survey conducted at the beginning of the spring semester when the students returned from their Christmas break. The survey consisted of two parts. The first part contained multiple choice questions while the second part collected open response opinions.

1. How many hours have you been studying during the working day 8:00-16:00?
    a) 5 h/day, 25 h/week
    b) 6 h/day, 30 h/week
    c) 7 h/day, 35 h/week
    d) 8 h/day, 40 h/week
    e) 4 h/day, max. 20 h/week
    f) < 20 h/week

2. How many hours have you been studying outside the working day 8:00-16:00?
    a) 1-5 h/week
    b) 6-10 h/week
    c) 0 h/week
    d) >10 h/week

3. What is your experience about the model?
    a) OK
    b) Too laborious!
    c) What model?

4. Has the amount of teacher guidance been sufficient in your opinion?
    a) No. Please explain.
    b) Yes. Please explain.

5. Have you been working besides studying? If yes, what have your working hours been?
    a) Weekdays in the evening
    b) Weekdays during the day
    c) At weekends

The open response section of the survey asked the following question: What would you keep and what could be changed in the working day model?

Table 1. Survey of Working Day model – outcome based questions (n=28)

1. How many hours have you been studying during the working day 8:00-16:00?		Answers
a)	5 h/day, 25 h/week	2
b)	6 h/day, 30 h/week	**10**
c)	7 h/day, 35 h/week	**9**
d)	8 h/day, 40 h/week	7
e)	4 h/day, max 20 h/week	0
d)	< 20 h/week	0

Table 2. Survey of Working Day model – outcome based questions (n=28)

2. How many hours have you been studying outside the working day 8:00-16:00?	Answers
a) 1-5 h/week	5
b) 6-10 h/week	**11**
c) 0 h/week	1
d) >10 h/week	**11**

Table 3. Survey of Working Day model – outcome based questions (n=28)

3. What is your experience about the model?	Answers
OK	9
Too laborious!	10
What model?	9

Table 4. Survey of Working Day model – outcome based questions (n=28)

4. Has the amount teacher supervision been sufficient in your opinion?	Answers
No	16
Yes	12

Table 5. Survey of Working Day model – outcome based questions (n=28)

5. Have you been working besides studying? If yes, what have your working hours been?	Answers
a) Weekdays in the evening	2
b) Weekdays during the day	1
c) At weekends	3

An observation that arises from the survey results is that most of the students answering the questionnaire have spent between six and eight hours a day at the university. This is well in line with the planned 8-16 working day model. The time spent studying has continued even though the school day ended for most of the students. Most of them spent six hours or more studying also in the evenings. The question concerning the sufficiency of teacher supervision divides the answers into two groups. A small majority finds the amount of supervision insufficient while the other half is satisfied with the amount supervision available. When the feedback from the “insufficient supervision” group is more closely investigated, one major finding, which also the staff interviews identified, is that there is lack of adequate material to support self-studies.

Material supporting self-studies can already be found for all topics. Though, the material available in the student material storage need to be organized into larger entireties. The organization of the material should make it easier for the students to associate the material with a certain assignment. The information can for the moment be experienced as fragmented and unorganized and not supporting self-studies.

The second part of the student survey collected open response opinions. The questions were "what would you keep in the working day model" and respectively "what would you like to change in the working day model". Almost 50 % of the students answering the open questions preferred the working day model prior to the more fragmented schedule. Only 10 % of the answerers declared they preferred normal school class teaching hours. By this the answerers meant in general two-hour lessons with the teacher lecturing in the front of the classroom. They experienced that the largest problem with working day model was the lack of adequate teaching contact time in combination with their experience of not enough self-study material and instructions available. Also problems like too much information in too high tempo and unclearness when the teachers are available for guidance outside the contact hours, were mentioned.

Self-directing learning has been discussed in detail by McLoughlin & Lee (2010). They claim that learning experiences that are made possible by social software tools are active and anchored in and driven by the students' interests. The method will then support independent learning. Self-directed learning (Biggs, 1987; Zimmerman & Schunk, 1989; Simons 1992) refers to the ability of the student to prepare for his/her own learning, take the necessary steps to learn in her/his own tempo and manage and evaluate the learning as well as provide feedback and judgment. All this can be achieved while simultaneously maintaining a high level of motivation

The data was collected and analyzed for two main purposes. Firstly, it is valuable to collect data and experiences in order to further develop the working day model based on the reactions of both personnel and students. The second reason was to review the student comments on the issues they regarded as reasons why the model in their opinion is not working. This information can be used in further guidance of the students. Also the positive comments are noted and further communicated. It is important to identify and communicate the benefits of the model as well as the issues identified as requiring further development. In particular, issues such as lack of adequate material and self-study examples need to be addressed promptly.

CONCLUSIONS

In this paper we have presented the working day model implemented for the first year students in Chemical and Materials Engineering. The department of Chemical and Materials Engineering started the work towards CDIO adaption already in 2010. The first step towards CDIO adaption was a first-year introduction to engineering course included in the curriculums. From these days have the curriculums been revised to include all steps needed to follow the CDIO strategy.

The working day model support the new curriculum better than the fragmented weekly schedule. The feedback after a half year implementation time of the model was collected. Several encouraging and expected findings were noted as well as parts where more development work needs to be done. One positive finding was a notable change in the time the students spent in school studying. Group assignments are scheduled in the weekly time table and thereby made in school. Among the first year students has the amount persons working besides their studies decreased remarkably. It needs to be followed up whether this finding is directly linked to a faster graduation process. Also the good team-spirit among the first year students is worth mentioning. Special efforts were put into teambuilding as this is the base for well working groups. Efforts need to be allocated to organization of material supporting self-studies as well as assignments instructions. The working day model will be further developed and the development plan will include statistical information about passing rates of courses as well as student grades.

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THE PEDAGOGICAL DEVELOPERS INITIATIVE – DEVELOPMENT, IMPLEMENTATION AND LESSONS LEARNED FROM A SYSTEMATIC APPROACH TO FACULTY DEVELOPMENT

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ABSTRACT

This paper presents a systematic, university--wide approach to creating an encompassing movement towards faculty development. In 2014, KTH Royal Institute of Technology launched the pedagogical developers initiative, appointing part--time pedagogical developers among teachers from all schools of KTH, to implement and strengthen good teaching and learning practices among faculty and students. They are teachers active in different educational programmes, with experience of, and interest in, pedagogical issues. In line with CDIO standard 10, the purpose of the pedagogical developers' initiative is to facilitate cooperation and knowledge exchange between faculty members, and to establish communities of practice. The paper presents the activities, processes for developing these activities and preliminary results from the initiative's second year, which focused much on supporting faculty development by putting into place a series of workshops, a format chosen for its combination of active community-building learning and time efficiency. The topics of the workshops emerged to meet faculty needs identified by the pedagogical developers during the first year. The workshops were created by smaller teams of pedagogical developers from different schools of KTH. This enabled a wide array of experiences and perspectives to be incorporated into the workshops. Main focuses of the workshops have been on creating internal discussions in dynamic communities of practice on specific subjects of interest, and on creating forums for exchange of ideas, open to the whole faculty. During Autumn 2015, the workshops have been offered as voluntary add-on parts of the basic course in teaching and learning offered to faculty at KTH. This first round of workshops generated a positive interest from teachers, and participant feedback indicates that they particularly appreciated the opportunity to work directly with their own courses and the opportunity to discuss pedagogical aspects with peers.

KEYWORDS

Pedagogical developers, educational developers, change agents, workshops, faculty development, CDIO standards: 10

INTRODUCTION

Faculty competence in teaching, learning and assessment methods needs to be continuously and systematically developed as described in CDIO standard 10. This has been argued for e.g. by Crawley et al. (2007). Many universities expect faculty members to learn more about new and alternative teaching methods that support student learning. Teachers are expected to successfully implement integrated learning experiences (standard 7), include active learning (standard 8) and use novel learning assessment methods in their courses (standard 11).

However, it is difficult to implement such changes in practice. In fact, many efforts witness of struggling attempts while providing little evidence of long-term success. In contrast, real and long-lasting educational improvements seem to have been achieved when either quality management has been closely related to the day-to-day work performed by individual teachers (Kleijnen et al. 2014), or when changes have been associated with a combination of top-down and bottom-up strategies (Elton, 2003, Graham, 2012). There exist also a few examples showing that systematic academic efforts through internal institutional programmes can lead to overall changes in teaching and learning at large research universities (Wieman et al., 2010). As the management of universities faces these educational challenges, as well as external quality concerns from governments and society at large, there is much pressure to evaluate teaching and learning, and to encourage and support continuous development of the teaching faculty.

To face these challenges, KTH dedicated internal funding to launch what would be known as the pedagogical developers' initiative (Berglund et al., 2015). This initiative started in 2014 and was organised as a development project, consisting originally of 24 pedagogical developers (PDs). KTH is organised in ten schools and the project finances about 40% time for 1-4 PDs per school, the number being based on how much education each school has. One important dissemination factor in this initiative is to document and share efforts made. The dissemination of new knowledge to faculty were designed to be consistent with Bloom's taxonomic reasoning (Airasian et al., 2001), and in support of engineering education guidelines found in the CDIO syllabus (Crawley et al., 2007).

Implementing change in large educational organisations is as a rule difficult. Changes often remain limited in scope and effect (Kotter, 2012). To go beyond such limitations, the pedagogical developers at KTH act as change agents, working both locally to create "communities of practice" (Wenger, 2015), and at university level to achieve coordinated efforts, and building bridges and contacts, across departmental and school borders.

During the start-up phase in 2014, each PD had their own sub-projects, which were organised by the PDs in a very informal way (Berglund et al., 2015). This means that each PD could initiate all the different pedagogical development activities in the best way suited for each school, at the same time as they could get feedback from their colleagues about things to be improved. Furthermore, the PDs met every third week and discussed common problems. These discussions resulted in that the PDs jointly identified a number of themes, where there was a need for further faculty development. The PDs decided to have a common focus on developing workshops, based on what the teachers at the schools wanted and had pointed out as relevant for them. A reason for this strategy was that the PDs as a group could not serve the development of the whole faculty on an individual peer-to-peer basis.

In this paper, we first describe how the teacher workshops have been developed to match specific problematic issues, related to teaching and learning, identified from course analyses and faculty needs. Secondly, we present the feedback and results on how the workshops have been perceived by the participating teachers so far. Last but not least, we discuss the next steps to develop faculty competence in the view of the bottom-up approach taken in the PDs initiative.

DEVELOPMENT OF WORKSHOPS

The work with the development of the workshops started in January 2015, although most of the themes had already been identified. As a first step, a small steering group with a strategic responsibility for the workshop development project was formed. All PDs were then allowed to voluntarily choose which workshop themes they wanted to develop. As a result, there were 3-7 PDs engaged in the development of each workshop, and by sharing the responsibilities, each PD was only involved in the development of 1-3 workshops. The Department of Teaching and Learning supported this development by shortly educating the PDs about how to arrange pedagogical workshops and suggesting some background material.

The development of all the workshops was managed in an agile and flexible manner, since PDs are faculty members with many other duties and, hence, their availability could not be steered. The development of the workshops was self-organised, so each group had the freedom to identify the workshop objectives and pedagogical design, as well as how the group internally should communicate and make decisions throughout the development work. Each group had a designated group leader, who was responsible for arranging meetings within the group and for reporting group progress at monthly pulse meetings where most of the PDs were present. Through this procedure, potential problems within a development group could be detected at an early stage and proper measures could be taken to support that group.

The common and accepted goals among the PDs were that all workshops should be ready by Fall 2015 and that they should be given internally for the group of PDs before they were given for other teachers. Most groups met 3-6 times before draft versions of the workshops were ready to be tested on the rest of the PD group. The PD group was informed before the start of the test-runs about their double role as teachers (test of the workshop contents) and PDs (help to improve the workshop) and when to switch roles. During the test offerings, the participating PDs were divided into groups, to systematically look at a number of aspects: structure and time management, intended learning outcomes and constructive alignment, meaningfulness, credibility, and persuasiveness, as well as other specific aspects asked for by the offering team. Meta-discussions were allowed only after the workshops, to allow for as much realism in the situation as possible (prevalence of teacher role). The designs of the workshops were then revised in the light of peer feedback before being offered to other faculty members. Thus, the internal quality process served two purposes – it gave the workshop developers a feeling of how it felt to give the workshop in reality and they also got an opportunity to receive constructive feedback from their fellow PDs on how to improve their workshop. On a meta-level, this procedure also helped the PDs to get deeper insights into the workshop format.

To promote further testing of the workshops, the Department of Teaching and Learning at KTH decided to include seven of the workshops as elective parts in their basic pedagogic course for new teachers at KTH during Fall 2015. In total, more than 100 participants (about 30 different teachers) participated. A few of the workshops have so far been given on other occasions too (locally at the schools), with an additional 70 participants. Furthermore, workshops will be offered at a pedagogic day in March 2016, and again as part of the basic course in teaching and learning for KTH teachers during Srping 2016. The marketing of the workshops to teachers continues to be a prioritised issue.

DESCRIPTION OF THE WORKSHOPS

The following themes were developed into nine workshops. Their connections to the CDIO standards are also shown.

- Assessment methods (CDIO standards 10 and 11)
- Designing courses for motivation (CDIO standards 8 and 10)
- Educational development with LEQ (CDIO standards 10 and 11)
- Formative feedback for learning (CDIO standards 8 and 10)
- Flipped classroom (CDIO standards 8 and 10)
- Get started with E-learning (CDIO standards 9 and 10)
- Help your students to study in your course (CDIO standards 7 and 10)
- Independent students (CDIO standards 7 and 10)
- Intended learning outcomes and the course syllabus (CDIO standards 2 and 10)

These workshops are described in more detail below.

Assessment Methods

The purpose of the workshop is to make the participants more aware of what role assessment plays in students' learning and how to choose assessment methods that will promote active learning. The participant works hands-on with a course of his/her interest. Each participant is expected to prepare for the workshop by reflecting on the learning outcomes and the assessment methods used in the course of interest.

Intended learning outcomes: after the workshop participants should be able to describe the purpose of, and criteria for, high quality assessment. The participant should be able to identify pros and cons of different assessment methods, and also be able to choose assessment methods that support learning and that are constructively aligned with the learning outcomes and the course activities. Finally, the participant should be able to design or suggest good assessment for a specific course.

Designing courses for motivation

Motivation is a core concept in theories of learning. Motivation is what makes a student invest time and energy to master a subject or to learn a new skill. This workshop lets teachers explore ways of designing learning activities that increase the level of motivation among their students. Designing for motivation is a comprehensive way of making teaching and learning much more rewarding and meaningful to students and teachers alike.

Intended learning outcomes: after the workshop participants should be able to use findings from research on motivation to enhance their teaching; analyse learning activities from a motivational standpoint; design learning activities that stimulate and motivate students; discuss different approaches to motivation based on contextual factors; and deal constructively with less than perfectly motivated classes.

Educational Development with LEQ

The workshop gives the participant an opportunity to gain hands-on experience of working collaboratively with course analysis and development based on the KTH Learning Experience Questionnaire (LEQ), described in Berglund et al. (2015). Each participant is expected to prepare for the workshop by viewing a video about the LEQ process, reviewing the LEQ questionnaire, and reviewing the course design of the course that the participants are to analyse using LEQ.

Intended learning outcomes: after the workshop participants should be able to explain the theoretical framework that LEQ is based on, set up an LEQ survey on the KTH course web, analyse a learning environment based on LEQ response data, and discuss different ways to improve a specific learning environment.

Flipped Classroom

The focus of this workshop is the design of a flipped-classroom learning activity. Participants design preparatory, in-class and post-class activities and discuss their designs with other participants. In preparation for this workshop, each participant should either participate in the Flipped Classroom seminar, reflect on their own experiences of flipped classroom techniques, or read suggested scientific articles on the subject.

Intended learning outcomes: after the workshop participants should be able to describe the difference in the design principles of a preparatory activity, an in-class-activity and a post-class activity, design learning activities appropriate to a flipped classroom scenario and to design preparatory, in-class and post-class activities that are constructively aligned.

Formative Feedback for Learning

This workshop gives participants knowledge and ideas on how to give feedback that support learning. Each participant is expected to reflect upon and assess a course of their own, in order to focus the workshop discussion and to work on how the constructive alignment between ‘examination-activity-objective’ are matched with course feedback provided.

Intended learning outcomes: after the workshop participants should be able to motivate why formative feedback is of crucial importance for learning and to put up arguments about the characteristics of efficient learning through formative feedback, create a situation analysis based on the level of formative feedback provided in your current course, design an action plan to enhance formative feedback in your course(s) and reflect how formative feedback functions as a catalyst in the constructive alignment of your course(s).

Get Started with E-learning

The workshop is designed to allow teachers to discuss and reflect about how the new possibilities given by information technology can be used for student learning. Before the workshop, they should have identified one issue in one of their courses which they want to improve using IT. During the workshop, they can either make a short video or create suitable questions to be used in interactive environments such a peer instructions during lectures or automatically corrected problems in a learning management system (LMS).

Intended learning outcomes: after the workshop participants should be able to either make their own video or to create well-designed questions for interactive environments.

Help Your Students to Study in Your Course

The purpose of this workshop is to make the participants aware of prevailing study skills and to enable the participant to achieve better alignment between study skills and course design. Each participant is expected to prepare for the workshop by viewing the same videos on study skills as most students see in their introductory courses, briefly review a number of articles, and reflecting on a set of questions concerning study skills.

Intended learning outcomes: after the workshop participants should be able to describe some common study techniques and in which situations they are useful, to propose suitable study techniques to the students of their course, and to adapt their course design to study techniques.

Independent Students

Students are supposed to be independent when they leave the university. In this workshop, the participants reflect on what this means and how to incorporate learning activities that promotes the progression in skills related to independence during the engineering studies.

Intended learning outcomes: after the workshop participants should be able to concretise what independent students means at different stages in their education and to implement learning activities that help students to become independent.

Intended Learning Outcomes and the Course Syllabus

This purpose of this workshop is to enable the participant to start working on constructively aligned activities and assessment, and create official course syllabuses with suitable level of detail and that fulfill the legal requirements. During the workshop, the participants work individually and in small groups with the contents of their respective course syllabi, in particular with the intended learning outcomes of your course. Each participant is expected to prepare for the workshop by bringing their current course syllabus, reviewing the concept of constructive alignment, e.g., through an introductory course in teaching and learning, the introductory seminar (*Constructive alignment - a way to improve course design*), or similar, and reviewing the document describing the course syllabus and the course PM.

Intended learning outcomes: after the workshop participants should be able to explain constructive alignment, develop intended learning outcomes that are result oriented, possible to assess, placed at a suitable and realistic level, understandable and serve as a base for constructive alignment, and be familiar with the different parts of the course syllabus and explain its function.

SUMMARY OF THE INTENDED LEARNING OUTCOMES

In order to analyse the type of faculty development intended with the workshops we have analysed how the different workshops have been described by the workshop development teams in terms of intended learning outcomes. Pretesting were made by adopting a priori coding of the intended learning outcomes using the cognitive goals of Bloom's taxonomy (Airasian et al., 2001). The resulting matrix is shown in table 1. The figures indicate the number of intended learning outcomes that belongs to each level in Bloom's taxonomy, for each workshop.
After discussing the results we agreed on combining two of the categories (applying and creating) to one category since in these intended learning outcomes involved changing actual courses which will involve both applying and creating.
As seen in table 1, the workshops have a clear emphasis on actually changing courses rather than more passive knowledge. Thus, the goals of the workshops go beyond the goal of CDIO standard 10 to enhance faculty teaching competence, to actually applying this competence by implementing change in courses. The evaluating step is met in neither of the workshops. It is also not aiming to do so either. A reason to this is because such step would only be efficient if a change has been put in action for a certain amount of time that would allow for valuable interpretation.

Table 1: Matrix mapping of intended learning outcomes of the WS according to Bloom's taxonomy

	Remembering	Understanding	Applying /creating	Analyzing	Evaluating
Assessment methods	1		2		
Designing courses for motivation			3	2	
Educational Development with LEQ		1	2	1	
Flipped Classroom		1	2		
Formative Feedback for Learning		1	1	2	
Get started with E-learning			2		
Help Your Students to Study in Your Course	1		2		
Independent Students		1	1		
Intended Learning Outcomes and the Course Syllabus		2	2		
TOTAL	2	6	17	5	

PARTICIPATING TEACHERS' FEEDBACK ON THE WORKSHOPS

To implement a built-in process supporting continuous enhancement of the quality of the workshops, a short questionnaire was handed out to all workshop participants towards the end of each workshop. This questionnaire had primarily a development focus, helping us improve the workshops and make them as useful as possible for the participating teachers. It included four open-answer questions:

- The three most helpful things that I learned at the workshop
- What I liked best about the workshop
- What I would have liked to be different/recommendations for future workshops
- Any other comments on the workshop?

Although not originally designed for research purposes, we have used the answers from these questionnaires for a contextual text analysis of the teachers' responses given so far. This included answers from 6 workshops (of which 4 were voluntary parts of the basic course in teaching and learning at KTH and 2 were given at pedagogic meetings at specific schools at KTH) and comprised in total 170 separate comments. The context analysis was made from a bottom-up approach without any a priori determined themes. Themes were constructed when trying to group the individual comments. The following themes were possible to identify among the answers to the questionnaire (the percentage of comments coded to a specific theme is shown in parenthesis):

Learning pedagogic concepts and ideas (26%)

When teachers answer the question about the most helpful things they have learnt during the workshop, many of them mention things related to basic concepts in teaching and learning. A few examples from the given answers are; 'clickers - peer discussions', 'different ways of giving feedback', 'summative versus formative feedback', 'importance of peer review' and 'a large understanding for the method of flipped classroom'. These answers clearly indicate that the workshops help teachers to become aware of basic pedagogic concepts.

Discussing and learning from peers (26%)

The possibility to discuss educational issues and learn new knowledge from other teachers by concrete examples is also very appreciated, which is one of the actions described for increasing faculty competence in CDIO standard 10 ('forums for sharing ideas and best practices'). Many teachers just mention 'group discussions' as the best thing about the workshop. Others are more concrete and concentrate on the learning effects, like e.g. 'the interactive nature of it and hearing experience and practice from other colleagues' and 'learning from my group mates experiences and get their perspectives and suggestions'. It also seems that it is the discussion of something teachers conceive as directly related to their own courses that really motivates them. This can be seen in the comments 'nice to be able to discuss own course syllabus' and 'it can provide learning in my courses'. Other teachers refer to learning from examples as e.g. seen in the comments 'example of how to include feedback in a course', and 'different approaches to solve similar problems'. Some teachers also asked for more examples like e.g. 'suggestions on how to give formative feedback' or 'more concrete examples, not just from project courses but also from more traditional/theoretical lecture-exercise lab-exam courses'. Hence, learning from concrete examples seems to be an important part of the teachers' workshop experiences.

Ideas for developing own courses (6%)

The ultimate proof of faculty development would be teachers changing their own courses based on pedagogical principles. We do not see any strong evidence for this in the answers to the questionnaires, but a few teachers mention the importance of peer discussions for getting new ideas and feedback about their own teaching. This is in line with the role of the workshops to create a forum for spreading good ideas within the faculty, which later on can lead to actual changes. However, to show such long-term changes, one would need to use other research instruments than a short questionnaire at the end of the workshops.

In addition to these themes, 18% of the comments consisted of practical feedback to the workshop leaders about how to improve the workshop and their time management between presentation and discussions. Other themes with a few percent of the comments each were coded as: finding information, work with own course, reflections about teacher/student relation, interest in subject and other comments. However, there are too few comments in these themes at the moment to allow for an analysis.

DISCUSSION

What have we learnt from the development process?

By establishing a process involving an internal review where each workshop was tested in the PD group, we had an appreciated way of progressing, not only within each workshop team, but also on generic aspects that were vital for all workshops. The themes developed were based on experiences and needs identified from course analyses. Still it should be remembered that each theme provides a mere fraction of what could be brought forward. The emphasis has been on providing best practices based on scholarly examples and relevant research. The opportunity to freely choose what workshop to develop strengthened each participating PD's motivation to contribute and also provided the emergence of the self-organised teams. Past educational change examples describe similar effects in how change agents can support implementation (e.g. Berglund et al., 2015; Graham, 2012). Crucial mechanisms for successful implementation are to sustain high motivation and engagement throughout and beyond the delivery occasions.

What have we learnt from the participants' feedback on our workshops?

The most prominent feedback from the participants is that they are very satisfied with the opportunity to discuss educational issues with colleagues. It seems that they appreciate the possibility to learn new knowledge usable for their own teaching, i.e. it is the direct connection to their own teaching practice that is important. The different themes in the teacher's feedback can at least loosely be related to steps in Bloom's taxonomy (Airasian et al., 2001) applied to teachers learning about pedagogics. During the workshops, the participants learn about pedagogic concepts and ideas. Then they discuss with other faculty members and get deeper understanding of the concepts. Last but not least, they discuss how to apply and implement these concepts and ideas to make changes in their courses. The ultimate goal is of course to encourage the participants to change their actual teaching in a direction that enhances student learning. This is a long-term process and it is still too early to analyse the outcomes of the workshops from this perspective since most courses are only given once a year.

What are the implications of these results for faculty development?

Feedback from the workshops indicates that we need to work continuously with repeated workshops, and that participants ask for further possibilities to have pedagogical discussions on their own courses with colleagues. However, our methodology has not ensured that all relevant themes have been identified since only a limited part of the faculty was involved in the initial work. This could indicate that some themes have been missed and that there is still a need for further development. Hence, these workshops should not be considered as a final product of the development work. Rather, they are meant to provide an inspiring first move towards continuous change among faculty. Whether the workshops in the end actually result in changes remains to be evaluated in a future study. In a further step, the participants also need to be able to analyse the effects of these changes, reflect about the results and make proper modifications in their teaching, corresponding to the highest level in Bloom's taxonomy (evaluation). In order to accomplish impact over time, workshops with discussions between participants is not sufficient. These efforts must be aligned with an overall university strategy that includes a pedagogical policy and a system for documentation and recognition of pedagogical merits.

CONCLUSIONS

The second year of the Pedagogical developers Initiative has focused on faculty development by producing and offering a number of workshops. The themes of the workshops were identified from course analyses and faculty needs which reassure implications for change. The workshops were developed by teams of pedagogical developers that were self-organised and driven by their own intrinsic motivation to participate. Testing and validation of workshops were done internally within the pedagogical developers group. This method gave vital feedback to the workshop developers group and ensured deliverance of high quality workshops.

The workshops allowed an appreciated opportunity to discuss participants own courses. By allowing guided discussions among peer faculty the workshops functioned as a catalyst to establish a cognitive awareness of new thematic areas essential for efficient teaching and learning practices. As participants actively worked with their own courses during the workshops, a first step to actually implementing change got established. The legitimacy of workshops in a larger scope is an issue of organisational and communicational concern. In retrospect, the workshops could be looked upon as the tip of an iceberg where the large majority of work remains obscured and as part of the participants' ambitions to actually go through with their intentions to change.

FUTURE DEVELOPMENT

The pedagogical developers' initiative is a three year project that in 2016 enters its final year. During 2016, the emphasis of the project will be on ensuring that the development work will be implemented and established at the university. Since the workshops are an outcome of a bottom-up approach based on faculty demands, they need to find their place in a larger quality framework at the university level. This concerns both how to follow-up pedagogic development at course level and how to reassure quality in educational programmes. The quality concern will become of vital importance when aligning with the 'Standards and Guidelines for Quality Assurance in the European Higher Education Area', ESG (2015). To be successful in implementing change, universities still need to communicate the urgency, formulate clear messages to the faculty, and build up a change strategy (Kotter 2012). These issues still constitute a challenge and will most probably determine whether or not the PD project will be able to create a sustainable change at the university level in the future.

In terms of PD action to proceed with faculty development, a proposed next step is to implement a course in *'Course development'*, encompassing all the steps in the LEQ process (see Berglund et al., 2015). This course concerns the course development process that allows participants to progress and track their changes made in their course by: evaluating the students' perception of their learning environment, analysing and pin-pointing actions for change, implementing suggested changes in the next course offering, conducting a new course analysis and evaluate the results from the two course offerings and reflect on how differences between the course offerings and actions taken, actually supported strengthened learning by the students. Such a course is intended to cover the evaluation part of Bloom's taxonomy and most importantly to stimulate and support a continuous pedagogic development process.

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TOWARDS DEVELOPING A COMMUNICATION TRAINING MODULE FOR CUSTOMER-BASED PROJECTS

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ABSTRACT

The development of project work skills forms the backbone of curricula in engineering education. Engineering students gain valuable work experience, develop interpersonal competences and a “customer-first” mindset, establish a professional network, and experience a smoother transition to the engineering labour market when working in customer-based projects. Yet, in such projects the development of interpersonal and communication competences remains overlooked or it is assumed to develop through experience and not necessarily through a more systematic training process. The systematic development of interpersonal and communication competences can positively contribute to successful project outcomes in addition to enhancing the engineering students’ overall competitiveness when they graduate. This paper aims to address this need in engineering education in general and more specifically to explore the current practices of communication between ICT students and project customers, find out example of good practices of communication, identify challenging areas and propose a list of training activities to improve communication. The scope of this study includes six exploratory qualitative interviews with Turku University of Applied Sciences ICT students and staff involved in customer-based projects. This paper concludes with a proposal for a training package to help engineering students acquire increased awareness of communication issues as well as tools and strategies for handling such issues in real life customer-based projects.

KEYWORDS

Communication skills, Customer-based Projects, Soft Skills, Training Module, Engineering, ICT students, Standards: 3, 5, 6, 7, 8

INTRODUCTION

The development of project work skills forms the backbone of engineering curricula for three reasons. Firstly, project-based learning promotes active learning in authentic real-life situations Secondly, through project work the students develop critical thinking, problem-solving, teamwork and communication skills in addition to subject knowledge. These skills are highly valued and desired by employers (Abdulwahed et al. 2013). Finally, project work especially in real-life projects helps students gain valuable work experience, develop interpersonal competences and a “customer-first” mind set, establish a professional network, in addition to experiencing a smoother transition to the engineering labour market.

The Degree Programme in ICT at Turku University of Applied Sciences (TUAS) has fully embraced project-based learning in its curricula. Since 2006 The Degree Programme in ICT has also been practicing the CDIO engineering education framework (Kontio 2012, pp7-12) which is based on active and experiential methods of learning. According to the CDIO framework, the ICT curriculum includes an introductory course to the engineering profession, called Product Development taking place in the first year of studies and a capstone-type course in the third year called Innovation Project (Kulmala et al. 2014). Both courses support CDIO standards 3, 5, 7, and 8 (CDIO v2.0) and both courses are project-based with the latter course involving real life customers. However, these are not the only courses which involve project work with real life customers because specialization courses, for example Game Development, utilize real life projects (Luimula & Skarli 2014). To take matters one step further and create an ecosystem that supports project-based learning in a real-life project-based environment, The Firma (http://thefirma.fi/fi/). The Firma was established in autumn 2015 and is a learning environment which encompasses:

- Turku Game Lab (http://turkugamelab.fi)
- a working environment shared by TUAS and the University of Turku, where students from both the technical and artistic fields can meet and develop games together.
- The former ESCfi, a company-like learning environment at TUAS in which students deal with customer support requests and develop an entrepreneurial mindset.
- The former CloudIT, a student-run cooperative which offers webpage and graphics solutions and sells IT equipment.(http://cloudit.fi)
- ICT Portti, or ICT Gate in English, where TUAS, the University of Turku and Turku Science Park collaborate to support SMEs in SouthWest Finland to exploit ICT more efficiently. ICT Portti acts as a portal to support the transition to working life and enhances the students’ professional skills (http://www.ictportti.fi).
- The Citizen’s Helpdesk, a help desk where students provide any member of public free IT technical help, advice and training (http://thefirma.fi/en_US/kmt/).

From the above courses and environment, it is obvious that projects form the backbone of the curriculum. In particular, the Firma also supports CDIO standard 6, Engineering Workspaces (CDIO v2.0). Furthermore, it is also clear that in project-based courses and environments, students have the opportunity to have learning experiences that enable the students to apply “knowledge to engineering practice and prepare them (the students) to meet the demands of their profession” (Standard 7). Having to deal with real project customers helps the students develop personal, interpersonal, and social skills and these are skills that are mentioned in most CDIO standards.

At the heart of these skills lie communication and soft skills which are often overlooked or taken for granted (Luimula & Skarli, 2014) in projects. In the recent years, there have been studies which have classified the body of skills, both technical and soft skills needed by software engineers in particular (Penzenstadler et al. 2009, Sedelmaier & Landes 2014) and provided examples of courses where project communication is incorporated in software engineering courses (Kumar & Wallace 2014) Yet, the need for developing soft skills (Kumar & Hsiao 2007, Gonzales Morales et al. 2011) still remains. Indeed, these skills are very important for the success of any project as well as for developing engineering leadership (Kumar & Hsiao, 2007). Unfortunately, developing these skills in a customer-based project context at TUAS appears to happen organically and without formal training or explicitly documented procedures or “code of conduct” handbook.

PURPOSE AND RESEARCH QUESTIONS

This paper aims to address the need for the development of a communication training module for ICT students who work in customer-based projects. In particular, this paper attempts to establish the communication issues and competences that need to be developed when ICT students liaise with customers in projects in the Faculty of Business, ICT and Chemical Engineering at TUAS in order to create content for a training module that addresses this need In other words, the focus is on the communication needs of the particular students in a specific faculty. The questions this paper aims to answer are:

a. What is the context and purpose in which communication between students and project customers occurs?
b. What are the current practices and protocols (if any) when students communicate with project customers?
c. What are the best practices for enhancing communication?
d. What are the most challenging communication situations for students, non-teaching project staff and supervising teachers?
e. What kind of training activity would be appropriate for developing better communication?

METHODOLOGY

The method for answering the above questions were exploratory interviews with the three stakeholders, namely, students, supervising teachers, and project staff (non-teaching staff). In total, six interviews were conducted. The interviewees were 2 students, who have worked with projects with the Turku Game Lab and both of them have started their own business; 1 teacher who has been supervising students in projects; 1 senior lecturer who is responsible for R&D in the faculty; 1 project manager responsible for running customer-based projects; and 1 project worker.

The interviewees represented well the students and members of staff at TUAS involved in customer-based projects. Interviewing external project customers was out of the scope of this study and they will be interviewed as part of a future study. The interviewees were briefed on the purpose of the interview. The interviews were recorded and lasted on the average 18 min. Then the findings of the interviews were summarized, and classified according to the themes that emerged. The following sections present and discuss the findings of these interviews.

RESULTS AND DISCUSSION

This section introduces the findings of interviews in relation to the research questions.

Context and Purpose of Communication between Students and Project Customers

Communication between the ICT students and project customers starts taking place mainly in their second year of studies. Typically the students do their compulsory Work Placement and this involves participating in a project that involves a customer. A Work Placement can be found in the industry independently, through the Firma, by directly contacting staff that are involved in R&D, or by applying for a Work Placement advertised usually internally. Students also communicate with customers in project-based specialization courses, such as Game

Development as well as in the Capstone Innovation Project. In addition, students usually do their thesis as a project commissioned by a customer, usually a company or a local governmental organization, e.g. a hospital, a different Faculty or Unit of TUAS, or as part of a larger R&D public-funded project which involves companies, educational and/or research institutions or public organisations. Thus, the customers can be internal or external to TUAS. The types of projects range from a simple design and implementation of webpage including customer training; carrying out a study to improve an update an automation system for a company; to larger EU-funded R&D projects, such as GeoSmart City (http://www.geosmartcity.eu/).

Communication between students and customers mainly occurs in physical (face-to-face) meetings taking place on TUAS premises, customer premises or a public meeting place, such as a cafeteria. Before the student or students meet the customer, a staff member, for example a project manager or a project worker has had a meeting with the customer to assess the needs of the customer, to clarify the scope and tasks to completed by the student, the timetable and the price if there is a paying customer. The member of staff then briefs the students about the project and the task involved.

The aim of the first meeting of the customer and the student(s) is to discuss the purpose of the project, the project tasks/deliverables and the deadlines. This first meeting is in most cases supervised by a TUAS member of staff and is attended one student or a small group of students. Sometimes, there may not be a member of staff present. This happens when a student usually works for a company and has to do a project for the customer of the employing company or when a student has his own company and does a project for a paying customer or when the student has enough project experience to be trusted with meeting the customer. The subsequent meetings are status updates meetings, occurring at weekly or bi-weekly intervals. These meetings are attended by the one or two students, usually the student project manager and the student who is responsible for a specific task, and the customer. The project closes with a final meeting where the final version of the project deliverables are presented to the customer.

Practices and Protocols Used in Project Customer Communication

Based on the conducted interviews, it appears that there is a process to be followed when working on a customer-based project. However, there seems to exist no documentation in a form of a handbook of code of conduct when interacting with a customer. For example, a short document giving guidelines for writing a first email to the customer or some ground rules concerning how a first meeting and/or the subsequent meeting should be conducted, how to more customer-focused or describing customer-focused behavior as well as providing communication techniques and language for particular functions. Communication seems to be developing organically; in other words, the more the students become involved in projects, the better their customer communication skills become. Thus, there is a small gap here for development of communication and soft skills, namely, establishing rapport, credibility, creating good first impressions.

The interviewed students mentioned that the first meetings they have had with customers were “free flow” but soon they developed their own communication strategies and checklists for running efficient meetings with customers. Concerning the actual content of the communication with the customers, one of the students mentioned the use task management software, e.g., Trello, for collecting items for the agenda of the meeting and ensuring that nothing important that needed to be discussed was forgotten.

Best Practices for Enhancing Communication

When asked about the best practices for good communication with customers, all interviewees mentioned **preparation**. For the students this meant knowing the purpose of the meeting, preparing questions that they would like to have answered, for example, the tasks, the requirements, the timetable, and the deadlines. In addition to these, for progress status meetings, preparation meant regularly communicating with the customer, preparing an agenda, going through what was done, finding different ways of demonstrating progress and explaining what they will be working on next. For the staff, preparation meant analyzing the needs of the customers, clarifying the scope of the project, defining the tasks, agreeing on deadlines, briefing the students on the project and managing customer expectations.

Another good practice was **following the agenda** to ensure that nothing important is left out and that the meeting are kept short so that no-one's time was wasted.

Politeness was also mentioned. The examples of politeness that were mentioned had to do with good manners, for example, taking off hats, not chewing gum, looking the customer in the eye, softening their tone when explaining to the customer that a demand is unrealistic. In addition, another example of politeness mentioned was providing information to a company providing the host server of their customer. Thus politeness here is a mixture of good manners, soft skills, and professionalism.

Using appropriate and clear language when presenting, explaining, or sending emails was also perceived as a good practice. In particular, using a language that the customer could understand and "*not bothering the customer with too many d*etails" were highly appreciated. From one of the interviews, it emerged that the students who worked at the Citizen's Helpdesk or had taken part in a course where they had to offer IT support to the general public in a public library developed very good customer service skills.

Finally *"**creating a good impression**"*, that is, giving the impression of *"being a professional rather than a hobbyist"* was considered very important by all the interviewees. Examples that were given included the writing of the first email to a customer, using formal and very clear language; and the students' self-introduction to the project partners where they briefly explained who they were, how long they have been studying, what experience they had and their interest in the project.

Communication Challenges

The communication challenges that emerged from the interviews can be classified into two categories: customer-related and student-related.

Customer-related Challenges

The first customer-related challenge mentioned by the interviewees was that some customers tend to be quite talkative about issues not relating to the agenda, therefore the meeting goes off-track and lasts longer than planned. In addition, the students mentioned that in such cases they had to send emails to enquire about information they needed. The students also mentioned that they found it quite hard or impolite to interrupt the customer and get the discussion back on track.

The second customer-related challenge has to with customer expectations in combination with the fact that the customer may not be a technical expert. This is point where the role of the project manager becomes invaluable because the project manager analyses the customer needs and negotiates a work package which is realistically feasible in terms of resources, skills and time. For example, a customer might require an X solution without realising that in order to implement the X solution, solutions A, B and C are pre-requisites and this might take a considerable pool of resources.

Student-related Challenges

The student-related communication challenges were mainly mentioned by the staff members and they are a mixture oral and written communication, non-verbal communication, interpersonal skills and attitudes. The staff interviewees felt that generally the majority of students communicate well with customers but there are always a small room for improvement.

The first challenge that was mentioned was **failing to communicate with the customers** about the progress of the project. Students are instructed to inform the customers about their weekly progress. In this particular case, the students kept working but for some reason they did not inform the customer about it. Thus the students were more focused on producing the deliverables and forgot about communicating their progress. In order to understand the occurrence of this incident, we need to examine the attitude and the students' way of thinking. Most students studying information technology are passionate about programming and love to concentrate on that. They might also be very shy and communication or interacting with the customer somehow becomes of secondary importance to them. However, the staff members are very much aware of the importance of this communication because "*even if you are not in direct contact with a customer, still in a company you have internal customers, for example, the marketing team."*
The second set of student-related challenges relates to **behaviour and communication during the meetings**. The challenging behaviours mentioned by the staff included:

- Not speaking confidently
- Not speaking loud enough
- Not making eye contact with the customer
- Being too quiet
- Behaviour not considered polite and respectful (e.g., not taking off hats, chewing gum)
- Speaking too much about themselves
- Displaying strong reactions to customers' suggestions without softening their tone or offering an explanation their reaction
- Not listening to the customer and focusing on the customer needs.

The third set of challenges could be named as **mastering the use of communication systems**. The example that was mentioned in the interviews was "*knowing how booking meetings with the calendar works*" and knowing the functions of project management tools used by the customer. This relates to larger R&D projects in which the partners use such tools.

A final set of challenges mentioned relates to **written communication**. One interviewee (staff) mentioned *"sending relaxed emails to customers"*, meaning that the emails sent were written in a very informal manner considering that the recipient is a customer and not a classmate or a friend. Another challenge relates to larger R&D projects where the students have two sources from where they can address their inquiries or questions, the TUAS contact person (staff) or the project customer. In these cases, the students sometimes send emails to the customer asking them for information that the TUAS contact person can very easily answer. A final challenge that was mentioned relates to special needs. For example, the documentation produced by a dyslexic student needs editing before sent to the customer.

Training Activities for Better Communication

The interviewees were asked what kind of training activities could be offered to students to address the challenges in communication. From the responses, it became obvious that the students would benefit from examples of efficient and not so efficient meetings. These could be videos of real meetings followed by discussion and briefing and feedback not only from a member of staff but also from a customer.

Another type of activity could be role play practicing various typical situations and roles where the students could practise using language functions and communication techniques, for example, re-directing the discussion back to the agenda, clarifying and eliciting information, explaining concepts and ideas in a clear and simple manner without using technical jargon, rephrasing ideas, confirming and summarizing actions. Two interviewees specifically mentioned that these activities would be good to practise face-to-face with someone they were not familiar or through a virtual platform where they would not know whether they are communicating with their friends or someone else.

Concerning practicing written communication, there are two types of activities that came up from the interviews. Firstly, the written tasks, such as memos, agendas and emails and phone calls could derive directly from a bank of real life videos of meetings. Secondly, the students could be practise using a project management tool.

Finally, one of the interviewees suggested the following method, "*theory, practice, and doing the real thing"* meaning placing the students in a situation or an environment where they could practise their customer interaction skills. A suitable environment for that purpose would be the Citizens' Helpdesk.

CONCLUSION

The purpose of this paper was to explore the current practices of communication between ICT students at the Faculty of Business, ICT, and Chemical Engineering and project customers, find out example of good practices of communication, identify challenging areas and propose a list of training activities to improve communication. For this purpose, six interviews with TUAS ICT students and staff involved in projects were conducted. Based on these interviews, it emerged that the development of communication skills occurs in an organic manner rather than being a result of a systematic process or training. From that perspective, a handbook of communication in projects which would include code of conduct and checklists would be a good place to start with.

However, a handbook of communications in projects would only cover certain aspects of communication. The proposed handbook would need to be accompanied by training activities that simulate the typical student-customer interactions. Such training activities could include:

a. Video recordings of real life meeting would provide excellent training material for the students followed by discussion and feedback from the communication trainer and the customer's perspective
b. Role play or simulation of student-customer interactions based on real life scenarios.

Finally, to create a full training package in addition to the proposed handbook and the training activities, we would need to incorporate real field practice in an environment where the students would have to interact with a real customer and practice their communication skills as well as soft skills with customers who have no technical knowledge or experience. This field practice would be followed up with a personal development discussion.

The scope of this study was limited to and intended for ICT TUAS students and staff. Areas for future study would include interviews with customers of different types of projects and actual observation and videotaping of customer meetings. In addition, a further area of future development would the evaluation and assessment of the training module to be developed. These areas of future study and development would facilitate the creation of a more systematic process and subsequent training material for an integrated curriculum.

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DIRECTED STUDENT ENGAGEMENT AND LEARNING IN A LARGE ENGINEERING UNIT.

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ABSTRACT

Most students when entering tertiary education have little idea what an engineer actually does. It is critical, therefore, that students transitioning into their university engineering program are exposed to learning experiences that allow them to grasp very early in their studies an understanding and appreciation of what real engineering practice is, and how this practice fits with their chosen degree program and how it supports their career aspirations. In 2011, the author was driven by an abiding commitment to broaden students' understanding of this profession, their insight into the scope of their capabilities as professional engineers, and to inspire and motivate them through learning about the challenges and opportunities they will face as professionals. It was from this premise that he spearheaded the development and introduction of a new core first year unit, a unit focused on real engineering practice. As a 'transition in' unit for predominantly domestic and secondary school leaver student cohorts, the unit served as a gateway to all engineering disciplines. The author's positive impact and influence on student learning was based on CDIO methodology through 'directed' peer- and self-learning leading and teaching this unit in collaborative learning spaces and integrating the *Engineers Without Borders Challenge* into it. Despite the size of this 1000+ student cohort and teaching team of 20+ tutors, student satisfaction scores (as judged by QUT evaluation indictors) jumped in the first year of implementing this teaching approach to 4.5 (on a 5-point scale); this satisfaction remains high with students' evaluation scores averaging 4.4, exceeding both the faculty (4.0) and university (4.1) averages over this same period. This innovative approach also halved the attrition rate for first year engineering.

KEYWORDS

Student engagement, Student learning, Directed self-learning, Directed peer-learning, Professional skills
Standards: 1, 2, 3, 4, 5, 6, 8, 10, 12.

CONCEPT

Most students when entering tertiary education have little idea what an engineer actually does. It is critical, therefore, that students transitioning into their university engineering program are exposed to learning experiences that allow them to grasp very early in their studies an understanding and appreciation of what real engineering practice is, and how this practice fits with their chosen degree program and how it supports their career aspirations. In 2011, the author was driven by an abiding commitment to broaden students' understanding of this profession, their insight into the scope of their capabilities as professional engineers, and to inspire and motivate them through learning about the challenges and opportunities they will face as professionals. It was from this premise that he spearheaded the development and introduction of a new core first year unit, a unit focused on real engineering practice. As a 'transition in' unit for predominantly domestic and secondary school leaver student cohorts, the unit served as a gateway to all engineering disciplines.

The author's own extensive experience in teaching showed that most students 'don't learn anything in lectures'. He has published many papers that describe various initiatives that were undertaken as incremental steps in addressing this observation, for example Hargreaves (1998, 2001).

The primary aims therefore of this initiative were

- to change the way that teaching is conducted from teacher-centred to an active student-centred approach,
- to utilise a completely different learning space, and
- to broaden the student understanding of what real engineering is and in particular to emphasise the particular skills and capabilities that a graduate engineer needs as he/she enters the workforce.

DESIGN

Student Learning

The lecture theatre with tiered seating and focus on strong lecture style didactic delivery is viewed by many undergraduates as the "typical" class however, they do not feel they get a lot out of them according to Boles et al (2010). Felder and Brent (2005) explored differences in learning styles and the methods traditionally used in engineering courses. The lecture style as "one-size-fit-all", they observe, fits almost nobody. Low attendance rates at lectures also indicate the current student view of this mode of delivery. The role of the lecturer was predicted to change from the traditional 'sage on the stage' to that of a facilitator (Hargreaves and Ternel (1997)). Almost two decades later, this perspective has not changed: it parallels current teaching approaches and strongly resonates with a long-held belief that peer learning and teamwork are crucial in developing the global engineer, a view also shared by industry. It was from this basis that the author guided ('directed') his students' learning, inspiring and motivating them to embark on a self-learning journey about what it means to be a professional engineer.

Learning Spaces Design

New spaces designed to facilitate active and collaborative learning supported by technology are known by many names. They are all moving toward the mix of furniture, layout and technology that support active and collaborative learning. In this paper, the author refers to the space generically as Collaborative Learning Space (CLS).

The design of what is sometimes also referred to as 21st Century or Next Generation Learning Spaces is very well documented, for example Joint Information Systems Committee (2006), Oblinger (2006) and Rasmussen et al (2012). "Many of today's learners favour active, participatory, experiential learning" and that "their behaviour may not match their self-expressed learning preferences when sitting in a large lecture hall with chairs bolted to the floor", Oblinger (2006). "Spaces are themselves agents for change. Changed spaces will change practice" (Joint Information Systems Committee, 2006).

A plan and typical fit out for CLS used in this unit at QUT are shown in Figure 1.

Figure 1: Collaborative Learning Space plan and fit out

Radcliffe et all (2008) developed a spectrum for places of learning; from completely structured such as the tiered lecture theatre to very unstructured such as at home or in a public place – see Figure 2. The CLS proposed here is indicated towards the structured end of the spectrum; the reason for this to be made more clear as a description of the actual processes of learning are described in more detail.

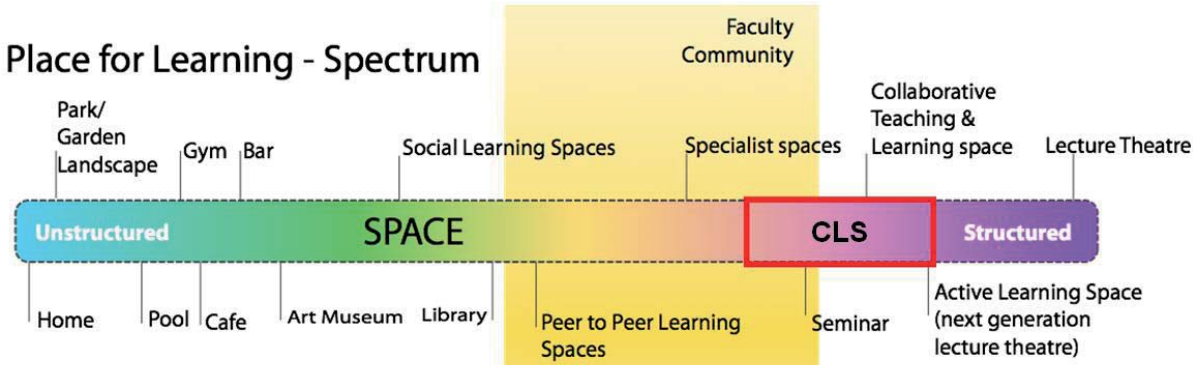

Figure 2: Place for Learning – Spectrum
Adapted from (Radcliffe et al., 2008)

Graduate capabilities

The Engineers Without Borders (EWB) Challenge was used as the spine that essentially integrated all of the particular skills and capabilities that were to be covered in this initiative. This is a humanitarian project that requires groups of first-year students to solve some problem or problems that exist usually in an overseas country. Employers of graduate engineers frequently indicate that their technical skills are more than satisfactory but professional skills are lacking. Professional skills include oral and written communication, ability to work effectively in teams, have an appreciation of ethical considerations and cultural differences (and this is becoming very important as engineering becomes a very global profession), being able to solve a problem such that sustainability is a main criterion in the design, being able to manage projects effectively, to be able to conduct research, as well as critically analyse existing information and/or projects especially when projects are very complex and contain many aspects.

Each of these professional skills were addressed and strongly aligned with the EWB project.

IMPLEMENT

There were about 1000 students undertaking this unit of study. Each of the Collaborative Learning Spaces (CLS) could accommodate up to about 50 students. The CLS was arranged such that six students sat around a table with full access to the internet and each with a large screen. There were up to eight such tables in any particular CLS. The lecturer/tutor/facilitator has control of each screen and is able to move images from one screen to all others and/or show it on the main screen. This arrangement meant that students were quickly introduced to at least a few other students. This is a crucial element as it is well-known that many students leave university because they feel isolated as they enter large cohorts compared to their secondary school days. They were allocated into groups in their very first tutorial. Obviously there needs to be about 25 different 'tutorials' each week. Students were required to attend one tutorial each week, each tutorial being two hours in length.

Unit Framework

Formal lectures were timetabled and in Week 1, the one hour lecture focused on 'What is engineering' and outlined how the unit would be run throughout the semester including the rationale for the unit being in the course, the learning outcomes for the unit, the importance of considering sustainability in every engineering design and the assessment of each learning outcome. In subsequent weeks, invited/guest lecturers from industry would present on particular aspects of engineering for example 'My first three years as a graduate civil engineer', 'How BMW are responding to customer requirements of sustainable modes of transport', and 'The importance of considering renewable sources of energy in all engineering product, process and system design'. Some of these lectures were more for general interest rather than be directly related to the assessed learning outcomes but there was always a strong message about what potential careers exist for graduates.

It was strongly recommended that students attend all tutorials. These are working tutorials and students worked in teams on given activities for much of the two-hour session. These tutorials always included short 'lectures' of about 10 minutes to introduce a new topic followed by directed activities, for example, as a team, find some examples of good oral communications. There may be several of these short lectures and activities in any one tutorial. Students engaged with the short lecture and then enthusiastically used the internet to complete the allocated task. When each task was completed, at least one member from each team was required to stand up and tell the rest of the teams what his/her team had found. This process is clearly dependent on the tutor 'directing' the students to complete a job but the job is done is a team environment and so both directed self- and peer-learning occurs.

The Unit coordinator prepared all material to be covered in the tutorial sessions and made it available to all tutors prior to the first tutorial each week.

Engineers Without Borders (EWB) prepare a challenge for all first year engineering students across Australia every year. It is an humanitarian project based usually in a developing world country. There are at least seven areas (and often subsets of these areas) from which the team can select; this ensures that all disciplines of engineering are covered. This project is the 'spine' that holds the whole unit together, that is all professional skills development are intricately connected to this project.

Choice of tutor and tutor training.

From the description of the Unit Framework above, it is clear that this is not conventional lecture and tutorial practice. The choice of tutor is therefore vital to the success of this new method of student learning. Tutors needed to be flexible in their approaches, be confident in their ability to respond to students' questions and have sufficient experience in the real world so that they can bring real examples to the tutorial sessions. The Unit coordinator met with tutors before the semester began and explained in some detail how this unit would run and met with them on a regular basis in order to address any issues that arose and to assist some tutors in content/material, especially examples. Tutors were encouraged to find their own examples of where this particular piece of content is used by practicing engineers. Most of the tutors were either postgraduate students or third and fourth year engineering students or technical support staff in engineering.

Graduate Capabilities.

Teamwork

Team members were first required to share contact details and share something about themselves including strengths and capabilities in terms of the EWB project that they would undertake throughout the semester. Each team develops their 'rules of behaviour' as well as the consequences of not obeying the team rules. This is done very early in the semester. Each team must write the minutes of each team meeting and make them available to their tutor. The minutes must include attendance, tasks completed and tasks allocated with timeframes. These requirements are generally not appreciated by the students at the beginning of the semester but certainly are towards the end of the semester. It is usually towards the end of the semester that 'things go wrong' in teamwork; for example one member not contributing to the project. Each tutor discusses with each team every week any issues or concerns and progress being made on the project.

'*Teamwork is critical to success in all of these learning endeavours, and while initially that may seem like a harsh constraint to place on students, it certainly fully reflects the nature of graduate work in the engineering field*' [Student, Unit Reflection, 2014].

Oral communication

As indicated above, each team member will have made several short presentations to the class throughout the semester. None of these are assessed. Students, especially those who do not feel confident in speaking in public really appreciate the opportunity to speak in a safe and non-assessed environment. At the end of the semester, each team must make a formal presentation to the rest of the class and in most cases, invited guests from industry are also present. This is a team presentation on their EWB project, so the team needs to arrange which member speaks about what part of the project whilst staying within the required time limit. Observations from all tutors are that there is a very significant improvement in oral communication from the beginning to the end of the semester. Throughout all tutorials, team and class discussions assisted in the development of this capability.

'*Through our weekly tutorials, we have been given numerous opportunities to speak in front of the class about real world situations raised during the lesson. These continual in-class* *speeches have helped me greatly in broadening my public speaking skills*' [Student, Unit Reflection, 2013]

'*After several years of teaching into this year, I have seen a dramatic improvement in the performance of student groups particularly around their ability to present'* [ENB100 Tutor comment, 2015]

Written communication

Students are required to perform a small research project each week and write a small report on it [no more than one page]. An example is "find four different definitions of sustainability, write your own definition and why is sustainable development so important in all engineering projects". These are marked on an individual basis and returned to the students every week. Referencing is very important in all of these small projects. Students generally did not like this process during the semester but did appreciate the significance and importance at the end of the semester when their full EWB report was being prepared. The EWB report was assessed as a team result.

'*The weekly progress reports provided the opportunity to enhance our research skills on specified topics; these helped with my writing skills especially correct referencing*' [Student, Unit Reflection, 2013].

'*The progress reports … proved to be extremely valuable in my understanding of what it takes to be a true and competent engineer*' [Student, Unit Reflection, 2014].

Cultural diversity

Following team and class discussions on what is culture and examples of cultural differences, teams were asked to find images of typical houses in various countries around the world, for example Iceland and Australia. The team was then asked to discuss possible differences in culture based on these images. Then they were asked to consider how cultural diversity could affect the designs or processes in their EWB project. Obviously, the message was to ensure that their design fitted the local culture. There are about 15% international students in these tutorials so the tutor is able to use the experience of these students to emphasise the importance of cultural diversity.

Ethical considerations.

This topic was approached in a similar manner to that on cultural diversity. Students need to understand that ethical considerations in one country may vary quite markedly to those in Australia. In their teams, students were asked to find examples of ethical and non-ethical practice in engineering. The discussion around this task was generally quite noisy and many students had very definite views on ethics. Again, using the experience of international students assisted in cementing the appreciation and importance of ethical considerations on any engineering design.

Research

The comments on written communication above indicate the need for students to research various topics on a weekly basis.

Project management

In teams, students were first asked to break a larger task into smaller one and then write them on a separate piece of paper. The next step was to arrange the smaller tasks into chronological order to that the larger task could be completed. Then the team was required to modify the structure of their pieces of paper considering that three persons were available to do the larger task. What each team developed was a Gantt chart. An example of such a task was to change a tyre on a car at night. Teams were then asked to develop a Gantt chart for their EWB project.

Sustainability.

As previously indicated, sustainable development was a prime part of this unit. Students firstly gained some appreciation of how engineering projects can be more sustainable than others. Students were directed to find why the Japanese bullet train is so shaped; why aeroplane wings have special designs on their wingtips, how Velcro was developed and several other such designs that we take for granted. This is clearly about biomimicry. Another activity related to their EWB project was about materials of construction. Can you use bamboo as a building material in certain parts of south-east Asia? Yes it is has very good building characteristics but if you use too much, you will destroy the habitat for chimpanzies. So now integrate ethical considerations with choice of building material. The prime message with this very important consideration, sustainable development, is to ensure that the design is sustainable and may involve several other considerations such as how to transport the building material to the building site.

***Assessment of graduate capabilities*.**

Not all graduate capabilities were individually or specifically assessed. Total assessment was about 40% individual and about 60% based on teamwork.

OPERATE

The author guided ('directed') his students' learning, inspiring and motivating them to embark on a self-learning journey about what it means to be a professional engineer. With this particular student demographic, combined with the author's extensive teaching and industrial experience, these first year students are not yet ready to 'go it alone'. As such, they are not expected to be self-directed learners; instead, tutors 'direct' them to what they should learn. This is facilitated in technology-rich, collaborative learning spaces through the formation of small study groups who remain working together throughout the entire semester. By flipping the concept of self-directed learning to 'directed' peer- and self-learning, the students are motivated and supported by their peers during their first year learning journey at university.

Despite the size of this 1000+ student cohort and teaching team of 20+ tutors, student satisfaction scores (as judged by QUT evaluation indictors) jumped in the first year of implementing this teaching approach to 4.5 and above (on a 5-point scale); this satisfaction remains high with students' evaluation scores averaging 4.4, exceeding both the faculty (4.0) and university (4.1) averages over this same period. This innovative approach also halved the attrition rate for first year engineering.

Students really appreciated the visiting/guest lectures as they brought real world engineering examples to the classroom and/or extended students' appreciation of for example the utilization of renewable energies.

'*Their presentations were great examples of how engineers should present to others and communicate. These [guest] lectures reinforced the principles presented in lectorials*' [Student, Unit Reflection, 2012].

Formal feedback from students indicated very clearly that this approach to teaching and learning through much improved student engagement was preferable to the formal 'sage on the stage'.

An unforeseen consequence of introducing this approach was that the attrition [students leaving engineering] halved to about nine percent. For the first time in many cases, students received a real world appreciation of what real engineers do in their daily work. This reinforced their choice of engineering for a career or did not. In both scenarios, it is a good outcome. This is because that the word 'engineering' is rarely used in primary and secondary education.

The EWB Challenge underscored not only the types of engineering designs/processes that engineers encounter in the real world but more importantly demonstrated that engineers need to possess a wide range of professional skills and capabilities and can make significant positive differences to the sustainable development in this world.

'*The EWB challenge … gives a real world application to engineering, and shows how engineers can help impoverished nations. It also gives real world application to sustainability in the world and why it is so important*' [Student, Unit Evaluation, 2013].

CONCLUSIONS

Using the CDIO framework to design and deliver this new unit has been very successful. The move from lecture-centred to student-centred learning has been greatly appreciated by most students.

Utilisation of the Collaborative Learning Spaces has been such a success at QUT that the university is modifying and refurbishing existing rooms so that this mode of student engagement and learning is the norm rather than the exception across the university.

The particular implementation of a combination of directed self- and peer-learning has also been shown by student comment and student evaluation of teaching to be a very acceptable mode of learning. Tutors 'directed' students towards particular topics and discussion in individual teams and across teams assisted all students in not just their learning but also in the development of their professional skills.

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BIOGRAPHICAL INFORMATION

Doug Hargreaves AM has published over 50 refereed papers in the field of engineering education during his 28 year academic career. In 2011, he returned to teaching following seven years as Head of School of Engineering Systems with 135 staff. He was driven by a desire to ensure students entering engineering had an understanding of the profession. He has published over 100 refereed papers in his discipline of tribology as well as about 10 papers on leadership including one book, "Values-Driven Leadership". In 2010, he was the National President of Engineers Australia with about 100 000 members. He was awarded a Member of the Order of Australia in June 2014 for his significant contribution to engineering education, the profession and the community.

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FINDINGS IN PROFESIONAL TRAINING: COMPUTER ENGINEERING SCIENCE PROGRAM, UCTEMUCO

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ABSTRACT

This paper aims to show the professional training of programing engineers from Universidad Católica de Temuco (UCT), Chile. The experience is focused on the development of the students' knowledge of Being, Making and Knowing.
The paper displays how to evidence competences lined up with the educational model called CDIO (for its name in Spanish: Concebir, Diseñar, Implementar and Operar).
This new way of teaching has demonstrated to be beneficial for the curricular development of students. By some measurements, positive results during the course of the program and after they graduate were observed. Also, there were improvements in the teaching and learning of engineering.
The educational model for Computer Engineering Science in our university is based on five axes: education based on competences, meaningful learning, ongoing education, ICT, and Christian-humanist education. Theses axes are interconnected with four specific competences that are part of the curriculum program.
The question we try to solve in this paper is: Is it possible to improve the skills of students from the region of La Araucanía in a social, economic and cultural perspective, by teaching and learning based on education that allows the student to discover, expand and exploit the improving professional training and human capital skills? The process of evidencing competences meets with the model CDIO being adapted to the program. The progression in the validation of competences is reached through a number of activities of teaching and learning, and the implementation of this process is achieved in several moments during the program in the four stages of CDIO. Those activities are carried out in laboratories, in interaction with the environment, in tasks of use cases, in simulations and in workshops.

KEYWORDS

Competences, CDIO, knowledge, educational model, learning.

INTRODUCTION

Several trends have boost changes in teaching ways around the world. Some of these trends are globalization, advancements in technology and the new organizational structures of companies and job organization (Lévano and Herrera, 2012). A variety of international initiatives have ended up becoming models, methodologies, and educational practices that have been incorporated to higher education. A common denominator in many of these educational proposals is the orientation towards education based on competences or skills. Competences are those behaviors, abilities, and visible aptitudes that people contribute in a specific field of activities to function effectively and successfully.

Since 2008, UCT has initiated a project of curricular changes in all its programs, in an effort to improve all the academic processes of the university. This project is built centered on a new educational model based on competences and focused on the students. It has been elaborated and developed during the last years.

The alumni from Computer Engineering of our university poses a good background in basic sciences, engineering sciences, management of specific contents (ICI, 2009). The new setting (ICI, 2009) of the program was developed by making questions to employers, ex-students, other universities, international organizations specialized in the area of computer engineering science (mainly from the Association for Computing Machinery) (ACM/IEEE, 2008; CE2004, 2004; IT2006, 2006), consultations on studies about teaching engineering (CDIO model) (Crawley, Malmqvist, Östlund, Brodeur, 2007), (Brodeur et al., 2002), (Poblete et al., 2007), and studies about higher education in Chile and some future changes (OCDE - Organization for Economic Co-operation and Development, and World Bank) (OCDE, 2009), (CNIC, 2010).

This study addresses the process in which how to evidence cognitive and metacognitive processes is demonstrated (Flavell, 1979) in order to achieve the competences. The process of evidencing competences meets with the model CDIO being adapted to the program. The progression of it in the validation of competences is reached through a number of activities of teaching, and learning and the implementation of this process is achieved in several moments during the program in the four stages of CDIO.

This paper shows the educational model based on competences implemented in UCT and also it displays a set of specific competences developed and implemented in the program of Engineering Computer in UCT. It also describes the framework of the validation of skills, the improvements in the curriculum, the results, conclusions, and finally, the references.

UCT EDUCATIONAL MODEL

In our university, we define competence as: “to know how to behave, using our own means and outside resources in order to solve real problems in an effectively and ethically responsible manner” (COMP, 2008); (ICI, 2009); (Kri et al., 2013). We also distinguish two kinds of competences or skills, generic competences, which are shared among all the programs and the specific competences which are directly related to the areas of study of each program.

The educational model in our university (MEUCT, 2008), is based on five axes. Therefore, the Engineering Computer program is set in the same way (ICI, 2009).

1) Model of education based on competences: we are committed to managing the quality of learning, so we have implemented four specific competences that are vital for the education and development of the students (MEUCT, 2008) and ten generic competences stipulated by the university (COMP, 2008); (Kri et al., 2013).
2) Significant learning focused on students (MEUCT, 2008).

3) Ongoing education: we hope that our students keep studding after they graduate, in post graduate levels that develop and increase the complexity of the development of the human resources among the students.
4) Information technologies in the process of learning and teaching: based on what is stipulated in the curriculum, we have intensively incorporated ICT as an important part of the evaluation and teaching processes in all the subjects of the program (ICI, 2009).
5) Humanistic and Christian education: our globalized society demands ethical professionals with robust knowledge about their specific area of study, ability to face problems from different perspectives, and a high capacity for handle a variety of competences or skills.

These abilities are developed throughout the five years of study by the validation of the generic competences (ICI, 2009).

ENGINEERING COMPUTER SCIENCE PROGRAM

The curriculum program operates based on four specific competences according to the stipulations of the university (see figure 1).

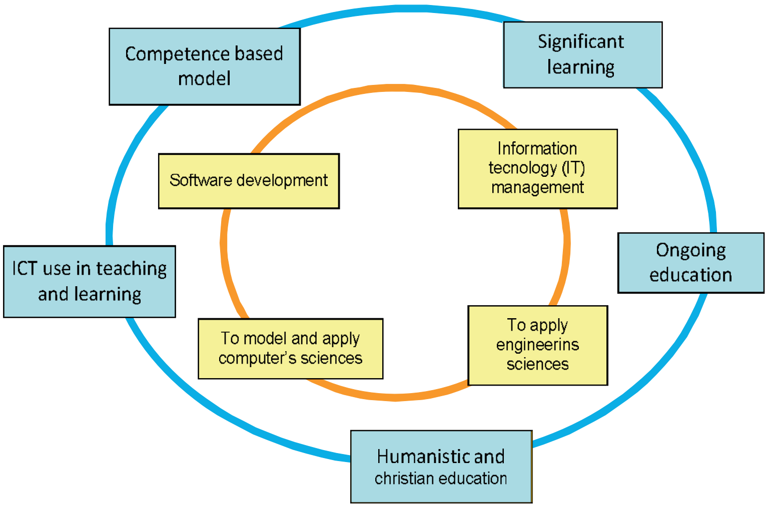

Figure 1. UCT educational model: general and specific competences.

Software development: the students are able to give solutions by the development of software for specific problems, by using a software engineering approach integrating technical, ethical, social, legal and economic aspects (ICI, 2009).

ICT using in teaching and learning: the students are able to manage hardware and software technology systems in an organized way, in order to automate management systems and production processes (ICI, 2009).
Modeling and application of computer science procedures: the students create and apply solutions related to informatics to solve real problems, applying computer science methods, taking care of abstract, logical, and scientific aspects of science. To do so, they use algorithmic methods in the automation process of engineering information (ICI, 2009).

Application of engineering science: the students implement mathematical and engineering models, as well as models from basic sciences by using logical and reasoning skills, in order to engage themselves in problems of analysis and design of technological systems based on software, linked to engineering special areas (ICI, 2009).

COMPETENCES VALIDATION PROCESS

The competences validation process was developed based on the following strategies:

Work meetings: these meetings are performed by an executive board of teachers in the area of computing and other disciplines. The function of these meetings is to evaluate and discuss some situations like: how to distinguish learning difficulties among students, how to generate communication between teachers, choosing advanced students to assist partners having difficulties, developing projects to support the student community, discussing about mechanisms to validate skills and competences and to develop evaluation guidelines.
The topics can be gathered as followed:

- Problems of specific students (check behavior in each group)
- Methods to validate generic competences
- Performance of each group
- Discussion of topics in a vertical way

There is a coordinator who keeps records of these issues and who moderates and prioritizes topics addressed and the actions to be derived from these meetings.

Integration of competences workshops: Evaluation processes have been carried out every year to evaluate the integration of the development of competences in a horizontal way. They are practical workshops to generate challenges, creativity, and innovation among students in several ways, for example, on a personal or attitudinal level, and how to use their knowledge.

Feedback: feedback is done at every moment, in all the subjects. It is accomplished through a learning resource center and also, it is done by all teachers. Feedback takes place in mixed hours, in which the teachers work individually or in groups with the students, as stipulated by the educational model. The objective is to solve analytic, application, or knowledge problems.

Peer tutoring: it is developed in each subject that allows intervention of other students. The objective is that older or advanced students help their partners. To do so, focused peer tutorials and tasks with the learning resource center are promoted.

Advisory services for teachers: every year, this strategy allows teachers to improve their pedagogical practices. They participate in workshops, training and guided classes. They are supported by the teaching innovation center of the university.

Record book: we keep track of all the generated and validated knowledge that students achieve in the different topics of the educational process. It allows validating competences, making self-assessments and making interventions in weak areas in medium term.

Control and tracking of professional training: in this stage of the educational process, we check, orient, guide and evaluate the validation of the competences in the work place. The evaluations are made taking into account our own formative discipline and the rules of each place of work in which the professional training is done.

Learning guidelines: it is based on the triple instrument according to the methodology, the assessment and learning outcomes or objectives of the subjects. To develop the guidelines, we worked on activities based on the development of the knowledge of knowing, being, and making.

ALIGNMENT OF CDIO WITH THE CURRICULUM

The alignment of the process of CDIO (Crawley et al., 2007) with the curriculum has been implemented based on the development of the graduated profile. A Computer Engineer graduated from UCT has a set of competences and a robust basis in engineering sciences that allows him to work in the areas related to software development and ICT. To enhance characteristics that are highly demanded by the working market, and to promote the identity seal of the university, we have boosted the competences of team work, creativity, and innovation (ICI, 2009).

Scheme of competences development

The process of developing competences in environments occurs in the classrooms, laboratories, visits, professional job practice, workshops, seminars, and final papers, all as described in the educational model proposed by the university. The process of experiencing the developing of competences goes along with the contexts of active, reflexive, conceptual and application experimentation (Kolb, 1984; Kolb y Fry, 1975; Bloom et al., 1956), see figure 2.

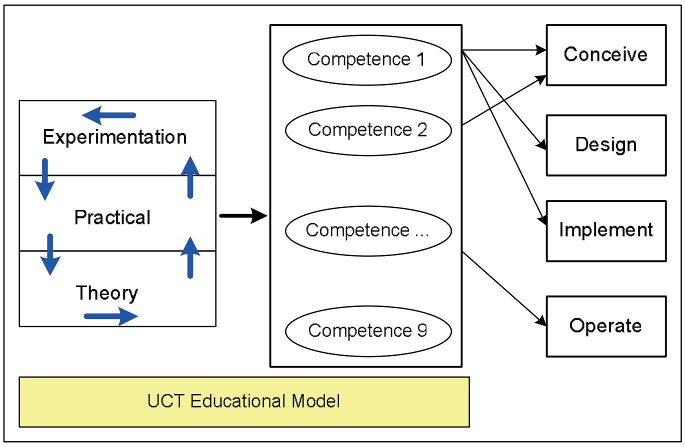

Figure 2. Scheme of competences development in the educational guideline.

In this section a part of how generic competences with the subjects of discipline are connected in the first two years is exposed, as showed in table 1. To exemplify, we just show four generic competences out of the total nine that exist on the curriculum. There are nine generic competences that must be developed in three levels: ethics, focus on quality, respect for diversity, creativity and innovation, autonomous learning, English language, teamwork, knowledge management and oral and written expression. When graduating, students must validate up to the level three for each of the nine generic and specific competences.

Table 1. Generic Competences (GC) Level and Subjects (ICI, 2009).

Subject / Level	**Generic Competence 1**			**Generic Competence 2**			**Generic Competence 3**			**Generic Competence 4**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
ICT basic introduction												
Programming I												
Robotics and programming				**X**								
Introduction to management systems database												
Christian education							**X**					
Maintenance and systems management	**X**											
Programming II												
Projects Robots												
Client Server applications development										**X**		
Integration workshop I												
Networking												
Programming III				**X**								
Hardware architecture												
Introduction to the development of business applications.	**X**									**X**		
Programming for system integration					**X**							
Microcontrollers												
Graphical interfaces for the user				**X**								
Mark-up language												
Business application development	**X**									**X**		
Integration workshop II												

In table 2, the relationship between generic competences and CDIO model is shown. Generic and specific competences go along together during the process of validation, and each subject can incorporate two or more generic or specific competences.

Table 2. CDIO Model and Specific Competences.

Specific Competences	**C**	**D**	**I**	**O**
ICT management	X	X	X	X
Modeling and application of computer science		X	X	

Software development	X	X	X	X
Application of engineering science		X	X	X

CDIO in the development of specific and generic competences

During the first year “to operate” is worked, while “to implement and to operate” are worked during the second and third year. During the fourth year “to design, to implement and to operate” are worked. Finally, during the fifth year “to conceive, to design, to implement and to operate” are worked altogether. During first year we begin with the vertical implementation and during second year we implement the horizontal integration of competences. This process is sequential and it is also combined along the subjects and the years. For example in figure 3, basic science knowledge is developed in activities inside the subject, because that course is focused on fundamental knowledge. That knowledge is manifested in a horizontal way of competences. In the figures 4 and 5 below we can observe what happens during the rest of the years.

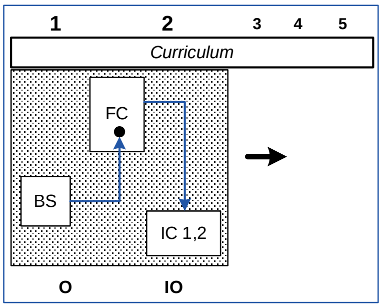

Figure 3. To operate (O); to implement and to operate (IO).

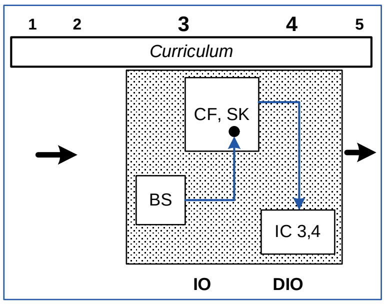

Figure 4. To operate (O); to implement and to operate (IO).

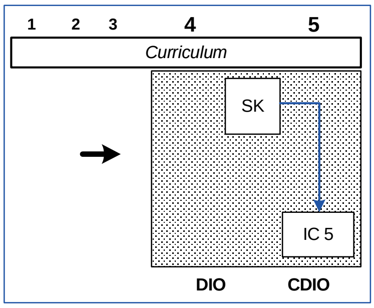

Figure 5. To operate (O); to implement and to operate (IO).

Note: (FC) fundamental knowledge; (BS) basic sciences; (IC) integration competences; (SK) specialty knowledge.

RESULTS

Based on the curricular structure of the curriculum

- 83% of alumni note that the program makes it possible to face the process of obtaining the academic degree and professional title without drawbacks.
- 85% of alumni consider that the program gives an education that allows facing the process of obtaining the academic degree and professional title without drawbacks.
- 95% of alumni consider that some of the contents were repeated in two or more subjects unnecessarily.

Effectiveness of the studying process

- 78% of alumni believe that the university do cares to diagnose the conditions of entry of its students to adapt contents and teaching strategies.

- 82% of alumni consider that the curriculum was consistent with the identity seal of the program.
- 87% of alumni note that the curriculum and subject programs were delivered without inconvenient.
- 86% of alumni consider that evaluations were always based on clear and known criteria.
- 96% of alumni think that they always had known the criteria and requirements for graduation and obtaining the degree.
- 91% consider that the criteria for obtaining the degree were adequate.

Employability of graduates

Table 3. Graduates tracking survey (2012-2013). From Computer Engineering Science Program.

Graduates tracking survey results	
Well timed employability (working in other areas)	Less than 3 months (90%); 3 or 6 months (9%)
Employability (working as an engineer)	85% of Adequate employability
Place of work	Araucanía (55%); Metropolitana (36%); Antofagasta (9%)

CONCLUSIONS

The competences based model of the curriculum of Computer Engineering Science from UCT does have some relevant elements for a program that pretends to be modern and innovative, according to what is expected from a university program in XXI century.

Ways of teaching: this new model of education is developed under the concept of competences and also under the concept of formation on engineers with the model CDIO (Brodeur et al., 2002; Crawley et al., 2007); it is made according to the guidelines given by the Association Computing Machinery, the Association Information Systems and the Computer Society. The model contains a new way of looking higher education in Chile, according to OCDE and the assessment criteria of the CNAP.

Competences in the curriculum: the School of Informatics of our university develops four specific competences: software engineering, ICT management, modeling and application of procedures in computer science and application of engineering sciences (ICI, 2009). The competences are divided into three levels of complexity in engineering and engineering sciences experiential learning. The levels of organization of the curriculum are built on reasoning and disciplinary knowledge, skills and personal attributes also professional and interpersonal competences as established by the norms of CDIO (Poblete et. al., 2007).

Order of the curriculum: the discussions of the Executive Board of Schools about the vertical integration help to maintain the order of the curriculum. This means that courses can be adjusted by knowing what topics and methodologies are being applied in other courses.

This also suggests the generation of joint activities in various courses. For example, a project one subjects that can use resources learned from other subjects.

Motivation: By having in his first two years a lot of specialty subjects, students can clearly see what their profession is about, and where they are going. They can get early achievements, which motivates them to advance and deepen issues specific to their specialty. Moreover, support and words of praise from top executives in companies of regional IT has an impact on them. That generates a valuable relationships and connections with companies and well future employability opportunities.

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HOW TO CULTURE INNOVATION COMPETENCY IN NETWORK PRINCIPLE COURSE

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ABSTRACT

Advanced higher engineer education must provide not only the discipline-specific fundamental knowledge, but also competencies and attitudes demanded by the labor market. Innovation competency, one of the popular concepts in the economy field, is considered to be the key component for improving the productivity, increasing the quality of products and decreasing production costs of companies. So the innovation competency should be cultivated by higher education, especially by application-oriented high engineer education. However, it is less discussed how to combine the innovation competency with professional courses. This study focuses on the cultivation of innovation competency in computer network principle course of network engineer specialty. We will introduce it from the course contents, teaching methods and pedagogy to assessment and evaluation. At last, the outcomes are discussed.

KEYWORDS

Innovation competency development, computer network principle course, course content, pedagogy assessment and evaluation, Standards:7,8,11

INTRODUCTION

This century is full of competition and challenge, which forces companies to be innovative and creative if they want to survive in this new globally competitive environment. Only by constantly improving existing products and developing new products can the companies grow bigger and stronger. Being the main body of enterprise innovation, employees have been considered as one of the most important sources for firms to remain competitive in a dynamic business environment (Wang et al., 2015). Employees are mostly the product of higher education and higher engineering education, so colleges and universities play the fundamental role in training innovation competency to facing challenges of the future. That is to say, advanced higher education, especially the higher engineering education must provide not only the discipline-specific fundamental knowledge, but also competencies and attitudes demanded by the labor market.

Many colleges are aware of the significance of training innovation competency of college students and have done many efforts to import innovative mechanisms into engineering education. For example, technological universities in Russia have integrated development of territory, based on mutually profitable interaction between the industrial enterprises and universities. This provided an opportunity to develop long-term persistent demand for innovations and to broaden considerably the domestic and international high-technology products market presence (Kupriyanov R V et al., 2015). And some technological universities in America have focused on tackling the issue of culture change in engineering education by developing a framework of educational innovations (Melsa J L et al., 2009). They emphasized that the education activities should be closely in harmony with engineering practice, in a real and complex project environment, aim at the practical need that "modern engineers need to participate in product, process and system life cycle stages of work" to cultivating students (Ye M, 2013). Realizing the importance of discipline-specific specialists to engineering projects, some universities in Canada have introduced an elective series of courses to further reinforce problem solving skills and product innovation ability (Strong D S, 2012).

When innovation competency training becomes the heart of the higher engineering education, curricular architecture, teaching mode, the roles of students and evaluation mechanism should undergo corresponding changes. As the basic units of specialty, professional courses and professional basic courses should become the most important components of innovation competency training. However, many existing research literatures about innovation competency training have more focused on the macro level of specialty framework and not paying enough attention to the comprehensive construction of specific course. In this paper, we describe the design and implementation of case studies through computer network principle, which is the professional basic course of network engineering specialty, as an example for training innovation competency. And above research work is finished under the framework of Innovation & Business Start-Ups education reform for Dalian Neusoft University of Information (DNUI) (Tao W et al., 2014).

The remainder of this paper is organized as follows. First, we give a brief definition of innovation ability trained in computer network principle course. Next, we describe the case studies in terms of the course contents, teaching method and examination mode. Finally, we introduce the effects and put forward some suggestions for further reformation.

THE DEFINITION OF INNOVATION COMPETENCY IN COMPUTER NETWORK PRINCIPLE COURSE

Because of multiple facets and bases for interpretation, innovation ability can be defined from various perspectives (Crossan M M et al., 2010). Generally speaking, there are two ways of looking at innovation: either as a final output or as a process innovation. From the point of process-oriented perspective, innovation focuses on the accumulation of knowledge and experiences. Then the innovation competency in engineering education contains three dimensions (Berglund A, 2013): (1) problem solving ability (2) process improvement ability (3) knowledge transformation ability. On the basis of above definition, three aspects of innovation ability are chosen by considering the characteristics of network engineering specialty: judgment, practical ability and research ability. The judgment ability involves analytical ability. The practical ability concerns on the ability of discovering problems and solving them. The research ability reflects self-learning ability, logical thinking and breadth of knowledge. All the three aspects of innovation should be continuous trained by professional course, so they should be enhanced in computer network principle course.

DESIGN AND IMPLEMENT OF TRAINING INNOVATION COMPETENCY

In order to train innovation competency of students, we should focus on the following aspects:

(1) Switch students' role and make them be active in learning process; (2) Renew teaching contents and make students understand design pattern and grasp the tendency of technology; (3) Instil students' technical skills by experiments and projects with engineering background; (4) Evaluate students' learning processes scientifically based on multidirectional evaluation mechanism and may better reflect the teaching effects. (5) Other resources configuration. Next, we will give the details about reforms.

(1) Peer teaching make students be active in learning process: strengthen research ability

Innovation competency training in engineering education has proposed that students must be active in their learning processes (Sheppard S D et al.,2008). Meanwhile, Smith(1998) pointed out the importance of mentors and peers for developing of engineering expertise. And there is extensive evidence that peers help students become active learners, especially in the in-depth study of materials, analysis, and formed a distinctive knowledge system.

So all the students are required to teach a small portion of the subject matter for 10-15 min to their fellow classmates in computer network principle course. About ten topics which have different scores for difficulty levels are released at least one month in advance. Teams of two students constructed on a voluntary basis freely choose one of the topics to prepare it and all the students will get corresponding marks base on their individual performance.

After each team choose the topic for delivering, the course teacher gives guidance on acquisition of new materials, content organization and teaching skills. The guidance makes the students gain not only confidence on teaching but also experience the transformation in them from passive receivers into active participants. In addition to the time spent with the instructor in receiving guidance, the students usually spend about 3-5 hours in preparing for their delivering topic. In order to encourage active learning, all students are allowed to ask questions and take part in the discussion in the class dominated by their fellow classmates. Especially, students asking the most valuable question will gain extra marks. Therefore, all the students are informed before the class and they should prepare for questions about the topic.

During the students' delivering part, the teacher plays in a dual role. On the one hand, the teacher is a student and he can make comments, even ask questions. On the other hand, the teacher is a teacher and he is responsible for the normal operation of the class by asking question or arousing student enthusiasm of active learning.

(2) Understand design pattern and grasp trend: strengthen judgement and research ability

Design patterns originated in the building field are described as a way of inheritance on successful methods of construction from craftsmen to less-inventive people. That is to say, design patterns can reflect the technology heritage and development. By introducing design patterns of internet, we hope that students can finish the inheritance then find driving force of the technological innovation and development.

In order to introduce design patterns of internet, we share eight topics to the students. Seven controversial topics of them are related to the history of internet (Day J, 2007) and the last one, software-defined network (SDN), represents the future of technology. All the students are split into 8 groups according to eight issues. They finish literature reading and group discussion after class in order to make literature review and comments on the documents in the class. At last, each group need to submit a report on core technologies and solutions on development of computer network. Specifically, the literatures on certain topic can be given by teachers or searched by students themselves.

(3) Experimental learning instils technical skills: strengthen practical ability

Current practices suggest that engineering graduates should be proficient at technical skills. SIGITE IT Computing Curricula Guideline (2008) also strongly recommend to incorporate hands-on lab components into teaching in order to improve students' technical skills. Not only because the hands-on laboratory environment sparks students' interests and practice, but also because it helps students to improve technical skills. In principle, training of technical skills can be accomplished by various approaches in different major courses. Among all the approaches, experimental learning is often referred as an effective means to instil technical skills by high quality experiences with complexity and fidelity. Especially, experiential learning is the expression of "learning by doing" (Kolb D A, 1984) and it is also the core feature of TOPCARES-CDIO educational model(Tao W, 2011) developed by DNUI.

Based on the core technical skills trained in computer network principle course and error-prone points occurred in trouble shooting of engineering practice, we designed four unit projects and one course project, the relationship among them is shown in Figure 1.

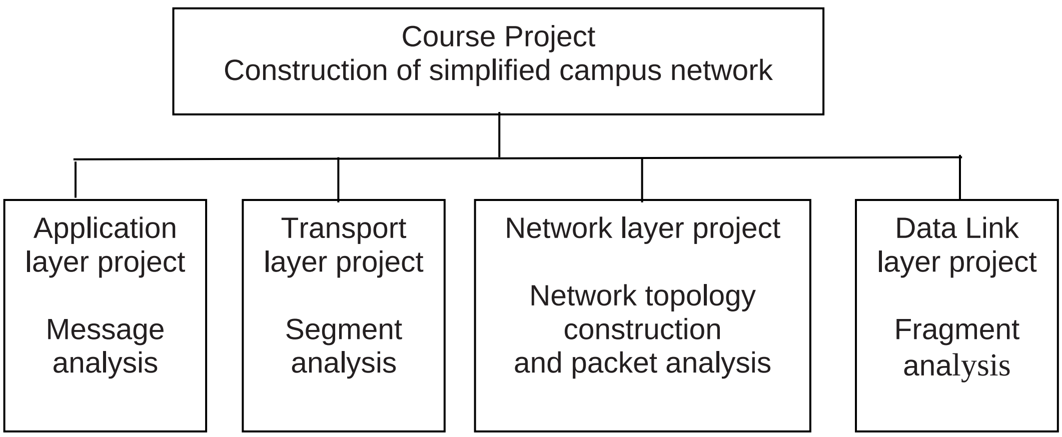

Figure 1. The relationship between the course project and unit projects

Course project is based on unit projects but is more complex and comprehensive than unit projects. Network layer project focuses on the construction of network topology with Packet Tracer (PT) software and other unit projects more concerns on capturing and filtering packets with Wireshark. While the course project includes not only constructing network topology (The topology is shown in Figure 2) but also analysing packets. In order to bring students creativity and motivation into full play, course project is only specified the basic functional points and experimental instructions. And students must implement at least two additional functions if they want to get innovative marks.

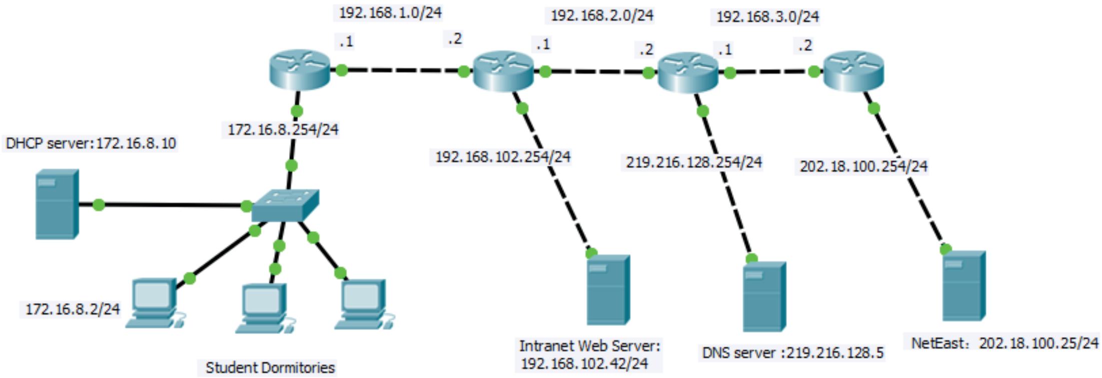

Figure 2. The network topology of course project

PT software can simplify the process of constructing topology and helps students check the outputs of network whenever they have time and wherever they may be. However, its functions are very limited relative to reality equipment in trouble shooting. In order to compensate for the limitations, basic and comprehensive experiments on real devices about debugging of protocols and services configuration are assigned to students as extracurricular experiments. And, the mistakes made by students in doing experiments are reorganizes as new experimental resources.

By means of configuring protocols and analyzing structure of datagrams in different levels, students understand not only abstract network protocols but also how to take these protocols into practice into networks. Besides that, students are also required to read and write source codes of protocols so as to understand the mechanism of network. According to the importance and complex of protocols, some source codes are provided directly, some codes are provided partly and some simplified version are written by students themselves, then all the source codes are integrated into a whole protocol stack program. By running the program, students can understand the process of reconciliation package, routing mechanism of routes and forwarding mechanism of switching.

(4) Multidirectional evaluation mechanism: examine innovation ability

Examinations and tests are an indispensable components of the teaching and learning, used to examine the effects of teaching and learning. Therefore, it has become an important part of the teaching reform to find a proper examination method and evaluation system, which can evaluate students' learning processes scientifically and can better reflect the teaching effects of the courses.

Traditionally, the most frequently used assessment is closed book exams, which main check students' ability of remembering knowledge and principles. However, this method can't effectively evaluate students' learning process and other abilities. While the purpose of learning is to complete the migration from knowledge to ability, understanding to applying, inheritance and innovation, from this point, closed book exam is not sufficient. Therefore exam method reform of computer network principles should adopt a wide range of examination mode, make theoretical knowledge combine to practice and pay more attention to students' innovative abilities.

Based on the above principles, the examination method of computer network principles ranges from single terminative evaluation mode to combine formative assessment concentrated on the learning process with terminative evaluation emphasized on abilities to solve problem and fast-learning. And the percentage of two parts is 50 per cent and 50 per cent respectively. The details of them are listed in Table.1.

Table 1. Examination methods

	Items	corresponding ability	percent	criteria
Formative assessment (50%)	Peer teaching	analytical ability 50%; solve problems ability 85%; self-learning ability 85%	10%	Quality of the oral presentation (35%); Quality of time management (15%); The correction of answering question (35%); Overall expressiveness (15%).
	experiments	analytical ability 100%; solve problems ability 100%	15%	Quality of experiments on PT (50%); Quality of protocol stack program (50%).
	course project	analytical ability 35%; solve problems ability 70%;self-learning ability 20%	15%	The correction of answering five questions (5% each); documents (30%); Quality of PT files (35%); innovative function points (20%).
	literature review and comment	analytical ability 100%; solve problems ability 100%;self-learning ability 100%	10%	Quality of literature review (30%); Quality of comment (30%); Quality of document (40%)
Terminative evaluation (50%)	solving problem	analytical ability 100%; solve problems ability 100%	35%	Network of debugging (50%); analysis of packet files (50%)
	fast-learning	analytical ability 50%; solve problems ability 50%; fast-learning ability 50%	15%	New knowledge learning (50%); solve problems using new knowledge (50%)

From Table 1, we can obviously find that the sum of percent on ability is greater than 100%, which is due to the calculation method that accumulates the score corresponding criterion. Then we can deduced the score of different abilities in Table 2.

Table 2. Score of different abilities

Ability	Score
analytical ability	77.75
solve problems ability	86.5
self-learning ability	33.5

For quality of the oral presentation in peer teaching, panel of judges composed of six students and one instructor grade it on a five-point scale(5=Excellent, and 1 =Poor).As for the questions in course project, they are all about trouble shooting or specific operations in construction of topology. Obviously, the extracurricular experiments are not involved in the part of formative assessment, but the points will be directly deducted from formative assessment if the students can’t hand in the lab reports timely. As we can design, the termination exam is a computer-based test and the exam questions put emphasis on network debugging and packet analysis, specifically, the termination exam contains some questions about new knowledge, which is never involved in class, to examine the fast-learning ability of students.

(5) Other resources configuration

In order to provoke students' enthusiasm and make them become the active participants in learning, we provide students comprehensive support as supplement of classroom teaching, such as MOOCs platform, online resources of Cisco Network Academy, Opening laboratory and ordering, club activities, technical presentations and networking competition.

EFFECTIVENESS EVALUATION

Since 2008, continuous improvements in course construction play important roles in the whole course realization process. This extends into every aspect of course, from initial course project down to the reform of examination. Obviously, this process is actually a huge challenge for students and teachers, and the challenge is not only misunderstanding from students and additional workload to the teachers, but also the risk of delaying teaching schedule. Fortunately, we often finally find effective methods to solve them.

By evaluation and comparison, there is an improvement to some extend in analytical ability, problem-solving ability and self-learning ability by averaging the values of examination corresponding ability point each year. Figure 3 presents the changing curves of ability improvement. And Figure 4 presents the differences of three abilities by comparing different stages of semester. To be fair, the comparison is executed on same measurement terms. Judging from the result, students’ abilities are improved in a certain degree, especially the problem-solving ability. Therefore, we acquire the expected results of reformation. But the question remains, such as how to effectively mobilize the learning initiative of students and how to greatly improve the self-learning ability. All these need to be further explored.

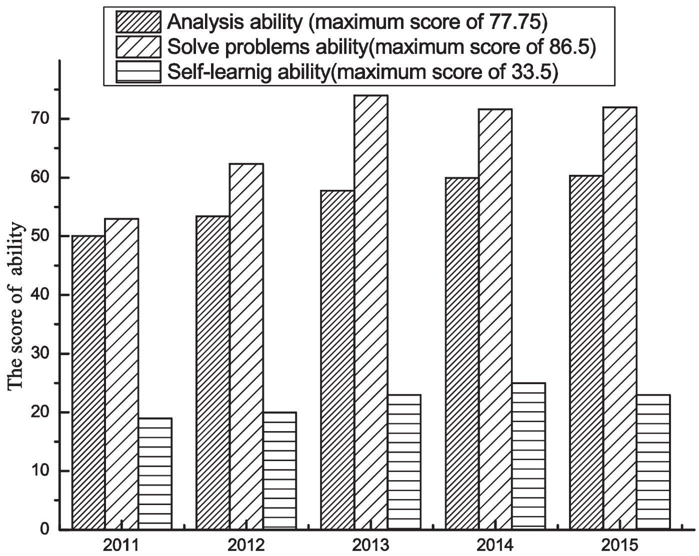

Figure 3. Changing curve of ability improvement

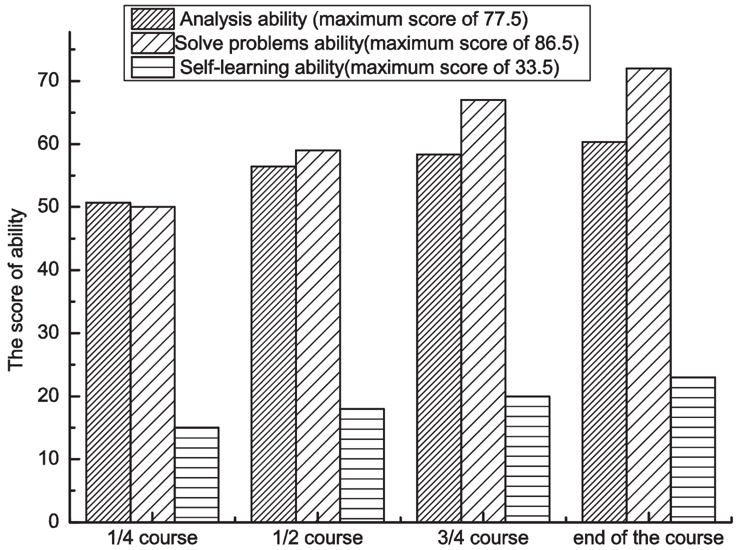

Figure 4. The differences of three abilities in different stages of semester

CONCLUSIONS

Our course reform aims to improve innovation competency of students in network engineering specialty. To achieve the goals, we start it from the transformation of student-role, the update of course contents, instilling students' technical skills to multidirectional evaluation mechanism then significantly train judgment ability, practical ability and research ability, i.e. three parts of innovation competency. Practices show that students’ innovation ability has been improved in a certain extent.

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IMPLEMENTING CDIO IN TWELVE PROGRAMS SIMULTANEOUSLY: CHANGE MANAGEMENT

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ABSTRACT
Since March 2015 the Faculty of Technology, Innovation and Society (TIS) of The Hague University of Applied Sciences (THUAS) is a CDIO member with all its twelve programs: Mechanical Engineering, Engineering Management, Mechatronics, Electrical Engineering, Building Engineering, Civil Engineering, Climate and Management, Industrial Design Engineering, Industrial Design Engineering [Open Innovator], Engineering Physics, Mathematics & Applications, and Process & Food Technology. This paper describes the implementation of CDIO at TIS and discusses methods, opportunities and challenges of such a large endeavor. The CDIO standards have been coupled to the faculty and program policy plans, based on a comparison of CDIO and the Dutch/Flemish compulsory NVAO accreditation standards. The self-evaluation process has exposed differences between the programs, which has lead to grouping them in a fast track (already working with CDIO), a drawing board track (implementing CDIO in a future new curriculum design) and a quality track (using CDIO to improve the quality of the current program). Each track has its own needs and challenges, and thus requires a different approach and will show a different speed of adaptation. Other factors also plea for a more customized implementation process. Challenges discussed are the varying level of understanding of CDIO, combining CDIO with educational blueprints such as 4C/ID or design thinking, technical bachelor of applied sciences programs versus engineering ones and the motivational drivers for change on faculty staff member level. Working in a professional CDIO learning community leads to ownership of CDIO. Despite being a top-down decision, the adoption of CDIO in the twelve programs takes place bottom-up, ensuring continuous education improvement.

KEYWORDS

Change management in an organization of professionals, large scale CDIO implementation, NVAO, all standards.

INTRODUCTION

The Hague University of Applied Sciences is 28 years old, a merger of fourteen schools in the region. It houses about 25.000 students of about 100 nationalities in seven different faculties, where about 2000 employees work. In total there are 44 Bachelor degree programs. The university also offers thirteen masters, several part-time, dual and associate degree options, and over 60 post-bachelor courses, trainings and master classes. The main campus is in The Hague, with satellites in Delft (Technology Campus), Zoetermeer (ICT Innovation) and The Hague Sports Campus. The faculty of Technology, Innovation and Society (TIS) is located both in the main campus and in Delft and has twelve programs, see table 1. Each is lead by a Head of Program and is grouped in one of five clusters, run by a Program Manager. THUAS' IT programs are part of another faculty.

Table 1. Clusters of the twelve programs of the Faculty of Technology, Innovation and Society (TIS) of The Hague University of Applied Sciences (THUAS).

TIS Clusters	Programs
Cluster BK, CT, CLE	Building Engineering (BK), Civil Engineering (CT), Climate & Management (CLE)
Cluster IPO, IDE	Industrial Design Engineering (IPO, 4 years bachelor program in Dutch), Industrial Design Engineering [Open] Innovator (IDE, international 3 years bachelor program in English)
Cluster PFT, TN, TW	Process & Food Technology (PFT, international 3/4 year bachelor program in English), Engineering Physics (TN), Mathematics & Applications (TW)
Cluster TBK, E, MECH	Electric Engineering (E), Mechatronics (M), Engineering Management (TBK)
Cluster W	Mechanical Engineering (W)

The aim of the Faculty of TIS is to provide high-quality, innovative education by establishing links between teaching, practice and applied research. For this purpose, TIS forms durable networks with local, national and international companies and institutions. Education and research is developed in co-production with students, external partners and the University's research groups. Facilities such as project studios, living labs and the H/Betafactory are at the students' disposal for authentic learning experiences, experimenting and prototyping.

DRIVERS FOR ADOPTING CDIO

Organizational drivers

The decision to implement CDIO was based on mid-management enthusiasm to adopt the framework for its merits in lifecycle thinking and its accrediting standards in two of the programs of TIS. The Engineering Management program (TBK), which is located in Delft, redesigned its curriculum based on CDIO principles, after presenting at the CDIO Boston conference in 2013. In The Hague in the meantime, Process & Food Technology (PFT) also used CDIO as their educational framework. At that time both programs belonged to different faculties. When TIS was formed during the reorganization of THUAS in 2014, the role that CDIO had played in the two separate programs led to the management's ambition to adopt CDIO as the designated educational innovation framework for all programs. The framework could function as a bridge between the different program cultures now united in one faculty, and as a common language in assessing the quality of the educational programs.

Strategic WINQ goals

Apart from an internal benchmark tool, there was also a need to benchmark the programs in an international setting. At THUAS all students are offered the opportunity to develop their international competences, as THUAS intents to be the most international University of Applied Sciences in the Netherlands. Besides Internationalization, THUAS has chosen World Citizenship, Networking, and Quality (WINQ) as its strategic goals for the coming years (THUAS, 2014). Strategic alliances and efforts within the faculties need to be in line with WINQ. With World Citizenship the university aims not only to qualify students for a profession but also to reinforce them as concerned, conscious, critical, and inquisitive human beings. To be innovative, knowledge has to circulate in an open connection between education, research and the professional practice. As a higher education institution, THUAS can play an important networking role in such open innovation networks (Hallenga-Brink & Vervoort, 2015). While working towards all these goals THUAS seeks to fortify a university employee culture of continuous improvement in quality. With WINQ in mind, the worldwide span of CDIO appealed, as well as the learning community approach and networking opportunities with other universities it provides. Adopting CDIO was a step forward for TIS in regards to both the Internationalization and the Networking goals. With sustainability, ethics, cultural differences and international communication embedded in the CDIO syllabus 2.0 (Crawley et. al., 2011), adopting CDIO would also contribute to the world-citizenship of TIS' students. And CDIO could function as a qualitative quality management system, in addition to the more quantitatively directed national accreditation system NVAO, by regularly self-evaluating on the CDIO standards (Crawley et. al., 2014).

Educational drivers

Next to the managerial and strategic drivers, educational drivers were equally important to adopt CDIO. In the application (Hallenga-Brink, 2014) TIS stated: "…*In all our ambition CDIO is a valuable standard for our engineering education; one that fits our vision. Its syllabus helps us to truly support students in the development of their professional identity. Its structure is highly effective for quality evaluation and improvement of our bachelor programs. And CDIO offers a concise framework for new curriculum development, helping us to take 'active learning', which has been on the university's agenda for some time now, to the next level…"* Belonging to a university of applied sciences, the engineering programs of THUAS have historically always been geared towards delivering engineers who can engineer and working closely together with future employers of the students. However, also from a historic point of view, undergraduate engineering education has also focused mainly on the disciplinary knowledge and skills, the professional expertise. With the emerging notion that students need 21st century skills to be employable to the many models of what these 21st century skills exactly are (Mishra & Kereluik, 2011), the search began what pivotal elements a curriculum of the 21st century would need: cross-curricular key skills, learning through experience, learning outside the direct academic context, blended learning etc. CDIO offers both an educational framework based on good practices of many international universities and universities of applied sciences, as well as a learning community to continuously improve this model. To add to the (applied) engineering education research within the CDIO network TIS wrote: *"… we also feel we can bring something to the CDIO network, for instance our experience with design-implement education in authentic learning environments, positioning the university as a (innovation and learning) network hub in society and using integrated learning didactics. …"* For example, THUAS' lector Frans Meijers led research by his research group on developing professional identity of students in higher education (Meijers, 2008). He identified three main conditions for developing a professional identity: learning should take place in an authentic setting, students should have the opportunity to choose part of their study activities according to their personal developing goals and there should be a professional, reciprocal dialogue between students and teachers about their development. The CDIO framework and the results of this research reinforce each other.

Based on these strategic, managerial, organizational, and educational drivers, the decision was made to move forward and apply for CDIO membership for all twelve of TIS' programs. No exception was made for the 2 technical Bachelor of Applied Science programs within the faculty, as one of them, PFT, had already implemented CDIO and other CDIO members also had such programs in the network. After applying officially, in March 2015 TIS was accepted.

METHODS OF IMPLEMENTING CDIO AT TWELVE PROGRAMS AT ONCE

Not project manager, not program manager, but process director

It was a top-down decision of the management team to apply for CDIO membership. Implementing changes according to the CDIO standards is a complex process within one program, let alone twelve at the same time. Opposition, doubts, criticism and discussion were all expected, and a bottom-up approach was chosen to deal with this. The driving forces in the two programs who already applied CDIO principles were assistant professors who did not have the means nor interest in this organizational and educational change management endeavor. Therefore, an educational sciences specialist with engineering background was appointed as process director for one and a half day per week to guide the process of application and implementation in all twelve programs. The implementation process was intentionally not labeled as a project, which has a clear goal, timeline, deadline and deliverables as result. CDIO is not something you do once and finish completely. It was also not labeled as a program, as that suggested it would run parallel to the efforts the study programs would put into designing, redesigning and improving their curriculum. For it to truly land and become daily practice the implementation process needed to take place within the course programs internally, with ownership from within the program, and bottom-up.

Mapping causes of opposition

When changing a curriculum, the easiest position to be in is if there is a high urgency and a high preparedness felt within the organization (Kamp & Klaassen, 2013). When internal concerns need solving and everybody feels that need, making sure everybody remains involved is enough and the organization can get to work. When there is a high urgency but low preparedness leadership commitment is an important starting point. And when there is a low urgency but high preparedness, capacities of employees can be explored and facilitated in a bottom-up approach. In the case of implementing CDIO at TIS, all three variations were seen. The process director first observed developments and attitudes per program on all levels. Opposition to the implementation of CDIO could be lead back to three causes as described by Mars (2006): urgency, incomplete information and the uncertainty for one's position that changes brought along.

Urgency

The decision to become CDIO was taken top-down, and overall management commitment was good on paper. The self-evaluations for the application helped to establish if there was a high urgency within the programs, and the results varied. One could argue that high scores on the self-evaluation lead to a low sense of urgency. But scores could be high depending on who one would ask. For instance, active learning had been a focal point of the university for a while already. This lead to beliefs that 'we already do this' (low urgency), as well as to beliefs that CDIO was a good way to finally 'really' implement active learning in the programs consistently (increasing urgency). In that sense the choice for CDIO lead to doubts within the teams on the urgency of that choice. 'Who says we should do this?' 'Do we need this change, aren't we doing well enough?' 'Shouldn't we first finish the last change?' 'Aren't there more important things to keep us busy?' etc. And doubts can lead to opposition (Mars, 2006).

Incomplete information

Another factor increasing opposition that Mars mentions (2006) is incomplete information. Not only doubts on urgency have a negative effect, but also doubts on the solution and doubts on the process. Because CDIO is quite an elaborate framework, incomplete information and partial interpretations are a high risk. Two of the twelve programs already worked with CDIO, but each had a different interpretation of the merits of the framework, and the teams had different attitudes towards it. Hence they could not automatically 'spread the word' to other programs. Doubts prevented some staff members from diving deep into the idea and knowledge behind CDIO, thinking 'this probably won't help' 'it is a fad' 'we already do this' 'old wine in new bags' 'too ambitious'. And sometimes there just hadn't been enough time to become well informed yet. Maybe the whole thing would blow over, so was it worth investing already?

Uncertainty about one's own position

A last factor for opposition (Mars, 2006) is the uncertainty about one's own position that a curriculum change driven by CDIO could cause. Not every staff member was convinced the changes done in the name of CDIO would have a positive effect on their daily activities. From filling in the first self-evaluations it was evident that ideas about 'activating education' or 'integrating personal and interpersonal skills in a course' were defined on different levels by different teams or individuals. CDIO sheds a different light on teaching competences and set the bar differently. Would lecturers be able to keep teaching as they were used to and believed to be a good way? This lead to doubts about the process: 'nobody asked us' 'the wrong people are in the task force' 'we don't have the means for this' 'there is already so much we have to do'.

Finding the value of CDIO

Having doubts and factors for opposition mapped, these could be addressed in the implementation approach. It is good to be aware of causes for opposition, be prepared for them and anticipate them. But focus should not only be on solving the negative. While a sense of urgency is a pushing force towards commitment, formulating ambitions can be a pulling force (Mars, 2006) that helps to put the dot on the horizon and prevent false consensus. Aspects such as planning, interaction and leadership are important in a change process because they can lead to commitment and being connected. In the end, implementation and change happen best when the people doing it have found an intrinsic motivation to commit to it. And for that everybody needs to find out what the value of CDIO is for them personally. And these values are bound to be different.

Leadership: Ready? Set! Follow!

In order to create support and ownership of CDIO in all layers in a bottom-up approach, it was still important that management showed clarity, support and facilitation. Their intentions on CDIO were formulated in the 2015 faculty-wide policy plan and spread to all programs in posters and leaflets:

1. We educate people to Conceive, Design, Implement and Operate in an integrated way.
2. We intensify collaborations within our local and international networks of schools and businesses.
3. We facilitate coproduction between students, researchers, teachers and businesses.
4. We coach people to articulate personal learning goals.

5. We help people to develop a unique professional identity.
6. We prepare people for an international career.
7. We create a healthy work-life balance for our people.
8. We reflect on what we do and try to do it better.

This set the dot on the horizon. However, there was still a risk of false consensus, when everybody thinks they chase the same goals, but interpretations vary considerably.

To go around that problem the role of the process director was to detect surfacing needs during the process and facilitate on demand. Rather than presenting teams with one solution to fit all, in other words one truth, in a 'follow, follow, ...lead' approach based on neuro-linguistic programming (Derks & Hollander, 2015) the different personal and team drivers for change were accepted and taken into account. Consequently, the needs would differ and they were clustered using spiral dynamics theory (Koenders & Nientied, 2011). Based on needs for safeguarding/emphasizing what is already there (purple), rules and structure (blue), focusing on result and success (orange), collaboration (green), concepting and experimenting (yellow), striving for a holistically better educational system (turquoise) and any combination of those, plans of action could be formed together or independently. As a result, not only different priorities in CDIO standards could be picked due to the self-evaluations, but different ways to get there that fitted each team best could form as well. For instance, in 'we reflect on what we do and try to do it better' the word better has quite a different meaning in the different teams, depending on their color(s).

Planning: All aboard, but each in their own pace

When implementing CDIO in twelve programs at the same time, one needs to keep in mind that each program is in another phase of its development. The programs vary from 26-year-old, settled programs that were once pioneers in their field such as Industrial Design Engineering, to young pioneers such as Mechatronics. Some have small numbers of students or compact teaching staff, enabling flexibility and quick decision making, whereas others have hierarchical structures in place, and longer process trees. Programs differ in intensity of contact hours for students with all effects on teaching work load and room for secondary tasks for staff. Thus each program has different needs and priorities, and asking the same implementation pace of all programs is unrealistic to a certain extent. To deal with the differences three tracks were identified:

- *The Fast Track*: these programs have already implemented CDIO, and needs to keep going. The basics of CDIO are known, they want to make the next step, work on fine-tuning their (teaching) skills, etc. They need to evaluate their efforts so far and adjust and get in sync with the other programs on faculty wide CDIO aspects.
- *The Drawing Board Track*: these programs are in the process of redesigning their curriculum and all time and energy besides the daily practice goes there. Only in the new curriculum will they teach via the CDIO principles. Standards and syllabus can already be included in the plans, but only on paper. There is no direct need for hands-on working with CDIO for learning purposes, unless they like to experiment in their 'old' program for 'prototyping' purposes.
- *The Quality Track*: these programs are in the middle of a curriculum without the need for a big redesign, so CDIO will be used as a quality improvement tool on incidental basis.

Challenges with the tracks were that in some TIS clusters there were different tracks, so the 'one cluster approach' was not possible. And within a track, the value of CDIO could be and still was viewed differently. For instance, people in the drawing board track with orange types of needs would get impatient for direct results. To be in the quality track and have blue needs could lead to a desire for more thorough rules for the whole program straight away, or to be in the fast track with purple needs could mean although being forced to do it still falling back to 'the old ways' whenever possible.

A roadmap was formulated to be included in the policy plans of both the faculty and the programs, defining possible actions to be taken by teachers, heads of programs or faculty management. For teachers, items such as increasing one's knowledge of CDIO, actively participating in the CDIO professional learning community, developing or improving an active learning course, involving students and/or the professional field in quality improvement of the course, and sending in conference abstracts were included. Management can take time to celebrate successes, facilitate CDIO experiments with support of the Betafactory, research platforms and supportive university units, make CDIO known to the university's board of directors, add CDIO in PR materials etc. And for Heads of Program the roadmap included actions such as integrating the roadmap in the program plans, steer curriculum commissions towards the use of the CDIO syllabus as a blueprint, look for partners within the CDIO network for exchange and (research) projects, and include CDIO in critical reflections of the program. As an a la carte menu each program can pick the actions and order of the actions to include in their smart goals for the coming year(s). Per cluster the exact roadmap for implementation of CDIO will differ, depending on the context and progress of each of its programs.

Interaction: Towards a Professional Learning Community

Besides the process leadership and the varied program planning, for individual needs for two-way communication with each other about the value of CDIO and its different interpretations, a social learning context was set up. Since 2014 TIS is developing towards a professional culture with result responsible teams. In this endeavor the concept of the Professional Learning Community (PLG) is an important way of facilitating continuous improvement of daily practice. According to Verbiest (2002) PLGs are built on:

- Personal capacity: comprising individuals' ability to construct, reconstruct (revise, adjust) and apply knowledge in an active and reflective manner, making use of up-to-date scholarly and practical theoretical insights.
- Collective capacity: comprising the ability of a group or collective to (re)construct and apply knowledge. This presupposes a shared vision of learning and shared vision of the role of the teacher. Is also implies shared practices amongst teachers.
- Organizational capacity: consisting of cultural and structural conditions supporting the development of the personal and interpersonal capacities. Supportive, stimulating and shared leadership is also an important aspect of this organizational capacity.

In these communities, students, staff and management are working together on the development of a common purpose. A CDIO PLG was formed to address the influence of incomplete information on the willingness, but also and not in the least to dive deep into the implementation process. This process started and continues with visiting the CDIO meetings and conferences with different interested staff members each time, teachers, mid-management and management alike (and in the near future students as well). These visits help to become inspired personally and consequently help spread the 'oil stain' within the faculty afterwards. Next prominent CDIO speakers were invited to the university to introduce staff members to the basics of CDIO as well as give hands-on workshops on active learning and assessment. An experimental CDIO workgroup was initiated by the internal staff development team for ten enthusiastic, early adopting teachers from different programs to work on improving a course on CDIO aspects. An intervision set-up was chosen to provide for support and reciprocal learning for the teachers in their experiments. The next step was to develop a ten week course in active, blended learning for all teaching staff of the faculty (with a 32-hour work load), in line with the CDIO principles. This ‘learning path’ is designed by an educational advice company in collaboration with the faculty. From May 2016 onwards this course will be given four times a year for all TIS’ teaching staff. Also, the process director functions as a help-desk on demand for the whole faculty; for example, as a sparring partner in the work sessions for the curriculum development of the new Built Environment program (a future merger of the programs Civil Engineering, Building Engineering and Climate and Management), as an advisor for the reconstruction project group (for the main building) on standard 7 ‘workspaces’, but also individually for teachers on their courses. Online key CDIO documents are accessible for all staff.

Aligning with existing frameworks, methods and approaches

Nobody wants to do double work, and during the implementation of CDIO it is therefore important to look at existing frameworks that are compulsory or have been chosen to work with within the faculty. On program level for instance, Mechanical Engineering chose 4C/ID as their educational blueprint for the new curriculum (Merriënboer et. al., 2002) right at the same time as CDIO was decided to be implemented. What is needed is insight in how the two models overlap, add to or contradict each other. In the experimental workgroup a small start was made to gain these insights. At Industrial Design Engineering [Open] Innovator (IDE), many parallels were seen between the CDIO syllabus and standards, and what was the basis of their curriculum: design thinking. There is a strong link between a design thinking curriculum and a CDIO curriculum in the integrated, interdisciplinary approach, teaching students to take contexts into account while solving problems and innovating and including stakeholders in a co-creational way during the process (Hallenga-Brink & Dekelver, 2016). For them the standards added a tool for good quality ‘housekeeping’ in the organization of the curriculum, and merging the CDIO syllabus with the competence profile of both IDE and the Dutch Industrial Design Engineering (IPO) proved to be a smooth operation.

But also on a higher level, the Accreditation Organization of the Netherlands and Flanders (NVAO) prescribes quality standards for the national accreditation of higher education which the faculty has to abide by. A comparison was made between CDIO and the NVAO accreditation standards, see table 2, partly based on the experiences of PFT. Transparency on this topic was important for the internal change process and led to integrating the CDIO standards into the tools the faculty uses to audit and control the programs such as policy plans, critical reflections and management reports.

Table 2: Relationship between CDIO and NVAO standards

NVAO	**Focus**	**Associated CDIO standards**
What is the program aiming for?		
1: The **intended learning outcomes** of the program have been concretized with regard to content, level and orientation; they meet international requirements.	> The intended learning outcomes fit into the Dutch qualifications framework (bachelor level).	
	> They tie in with the international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the program.	CDIO standard 1 CDIO Context: educating Engineers who can engineer. (Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education).
	> So far applicable, the intended learning outcomes are in accordance with relevant legislation and regulations.	

With what curriculum?		
2: The **orientation of the curriculum** assures the skills development in the field of scientific research/the prof-essional practice.	> The curriculum has demonstrable links with current developments in the professional field and the discipline.	CDIO standard 3 Integrated Curriculum: A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills.
3: The **contents of the curriculum** enable students to achieve the intended learning outcomes.	> The learning outcomes have been adequately translated into attainment targets for (components of) the curriculum.	CDIO standard 2 Learning Outcomes: Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders. + CDIO standard 8 Active Learning: Teaching and learning based on active experiential learning methods.
	> Students follow a study curriculum which is coherent in terms of content.	CDIO standard 3 Integrated Curriculum: A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills. + CDIO standard 4 Introduction to Engineering: An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills.
4: The **structure of the curriculum** encourages study and enables students to achieve the intended learning outcomes.	> The teaching concept is in line with the intended learning outcomes and the teaching formats tie in with the teaching concept.	CDIO standard 5 Design-Implement experience: A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level. + CDIO standard 7: Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills.
	> Factors pertaining to the curriculum and hindering students' progress are removed as far as possible.	CDIO standard 8 Active Learning: Teaching and learning based on active experiential learning methods.
	> Students with a functional disability receive additional career tutoring.	
5: The curriculum **ties in** with the **qualifications of the incoming students.**	> The admission requirements are realistic with a view to the intended learning outcomes.	
With what staff?		
6: The **staff** is qualified and the size of the staff is sufficient for the realization of the curriculum in terms of content, educati-onal expertise and organization.	> The factual expertise available among the staff ties in with the requirements set for professional or academic higher education programs. > This includes content, educational and organizational aspects.	CDIO Standard 9 Faculty CDIO skills: Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills. + CDIO Standard 10 Faculty Teaching Competence: Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning.
	> Size of personnel is sufficient for offering program.	
With what services and facilities?		
7: The **accommodation and the facilities** (infrastructure) are sufficient for the realization of the curriculum.	> Accommodation is fit to offer program.	
	> Facilities are fit for offering program.	CDIO standard 6 Engineering Workspaces: Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning.
	> Tutoring matches student needs.	
	> Student information fits student needs.	
How does the program intend to safeguard quality?		
9: The program is **evaluated on a regular basis,** partly on the basis of assessable targets.	> The program monitors the quality of the intended learning outcomes and the learning outcomes achieved through regular evaluations.	CDIO standard 12: A system that evaluates programs against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.
	> Includes the curriculum, the staff, the services and facilities, the assessments.	
	> The outcomes of these evaluations constitute the basis for demonstrable measures for improvement that contribute to the realization of the targets.	

	> Program committees, examining boards & staff are actively involved in the program's internal quality assurance.	
	> Students, alumni and the relevant professional field of the program are actively involved.	
Is the program achieving its objectives?		
10: The program has an adequate **assessment system** in place.	> The tests and assessments are valid and reliable	CDIO Standard 11: Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge.
	> The tests and assessments are transparent to the students.	
	> The examining board of the program safeguards quality interim and final tests.	
11: The program demonstrates that **intended learning outcomes are achieved.**	> The level achieved is demonstrated by interim and final tests and final projects.	
	> Level achieved is demonstrated by the performance of graduates in actual practice or in subsequent programs.	

CONCLUSION

Relatively early in the implementation process management made it clear professional development opportunities would be offered to improve or continue to work on quality, decreasing feelings of uncertainty about positions. All programs were asked to do the self-evaluation as an active learning exercise of getting acquainted with the framework. Three questions were added to the self-evaluation format to spark adoption: What value does CDIO hold for your program? What standards does your program want to prioritize working on in the coming year? And what contributions from the faculty do you need for this?

The value of CDIO was found in international networking and positioning, providing students with 'something better', a hands-on quality management checklist, a common language amongst the programs to facilitate interdisciplinary education and a grip for structure. The feeling of urgency varied per program, as expected. There were also questions raised instead of an answer found, for example by Engineering Physics who have a Bachelor of Science program and first wanted to investigate the impact of CDIO in their well established research-based curriculum. This investigation is a work in progress.

The overall self-evaluation can be seen in figure 1. Priorities were identified for the faculty as a whole. Unsurprisingly standard 1 was the weakest, as most programs were still unaware and unequally involved in CDIO so far. Standards 9 and 10 were also considered priority, as they had lower average scores. Because active learning was a focus of the university already, standard 8 was filled in self-consciously and also needed attention.

Desired contributions from the faculty to facilitate the implementation of CDIO were congruent to the set-up as described. Time, flexibility, central organization including a FAQ point (someone who can help a team on CDIO implementation and can share examples and experiences of colleagues) were core choices in the process. The need for CDIO key persons in every program was not filled in top-down, but bottom-up as people became more and more involved. The next phase will be to form a taskforce group around the process director, whose function is intended to become obsolete in the near future as the oil stain spreads. A reflective session was organized in February 2016 with the Heads of Program and/or those highly involved in CDIO, where the experiences and perceptions of the implementation process so far were discussed, not the results on standards and syllabus implementation. Results showed a need to do the next self-evaluation and this time focus on sharing all the gathered proof on each standard within the team and with management, to increase understanding and awareness of CDIO.

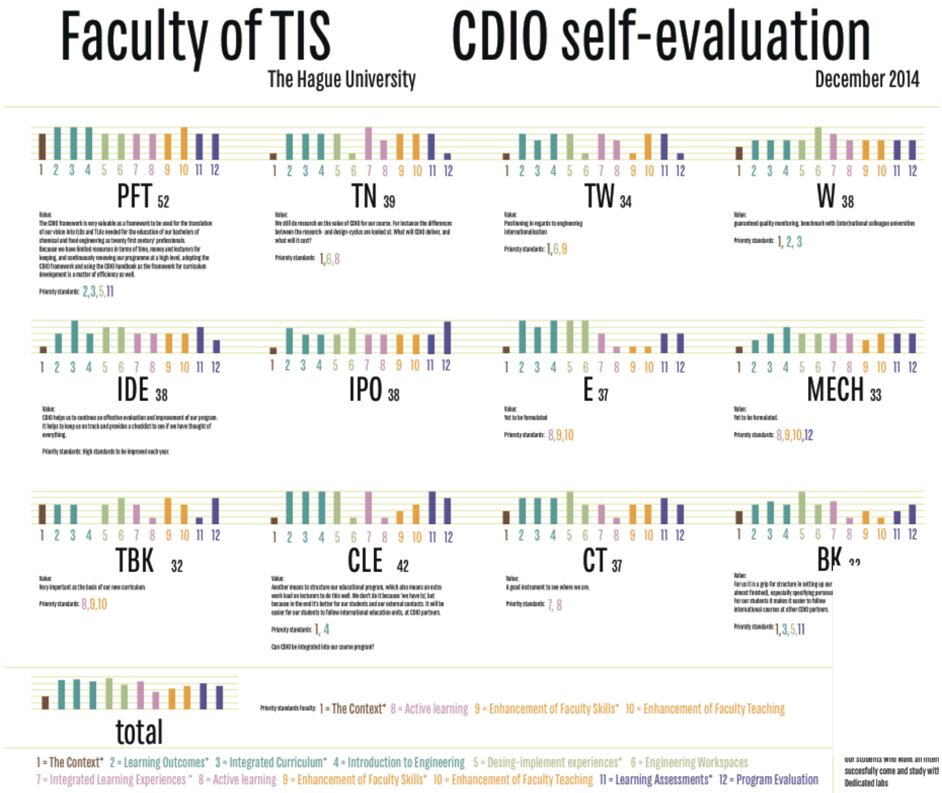

Figure 1. The first self-evaluation of all twelve programs of TIS.

There was also a call for vision; vision on joint practice opportunities (including teacher internships) within the faculty, and on enhancement of knowledge and skills of personnel with explicit commitment for standard 9 and 10, such as courses or training in active learning, and assessment of active learning. These are addressed in the PLG CDIO. One of the challenges ahead is to keep the information flow going. Having two locations, different team cultures, and daily distractions asks for more than an online repository of CDIO documents. The learning path on active blended learning is a good bottom-up step, but the formation and continuation of internal collaboration and reciprocal learning between the programs is important to keep all programs aboard. In a professional culture change management cannot be reduced to smart targets and one solution for all. In the faculty PLGs are starting on other themes as well. The management of the faculty is aware that they need to remain sharp in their stimulation, facilitation and guidance of this way of working, learning and improving together for the benefit of this and other PLG's.

Despite being a top-down decision, the CDIO adoption process at TIS is directed in a bottom-up way, aimed at the different personal motivations for lecturers and management alike. Although it may not always be in simple, equal for all, measureable targets, progress is fluidly but certainly made and CDIO provides TIS with a tool for its desired continuous educational quality improvement.

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ADDING CDIO-COMPONENTS TO (NON-)CDIO COURSES

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ABSTRACT

CDIO projects teach engineering students relevant competences and improve the learning process by integrating topics within and across semesters. These benefits often seem unachievable for individual courses that are not embedded in a CDIO setting. In this article we present an approach to achieve CDIO-like effects in non-CDIO courses, also outside of engineering curricula.

In typical project-based courses, students work on one or more individual phases of a project. The bigger the project in question, the bigger the efforts to fit the whole project inside a course, and the steeper the learning curve for the students.

Our approach personalises projects with extensions based on the students' experience and level of knowledge and competencies. In the beginning of the course, students get a functional subset of the project to work on. During the semester, they extend the project subset through a set of assignments. These extensions are partly mandatory, partly either chosen by students from a set of well-known, pre-specified extensions, or suggested by students. To ensure that each group reaches a minimum level of experience, each extension is assigned a value; each group has to choose extensions with a sum value that passes a certain threshold. For extensions suggested by groups, the group members and the educator determine a value. The resulting project setup enables groups on all levels to adapt their project to their capabilities, knowledge, competencies, and, last but not least, level of ambition.

We have implemented our approach in a compiler course on the 3rd term of our CDIO-based B.Eng. study line, and the results are very promising. Students appreciate the possibility to work on open problems, and the educators benefit from the kind of closed setting the projects run in. The project is based on a compiler for a subset of the programming language Java. The students have sufficient experience to know some standard extensions that are missing in the initial project, as well as other concepts that are not present in Java, or are not supported by the course project. This leads to interesting and challenging nuances for some of the groups.

KEYWORDS

Computer Science, project work, Standards 2, 4, 5, 7, 8, 9, 11

INTRODUCTION

CDIO projects have proven to teach engineering students relevant competences and to improve the learning process by integrating topics within and across terms. These benefits often seem unachievable for individual courses that are not embedded in a CDIO setting, or that have not yet been transformed to comply with the CDIO standards.

In this article we present an approach to add CDIO-like elements to project-based courses, be they CDIO-based or not. Using our approach, educators can achieve CDIO-like effects in non-CDIO courses, also outside of engineering curricula.

Engineering courses, especially in CDIO-based curricula, often are centred around projects that students work on in groups. Depending on the size of the problem, the efforts to fit the whole project inside a course can be rather big, and the learning curve for the students quite steep. Therefore, especially in early semesters, the projects are closed problems with a predefined methodology and solution. For many students, this is the appropriate approach. However, in every student population there is a group of students that will enjoy working on open problems from the first day.

Our approach addresses all these issues, independent of the status of adaptation of CDIO standards and branch of study. The only requirement is for the course work to be based on some kind of project that the students extend during the course. Our approach works by personalising this project and its extensions based on the students' experience and level of knowledge and competencies. This personalisation can either be implemented by the educator, or by the students, or in mutual agreement.

In the beginning of the course, or at the beginning of a project work period, students get a functional subset of the project to work on, and to through a set of assignments during the semester. The kind of extensions and assignments are not constrained. There can be any number or combination of mandatory, optional, and elective assignments, and they can be predefined, chosen by students from a set of well-known, pre-specified extensions, or they can be suggested by students. The spectrum from completely predefined by the educator to completely suggested by students results in fine-grained customizability of the project. Depending on characteristics of the class or the groups – for example, their level of knowledge, competencies, or ambition – project and extensions can be fine-tuned to match the students' requirements.

To ensure that each group reaches a minimum level of experience, each extension is assigned a value. For extensions suggested by groups, the group members and the educator determine a value together. This step is important to ensure that trivial or unreasonably complex solutions are excluded, and that students later will have the feeling of a point value in line with their work efforts. The resulting project setup enables groups on all levels to adapt their project to their capabilities, knowledge, competencies, and, last but not least, level of ambition.

The remainder of this article is structured as follows. After a description of the course, in which we have developed this approach, and the study line, in which the course is embedded, we discuss how to add CDIO components to project-based courses. We then highlight some of the challenges faced by educators and teaching assistants, and briefly discuss how to apply our approach to courses in non-engineering curricula.

COURSE DESCRIPTION

Before discussing our approach in the next section, we briefly present the course, in which we have developed our approach: a compiler course for 3rd term B.Eng. students. The course is embedded into two study lines: one for software technology, and one for computer systems engineering. Both study lines have recently (Nyborg, Probst, & Stassen, 2015) been developed from a common predecessor (Sparsø, et al., 2011), to strengthen the focus on software and computer systems engineering, respectively. We therefore only describe the software technology study line.

Study Line "Software Technology"

As mentioned above, the course in which we have implemented our approach is part of a B.Eng. study line on software technology. The study line covers software engineering and core computer science, with a focus on systematic approaches for requirements engineering, design of system models, system implementation, and finally the deployment of the system, thus clearly mapping to the core competencies in the CDIO syllabus (Crawley, Malmqvist, Östlund, & Brodeur, 2007).

Table **1** shows the study plan for the respective study line, which is a development of an earlier B.Eng. study line on computer systems engineering (Sparsø, et al., 2011) as part of a merger between the Engineering College Copenhagen and the Technical University of Denmark (Nyborg, Probst, & Stassen, 2015). Throughout the first 4 obligatory terms, students get a basic education in software engineering, systematic development, and mathematics, eventually leading up to the CDIO project in the fourth term.

In each term several courses contribute to a (smaller) CDIO project. In the computer systems engineering version of this study line, the compiler course contributed to the 3rd term CDIO project together with a course on hardware/software (Todirica & Probst, 2014). With the revision of the study line as part of the merger, this collaboration was no longer possible, leading to the need for adding more CDIO aspects to the now stand-alone project in the course.

The Compiler Construction Course

The overall aim in the 3rd term course "Compiler Construction" and the associated project is to teach the fundamentals of translating high-level languages into native code, and how a compiler realizes this task, with a focus on the software side of this process. During the semester, the course teaches scanning, parsing, and intermediate representations (2 weeks), semantic analysis (4 weeks), processors, virtual machines, and runtime environments (2 weeks), and code generation (3 weeks).

Table 1. Study plan of the study line B.Eng. Software Technology.

Term	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS	5 ECTS
1	Mathematics	Discrete Mathematics	Version Control & Testing	Development methods for IT systems	Introductory Programming	
2	Database Programming	Algorithms and Data Structures	Data Communication	Networking Lab	Advanced Programming	
3	Probability and Statistics	OOAD	Game Physics	Compilers	Development for Mobile Devices	
4	Operating Systems	Distributed Systems	Parallel Systems	Model-based Software Development	CDIO Project	
5	Electives				Innovation	
6	Internship					
7	Electives		Exam Project			

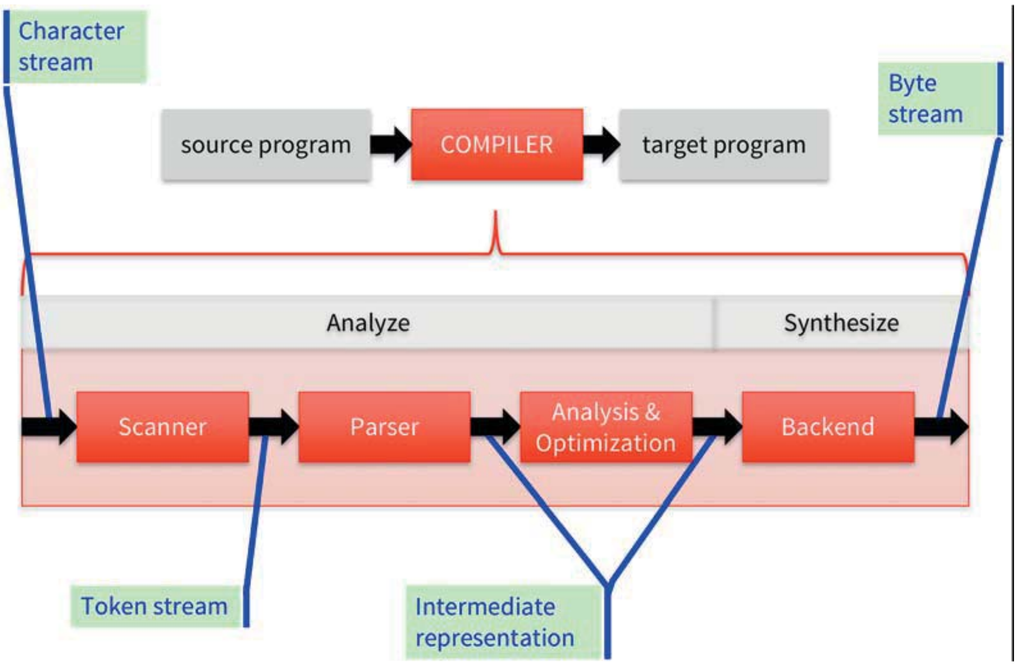

Figure 1. Structure of a compiler. The course covers all four phases (scanner, parser, analysis, and backend).

In the project associated with the course, students get a rudimentary, working compiler for a subset for Java (Appel, 2002). The task is to add functionality to the phases of the compiler, shown in Figure 1, by adding support for new constructs from scanning to code generation. When the compiler course still contributed to the 3rd term CDIO project in the earlier version of the study line (Todirica & Probst, 2014), this training contributed to the semester project, as the students had had intensive training in adding functionality, which they could use in the project as well. Interestingly, the decoupling of the two courses as part of the re-design of the study lines described above, resulted in a clearer project for the compiler course.

The learning objectives for this course are

- Understand the principles of compilers and virtual machines.
- Use and construct software tools to implement a working compiler.
- Explain the different phases in compilation and execution;
- Operate selected tools relating to the compiler phases (e.g., lexers, parsers);
- Explain the different elements in the description of a programming language;
- Derive specifications of the compiler phases, given a textual description of the syntax of a programming language;
- Implement an analysis and code generation phase, given a textual description of the semantics of a programming language;
- Acquire necessary skills to navigate large code bases; and
- Develop a working compiler.

The focus of the course is on understanding the rather large code base of the initial subset of the working compiler, extend it with new functionalities, and do so through all phases of the compiler. Based on their earlier knowledge and skills, students are able to transfer that knowledge to the implementation of new elements.

ADDING CDIO TO PROJECT-BASED COURSES

We now describe how the original, pre-CDIO version of the compiler course was adapted to embed a CDIO-like project in the course. In the next section we will then discuss how this approach can be generalised to other courses and even non-engineering curricula, and consider implications for educators and teaching assistants.

Our approach personalises projects with extensions based on the students' experience, knowledge, and competencies. In the beginning of the course, students get a working prototype of the project to work on. During the semester, they extend this prototype through a set of assignments. These extensions are partly mandatory, partly chosen by students from a set of well-known, pre-specified extensions, and partly suggested by students. To ensure that each group reaches a minimum level of experience, each extension is assigned a value; each group has to choose extensions with a sum value that passes a certain threshold. For extensions suggested by groups, the group members and the educator determine a value. The resulting project setup enables groups on all levels to adapt their project to their capabilities and level of ambition.

The Project

At the beginning of the course, students get a rudimentary, working compiler for a subset of Java (Appel, 2002). Since the programming education in the study line is based on Java in the first four, mandatory terms, students know the programming language and many of its constructs sufficiently well to be able to either map new constructs to existing ones, or to develop approaches to identify the new features. The task in the term-long project is to add functionality to the individual phases of the compiler, as they are being covered in the course.

Programming a compiler is a daunting task, and the initial project is of considerable size. The goal of the project is thus not only to give students the opportunity to develop a compiler – it is also to train them in navigating and exploring large code bases, a skill that will be essential when they start working, and that repeatedly has been demanded by our industrial advisory panel.

Throughout the term the students therefore get two kinds of assignments: one about extending the compiler, which we discuss in more detail in this paper, and one about exploring, understanding, and explaining the project that is handed out. These activities provide the students with the insight into the structure and the functioning of the project that they need for extending it.

We use the term "project" for the semester-long activity in the course. This overall project is the task of implementing extensions to the compiler. The individual extensions, which will be covered in the next sections, can be seen as group exercises. However, most extensions need to be considered in all phases of the compiler (see Figure 1), so students are repeatedly exposed to the problem how a certain programming language extension is added to the different phases of the compiler.

The required effort for the extensions can differ a lot; some may only require small changes in early phases, others may require changes to several phases, and finally some require quite

Table 2. Menu of extensions for students to choose from.

#	Description	Value
1	datatype char	5
2	Implement square root as call to Math.sqrt()	10
3	datatype double	10
4	pre or post increment/decrement (x++)	10
5	private	10
6	one other operator, eg, greater than, divide, modulus, exponent	10
7	ternary operator (a ? b : c)	15
8	for-loops	15
9	untyped variables (var x)	20
10	constructors	20
11	type cast	20
12	exceptions and try, catch	30
13	SQL support a la LINQ	60

involved changes of large parts of the compiler. While implementing these changes, and learning about the structure of the compiler code, students not only acquire the skills to implement a compiler, but they also get a better understanding for, how the Java language works internally.

Group forming

We briefly want to mention one change we have applied in the course, which is independent of the main topic of this paper. We asked students to register their level of ambition among the choices “top grade”, “medium grade”, “just pass”. We have then asked them to form groups with peers with a matching level of ambition. This small change has reduced the number of group changes in the term, and frustration between the students, significantly.

Student teams, which have formed over the first and second semester, usually have the same level of ambition anyway, but for students without a fixed group or exchange students this change has made group forming much simpler.

Predefined Extensions

Once students have formed groups and have started to explore the code base, their first task is to choose the extensions they will add to the compiler project. One of the first assignments is therefore to pick extensions from the list shown in Table **2**. To ensure that each group reaches a minimum level of experience, each extension is assigned a value. In our course, students must choose extensions of at least a given sum value, allowing them to choose from the simpler ones, but also challenging them to choose some of the more complicated ones.

The value of extensions shown in Table 2 represents approximately the difficulty or workload of adding the extension to the project. Adding the data type “char” to the project, for example, is considered to be relatively easy, since the initial compiler already contains a data type “int”. On the other hand, adding support for exceptions or inner classes requires significantly more work.

Defining the extensions requires some attention to the detail. It is important that the values of extensions “seem right”, that is fit with the students’ understanding of how difficult it is to implement them. A discussion in class about the extensions and their values is an excellent opportunity to give students an initial idea of, what kind of work is needed for some of the extensions. This is also a good preparation for students to choose extensions and to define their own extensions.

The predefined extensions mostly represent bucket-of-water projects (Vigild, et al., 2009) with a fixed starting point and a fixed result, but an open method: when implementing the extensions, students are free to choose a method to do so, as long as the result fits into the compiler. By providing a functional subset of the project, students can explore how the features present in this subset are implemented, thereby “learning from the known”. This decoding of available information and transferring it to a new problem is an enabling factor in our project work. Through the study of the existing project, students are encouraged to understand certain aspects of a problem. In a next step they realise that the same technique can be applied to similar problems.

Student-defined Extensions

For many students, picking only from the suggested, predefined extensions is sufficient. On the other hand, many students prefer open projects that enable them to explore new ideas, and to challenge their knowledge and competencies. Extensions to a predefined project combine a staged setting, where the boundaries of what students will work on are known, with an open setting, where students can define themselves what they will work on.

Table **2** shows some of the extensions suggested by students and the values assigned to them. For student-defined extensions, fixing the value is an important part of the process. The group members and the educator determine a value together. This step is important to ensure that trivial or unreasonably complex solutions are excluded, and that students later will have the feeling of a point value in line with their work efforts. In general, it will be difficult for students to judge the effort required for implementing an extension; this is especially true for the required work in later phases in the compiler project, which they might not even be aware of yet. On the other hand, students tend to overestimate how many points they should receive for their suggestions.

Table 2. Menu of extensions suggested by students.

#	**Description**	**Value**
S1	variable declaration with initialiser (int x = 10;)	15
S2	static array initialisation (int[] x = 1, 2, 3;)	15
S3	combination of operator and assignment (x+=7;)	15
S4	declare variables in the middle of the code	15
S5	struct and typedef	25
S6	inner classes	30

Evaluation

The reception by the students has been mixed in the first attempts, but the overall trend is very positive. While some of the students struggle with the potential choice of self-defined extensions and choose only from the pre-defined ones, a large group of students appreciates the possibility to work on self-defined, open problems, and makes eager use of this possibility together with sparring with their peers and the educators. It is clear from the discussion that they advance well beyond the level of understanding that has been observed in earlier editions of the course.

The evaluation of the course is currently a combination of project work and written exam. To reduce the potentially negative impact of a failed project, the project part contributed a smaller percentage to the grade than it did in earlier years. Nevertheless, the grade average has been stable over the last years, indicating that our approach has contributed to a significantly better understanding of the course’s topic. This observation is supported by an evaluation of the answers in the written exam.

CHALLENGES FOR EDUCATORS AND TEACHING ASSISTANTS

The potential degree of free choice in the project is not only attractive to students, but also to educators and teaching assistants. Since students, who contribute their own extensions, can be expected to be highly motivated, the interactions with them very likely are rewarding for all parties. The focus shifts from repeating known facts to enabling innovative processes.

On the other hand, the amount of freedom also can result in some challenges, which need to be addressed. First of all, as mentioned above, the student-defined extensions need to receive a value that represents the amount of work required to add it to the project. This valuation needs to be realistic and adequate to avoid frustration, and it needs to be communicated in a clear way to students to avoid any misunderstanding. This requires a sufficiently deep understanding of the project and possible extensions by the educator, such that trivial or too difficult solutions can be avoided. Difficult extensions are in principle acceptable, if the educator and the students both are aware of this; in that case the students can learn even more about the topic of the project.

The amount of freedom requires special effort for the supervision of the personalised projects. For a staged project, solutions can be prepared or are even available before the start of the term; for the student-base extensions, this is naturally note the case, at least not for completely new extensions. While educators and teaching assistants might have an idea about feasibility, required effort, and potential obstacles, preparing a solution requires intensive work, which ideally can be executed together with the students who suggested the extension.

The challenges of freedom of choice also applies to the evaluation of the project work. How should a group that tries to solve a very advanced problem be evaluated in comparison to a group that only solves standard extensions, for which a solution can be found in the source code? Failing to solve advanced problems can have many different reasons, from very subtle challenges to lack of competencies. Ideally, the examination in this setting would be oral; due to the large number of students taking this course, this is currently not feasible. Instead, students get continuous feedback on the individual phases.

CDIO-FYING GENERAL COURSES

The applicability of the approach described above to CDIO course is obvious. However, it is equally well suited for all kinds of project-based courses. The only requirement is that the project can be structured in a way that students obtain a subset of the project in the beginning of the class, and that they work on this project throughout a certain period.

Any project that can be structured in an initial, functional subset and extensions, which are either pre-defined or student-defined is suitable. As pointed out above, it is important that the extensions are valuated beforehand, and that a risk assessment for student-defined extensions is performed to judge their chance of success and the required amount of work. It is of uttermost importance that students are protected against or at least receive an advance notice of potentially prohibitively complex extensions, both to avoid failure and to avoid frustration.

While we have developed our approach in a computer science course, and have discussed it with colleagues within engineering sciences, the approach is equally applicable to non-engineering curricula and courses. With a colleague we are currently working on applying the approach to a psychology course; here, the "functional subset" is the description of a case study, and the pre-defined extensions are aspects of the case study that students are asked to investigate. We envision the student-defined extensions to be further aspects of the case study, or different methodologies to apply. The whole project will be purely report-based, as a kind of gedankenexperiment.

For courses included in a CDIO curriculum, our approach contributes to a number of standards, mainly those related to learning and learning assessment, but also to introduction to engineering, design-implement experiences, and enhancement of faculty competence. We believe that the latter is especially interesting, since it reflects the educator's involvement in enabling unpredictable student-defined extensions and their implementation.

CONCLUSION AND FUTURE WORK

In this article we describe how to add CDIO aspects to courses in CDIO study lines, but also to courses (still) outside a CDIO curriculum or during introducing CDIO. We argue however that our approach is so general that it equally well can be used in study lines that are outside the engineering or natural sciences. We are currently exploring options for applying our approach to a course in the social sciences.

The personalisation of projects for individual students or groups of students has proven to be an excellent factor for unleashing students' creativity, and for giving them freedom even in almost staged projects. By being able to either choose a set of predefined extensions or by suggesting their own extensions, students can be integrated in the project. The discussions about feasibility of extensions, the involved work, and the valuation of such extensions, contribute massively to the students' understanding and learning.

As described above, another important factor is the availability of the functional subset of the project, where "functional" addresses very different aspects depending of the course's topic. We are currently investigating the applicability of our approach to non-engineering curricula, such as the psychology class discussed above. We believe that CDIO-like structures can be developed in almost all sciences, with similar effects.

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BIOGRAPHICAL INFORMATION

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THE “INGENIA” INITIATIVE FOR PROMOTING CDIO AT TU MADRID: LESSONS LEARNED FOR ENHANCED PERFORMANCE

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ABSTRACT

The implementation of the “Bologna process” has culminated at ETSII-TU Madrid with the beginning of the Master’s Degree in Industrial Engineering, in academic year 2014-15. The program has been successfully approved by the Spanish Agency for Accreditation (ANECA) and includes a set of parallel subjects, based on the CDIO methodology, denominated generally “INGENIA”, linked to the Spanish verb “*ingeniar*” (to provide inspired or creative solutions), also related etymologically in Spanish with “*ingeniero*” (engineer). INGENIA students live through a complete development process of complex products or systems linked to different engineering majors at ETSII-TU Madrid. All subjects within the INGENIA initiative have an analogous structure and aim at the promotion of similar professional outcomes, linked to the ability to design, implement and operate engineering systems, also focusing on teamwork and communication skills, and trying to systematically promote student creativity and their interest in social and ethical aspects of engineering for a sustainable World.

In this study we present a complete development of the INGENIA initiative, the main results from the first implementation from 2014-2015 academic course and the principal challenges and difficulties faced, when trying to systematically promote CDIO and to encourage a shift from traditional teaching-learning methodologies to student centered approaches. Present analysis is carried out focusing on the main drivers of change: students, teachers, environment and resources, taking into account opinions from the Managing Board at ETSII-TU Madrid, which have been systematically gathered by means of comprehensive surveys and personal interviews. Key aspects, including: student motivation, coordination between teachers and subjects, supervision of projects under a tight schedule, promotion of topics for all industrial engineering areas, rapid prototyping resources for reaching the implementation and operation stages, among others, are discussed and the more relevant lessons learned and proposals for improvement are put forward. We also provide an analysis about the impacts of such proposals for improvement on the second implementation from 2015-2016 academic year in which the INGENIA initiative is performing with even better results and involving more than 250 students, almost doubling the numbers from the first implementation.

To our knowledge, the INGENIA initiative constitutes the first integral application of the CDIO methodology to the field of Industrial Engineering in our country.

KEYWORDS

CDIO as Context, Integrated Curriculum, Integrated Learning Experiences, Active Learning. (Standards: 1, 3, 7, 8).

INTRODUCTION

Student motivation and active engagement to their own learning process is a key success factor in Higher Education, especially in Science and Engineering paths, as recognized and highlighted in several studies (Prince, 2004, Hmelo-Silver, 2004), reports and declarations, such as the Bologna Declaration and the subsequent related declarations from Prague, Berlin, Bergen, London, Leuven and Budapest-Vienna, aimed at the implementation of the European Higher Education Area (EHEA). Making students drivers of change is perhaps the most effective part of a global strategy, for the promotion of a wide set of professional skills in Engineering Education (Shuman, et al. 2005, Díaz Lantada, et al. 2013). Problem- or project-based learning (typically PBL) methodologies clearly tend to motivate students to participate and become involved in their own learning process and constitute an excellent way of analysing whether students have acquired basic concepts taught in the theory classes and if they are capable of applying them in real situations. These PBL experiences have proven to be effective in primary, secondary and university education and in scientific-technological, bio-sanitary, humanistic and artistic contexts. In consequence, most technical universities, before awarding the engineering degree, almost always include the standard final degree project as part of the studies, which, basically, is a PBL learning experience. In direct connection with the promotion of project-based learning methodologies worldwide, even though its holistic approach to engineering education development goes far beyond project-based learning, the CDIO™ Initiative (www.cdio.org) is probably the most ambitious approach. The CDIO™ Initiative is focused on the establishment of an innovative educational framework for producing the engineers of the future, by means of providing students with an education stressing engineering fundamentals by means of "Conceiving - Designing - Implementing – Operating" (CDIO) real-world systems, processes and products (Crawley, et al. 2007). Throughout the world, CDIO Initiative collaborators are adopting CDIO as the framework of their curricular planning and outcome-based assessment. CDIO also promotes collaboration and sharing of good practices among engineering educational institutions worldwide.

The main purpose of present study is to detail current actuations at ETSII – TU Madrid oriented to a more systematic integration of CDIO experiences within our program 6-year integral program of Industrial Engineering (Grade + Master's Degree), paying special attention to the "INGENIA" initiative, which was implemented for the first time in academic year 2014-2015. Main results from the first implementation, together with the principal challenges and difficulties faced, when trying to systematically promote CDIO and to encourage a shift from traditional teaching-learning methodologies to student centered approaches are presented. Key aspects and good practices, based on the experience of the Managing Board at ETSII-TU Madrid, are discussed and proposed.

THE "INGENIA" INITIATIVE: INTEGRATED PROMOTION OF CDIO INITIATIVES

The ETSII – TU Madrid (www.etsii.upm.es, see Figure 1) has been promoting student-centred teaching-learning activities, according to the aims of the Bologna Declaration, well before the official establishment of the European Area of Higher Education (Vera, et al. 2006). In the last years we would like to highlight the Innova.Edu educational projects, funded by our centre during the academic years 2004-2005 and 2005-2006, which helped to promote several project-based learning activities in different subjects and to set common practices among our teaching staff for activities in the field of "conceive, design, implement & operate". Additional educational innovation projects, funded by our University since 2007, have helped us to establish supplementary best practices for promoting student motivation, to implement novel subjects linked to project-based learning, to enhance our faculty teaching skills, to improve our assessment and evaluation plans, among other innovations. Such improvements have led to the Accreditation of our Industrial Engineering program by ABET (www.abet.org) in 2010.

Figure 1. ETSII – TU Madrid Campus, main hall and collaborative learning environments.

The level of commitment of our teachers with these educational innovation activities is noteworthy, as the teaching innovation experiences carried out in last ten years have led to the foundation of 17 Teaching Innovation Groups at ETSII – TU Madrid, hence leading the ranking of teaching innovation among all TU Madrid centres. The historical background was previously reviewed and presented at 10th International CDIO Conference, held in Barcelona in 2014 (Díaz Lantada, et al. 2014), and discussed at the Rejkiavik European Regional Meeting in 2015, which eventually led to our ETSII – TU Madrid joining the International CDIO Initiative, as first Industrial Engineering School of our country to fulfil the required criteria.

In any case, it is important to highlight that, at ETSII – TU Madrid, we are deeply concerned about students' involvement in their own learning process and implicated in strategic actuations for the promotion of project-based learning activities, linked to real products and systems, as drivers of curricular planning, of continuously evolving teaching-learning methodologies and processes, and of an outcome-based assessment. We have been working towards providing an integrated support framework for driving the aforementioned PBL actuations, searching for common principles, based on the "conceive – design – implement – operate" guidelines and standards. The implementation of the **"INGENIA" Initiative** has been the key for achieving standardized and complete CDIO experiences (from the conceptual stage to the operational phase) and for providing the 100% of our students with the opportunity of living the whole development process of a product or system, as detailed further on.

In short, the implementation of Bologna process has culminated at ETSII – TU Madrid with the beginning of the Master's Degree in Industrial Engineering, in academic year 2014-15. The program was successfully approved in 2014 by the Spanish Agency for Accreditation (ANECA), with the inclusion of a set of subjects based upon the CDIO methodology denominated generally "INGENIA", an acronym from the Spanish verb "*ingeniar*" (to provide ingenious solutions), also related etymologically in Spanish with the word "*ingeniero*" (engineer). INGENIA students experience the complete development process of a complex product or system and there are different kinds of subjects (and projects), within the initiative, covering most of the engineering majors at ETSII – TU Madrid. Students choose among the different INGENIA subjects (and projects), depending on their personal interests. It is important to note that the INGENIA subjects are compulsory for all students enrolled in the first year of the Master's Degree program at ETSII – TU Madrid (a two-year program with 120 ECTS after a four-year Grade in Industrial Technologies with 240 ECTS). The subjects (with a similar CDIO orientation but offering different topics and projects) are 12 ECTS equivalent, which correspond to a student workload between 300 to 360 hours, distributed along two semesters with the following structure: 120 hours of supervised work plus between 180 to 240 hours of personal student work, organised usually in teamworks. Professor supervised part of the subjects is divided into 30 hours dedicated to adapt basic theoretical knowledge derived from other subjects to those directly related with the project, and a second set of 60 hours is devoted to practical work in the lab, with professor supervised sessions. Students also receive two seminars of 15 hours; one oriented to transversal outcomes, in particular, workshops on teamwork, communication skills and creativity techniques, and the other one about social responsibility issues such as environmental impact, social, political, security, health, etc. The distribution of these lectures, practical sessions, seminars and workshops, is distributed along the 28 weeks of the two semesters of the first year, resulting in 5 hours per week of lectures or practical sessions in the regular schedule of students (Lumbreras et al. 2015).

Hours/week	THIRD SEMESTER	ECTS
	Final Master's Thesis	6
6	Curricular configuration	9
2	3 specialization subjects (Automation & Electronical,	3
2	Chemical, Electrical, Energetic, Materials,	3
2	Mechanical, Construction, Org.)	3
2	1 subject on Industrial Installations	3
2	1 subject on Industrial Technologies	3

Hours/week	FOURTH SEMESTER	ECTS
	Final Master's Thesis	6
6	Curricular configuration	9
2	3 specialization subjects (Automation & Electronical,	3
2	Chemical, Electrical, Energetic, Materials,	3
2	Mechanical, Construction, Org.)	3
2	1 subject on Industrial Management	3
2	1 subject on Industrial Technologies	3

Hours/week	FIRST SEMESTER	ECTS
4	INGENIA (first part)	6
2	2 subjects on Industrial Management	3
2		3
2	2 subjects on Industrial Installations	3
2		3
2	4 subjects on Industrial Technologies	3
2		3
2		3
2		3

Hours/week	SECOND SEMESTER	ECTS
4	INGENIA (second part)	6
2	2 subjects on Industrial Management	3
2		3
2	2 subjects on Industrial Installations	3
2		3
2	4 subjects on Industrial Technologies	3
2		3
2		3
2		3

Figure 2. Program structure (Master's Degree in Industrial Engineering).
120 ECTS program with at least 20% devotion to project-based learning activities.

Placing the INGENIA subjects in the first year of a 120 ECTS program is indeed interesting, as additional 12 ECTS are devoted to the final degree thesis normally during the second year. Therefore, at least 20% of the whole Master's Degree is devoted to project-based learning aimed at the complete development of engineering products and systems. Program structure is detailed in Figure 2 and the integration of CDIO activities can be easily appreciated (INGENIA subjects in pale blue and Final Master's Thesis in pale green). In addition, the INGENIA subjects are helping us to complement our competence-based strategy, in accordance with CDIO Standards 1, 3, 7 & 8, by placing special emphasis on several professional skills difficult to obtain in more traditional teacher-centred activities, such as conventional master classes and expert talks. Main perceived outcomes include the promotion of: students' ability to apply knowledge of mathematics, science and engineering, students' ability to design experiments and interpret data, students' ability to design engineering systems and components to meet desired goals, students' ability to communicate effectively and to work in multidisciplinary teams, or students' ability to use modern resources, in accordance with the ABET professional skills our program pursues (Shuman, et al.

2005). Table 2 includes the different CDIO topics (or subjects) taught within the INGENIA scheme for the academic year 2014-2015, covering several disciplines.

Table 1. CDIO topics of the INGENIA subjects for the last couple of academic years.

Different INGENIA Subjects	**Product / system developed & objective**
Formula Student	Students take part in the complete development project of a competition car, from the conceptual design, to the final competition.
Engineering design: Machine development projects	Students live the whole process of creating an innovative machine, from the conceptual design stage, to the final trials with real prototypes, searching for design improvements.
Development of daylife products / household goods	Students live the whole process of designing innovative products, from the concept step, to final simulations and trials with prototypes.
Smart systems engineering	Students experience the process of designing a smart system, using state-of-the-art engineering resources and taking account of the whole life-cycle. (A set of co-operative drones in current year).
Development of electronic devices	Students live the whole process of creating a new electronic product, oriented to improving daylife in our ETSII-TU Madrid, from the concept, to the prototyping stage and trials.
Development and management of industrial construction projects	Students experiment with information management and project planning resources applied to a real industrial construction project, (a beer-factory in the first two implementations) .
Development of electricity supply networks	Students live the development project of an electricity supply network, from an initial renewable energy source to population.
Biomedical engineering design	Students experience the process of creating an innovative medical device, from the conceptual stage, to the final trials with prototypes.
Finite-element and testing in machine elements (new 2015-2016)	Students design, model, manufacture and test machine elements for the automotive and aeronautic industries.
Development of video games (new 2015-2016)	Students live through the whole development process of a video game, from specifications, to implementation and testing.

Some of the proposals for the INGENIA subjects evolve from previous experiences, but most of them are novel initiatives consequence of the progressive involvement of our teaching staff in student-based teaching-learning methodologies for the promotion of integrated learning experiences (7th CDIO Standard) and of active learning (8th CDIO Standard). The topics from Table 2 cover most specializations of our Master's Degree in Industrial Engineering and we believe that all of them are interesting, although continuously improving the offer is a key-point. As additional reflection, the proposed two-semester structure for the INGENIA subjects is very appropriate, as the "conceive" and "design" phases are adequately carried out during the first semester and the "implement" and "operate" stages are tackled in the second semester. A whole academic year is ideal for maturing the development process of complex products and systems and is helping us to improve several prior experiences, limited to design and simulation activities, with the benefits from obtaining final prototypes and carrying out operational trials.

SYSTEMATIC DETECTION OF CHALLENGES AND DIFFICULTIES ALONG THE WHOLE IMPLEMENTATION PROCESS OF COMPLETE CDIO EXPERIENCES

Once the INGENIA Initiative, inspired by the CDIO approach, has been running for almost two complete academic years, we have decided to gather main challenges and difficulties linked to the whole implementation process of such a methodology for the promotion of complete CDIO experiences. The implementation of these experiences has been divided into different phases, including: planning and preparation, assignment and organization, project development (the actual CDIO experiences, which students live) and assessment. A survey has been prepared, highlighting some possible key aspects linked to the aforementioned phases. Eventually relevant aspects, ordered along the implementation process, include:

I) Planning and preparation of complete CDIO experiences

a. Designing projects that properly reflect how the subject evolves
b. Designing stages that will ensure progressive learning
c. Designing the assessment system to be used
d. Preparing a sufficient number of different questions
e. Preparing questions of equivalent difficulty
f. Choosing appropriate support tools
g. Implementing manuals and help examples
h. Implementing software support tools
i. Planning projects to fit the time allocated to the subject
j. Searching for a realistic approach ("real" projects) but feasible for students

II) Student organization and assignment of projects

a. Explaining to students the "PBL" methodology to be used
b. Students' acceptance of "PBL" methodologies as something positive
c. Decision between group and individual projects
d. Choosing the number of students per group
e. Group training process
f. Assigning projects (should students be unable to propose them)
g. Choosing projects (should students be able to freely propose them)
h. Acceptance of projects by students / teachers
i. Consideration of alternatives to "PBL" methodology, if appropriate
j. Project coordination and timescales compared to other experiences in other subjects

III) Development of the projects (the actual CDIO experiences lived by students)

a. Setting milestones throughout the process
b. Taking action to adapt students' starting-out levels
c. Tutorials throughout the process
d. Coordinating the development with other experiences in other subjects
e. Motivation and follow-up to avoid deviations in the results
f. Motivation and follow-up to avoid deviations in the timescales
g. Student access to learning resources
h. Student access to laboratories
i. Student access to software tools
j. Carrying out practice to back up the "PBL"

IV) Assessment

a. Setting a diagnostic assessment system to find the starting-out level
b. Setting an adequate system to evaluate knowledge
c. Setting an adequate system to evaluate skills
d. Setting an adequate system to evaluate generic competencies
e. Setting an adequate system to individualise group experiences
f. Detecting and controlling unacceptable conduct (copied projects, "parasite" students…)
g. Public presentation of results as a supplement to assessment
h. Use of other conventional assessment methods to supplement (final exam, test…)
i. Use of questionnaires to assess the progress of the experience and possible improvements
j. Use of questionnaires to evaluate students' work load

Such phases and eventual key processes have been implemented in form of survey, in order to evaluate their: i) relevance for the overall success, ii) difficulty of taking them into account, iii) maturity of implementation. Their connection with the main drivers of change (professors, students, environment and resources) is also evaluated within the survey. The degrees of relevance, difficulty, maturity and connection with drivers of change have been assessed from 0 (none) to 10 (extreme). The survey has been filled by members of the Managing Board at ETSII – TU Madrid, which have been involved in the conception, design, implementation and assessment of the INGENIA Initiative, as a multidisciplinary set of subjects with a similar approach for the systematic promotion of the CDIO methodology.

Main results regarding the most relevant processes are summarized and discussed below. In fact, some of the most relevant ones for the overall success are perceived as quite easy to handle, while some others still need special attention for an improved maturity, as will be pointed out in the lessons learned section. Figure 3 shows the relevance of the different phases linked to the whole implementation process of CDIO experiences and related relative importance of main drivers of change, as obtained directly from the survey results. It is interesting to note that the "development" stage, which corresponds to the actual development of projects by the students, is considered to be the most important. The "planning" stage, which corresponds to the strategic definition, orientation and preparation of the actual course, follows as the second most relevant phase. The "assignment" stage, which is linked to dividing students into groups and to assigning the topics and projects to be developed, and the "evaluation" stage, linked to students' presenting their results and to the final course assessment, are considered also quite relevant. In any case, there is not a single stage with an outstanding figure, when compared with others.

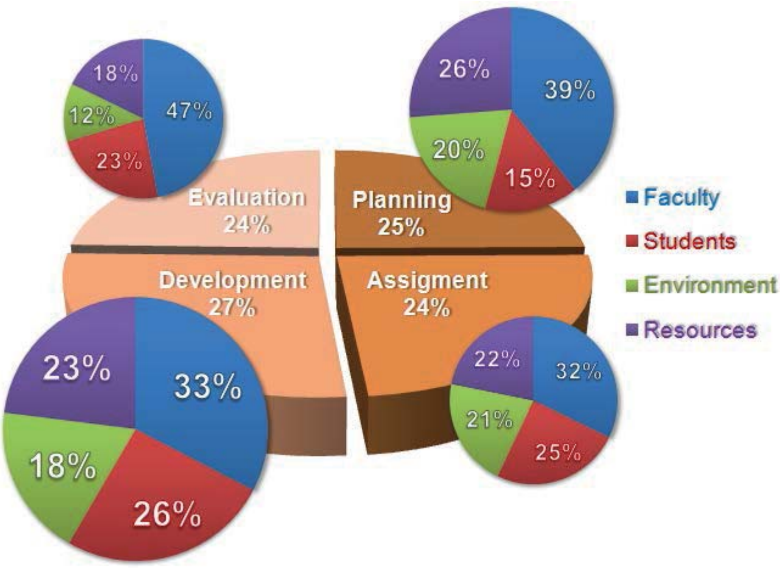

Figure 3. Relevance of the different phases linked to the whole implementation process of CDIO experiences and related relative importance of main drivers of change.

Regarding the drivers of change, it is interesting to note that in all stages professors (and their motivation and implication) have been perceived as the most relevant driver of change, not just in the planning, assignment and evaluation phases, but even in the development stage. In future studies we should also consider students' opinions, but we believe that the provided results are quite objective. Clearly the motivation of professors is a key for shifting from teacher-based to student-based Higher Education and for "re-thinking Engineering Education", as proposed by the CDIO Initiative.

Figure 4 presents the 12 more relevant aspects, which have received an assessment of "importance" above 9.25/10, within the different phases of the whole implementation process of CDIO experiences. Their "importance", "difficulty" and "maturity" mean values are presented and can be compared with the mean values of all aspects presented in dotted lines. The more relevant aspects, including: adequate explanation of the PBL methodology, definition of milestones and tutorials along the process, are in fact quite easy to implement and very mature in our CDIO-related experiences.

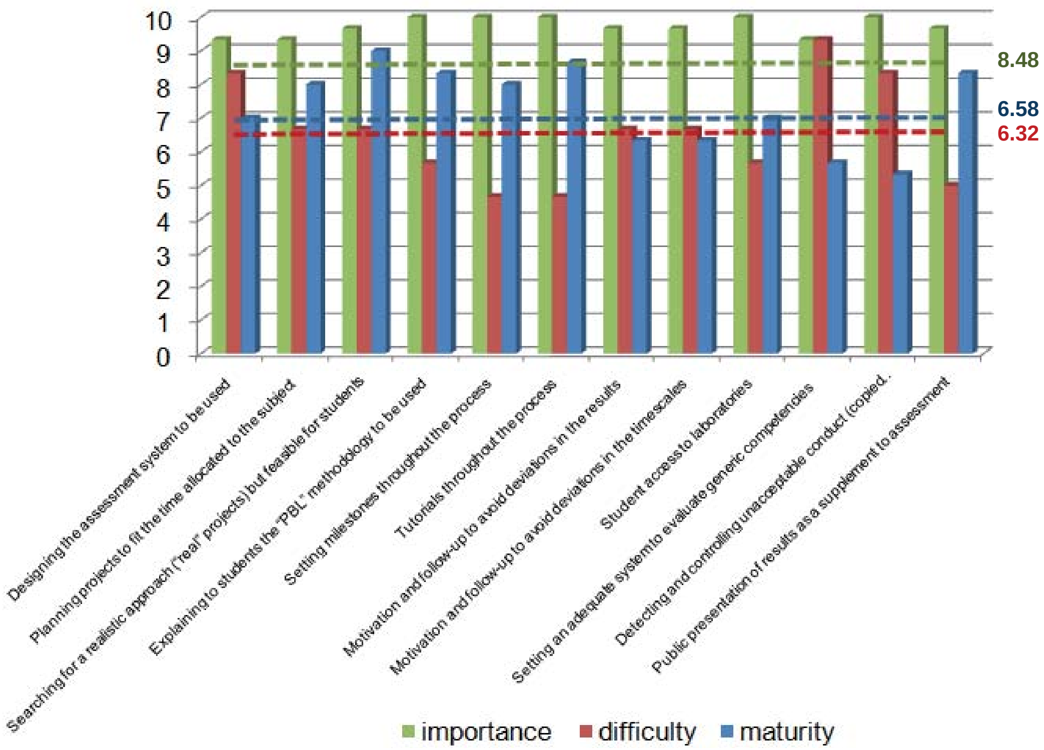

Figure 4. Importance, maturity and difficulty of the 12 more relevant aspects connected to the different phases of the whole implementation process of CDIO experiences. Mean values are presented and compared with the means of all aspects (dotted lines).

MAIN LESSONS LEARNED, GOOD PRACTICES AND FUTURE PROPOSALS

Although the gathered results can be additionally discussed (hopefully *in situ* with colleagues attending the Turku CDIO Conference) and even if deeper analyses are possible, we would like to summarize here some main lessons learned, good practices applied and future proposals in mind.

First of all, an adequate concentration, collaboration, communication and co-motivation between teachers and students during the development stage are fundamental good practices for the implementation of successful CDIO experiences. The planning phase, in which the professors are the clear main characters, is also of remarkable importance. Above all, the impact of the human factor (students and teachers) is much higher than the impact of the material resources and environment for the expected success of novel CDIO experiences.

In consequence, really interesting and formative CDIO-inspired courses can be implemented, counting with the efforts and motivation of students and teachers, without requiring many additional resources. This leads to highlighting the CDIO approach, not just as the preferred methodology for “re-thinking Engineering Education”, but also as a key towards the concept of “Engineering Education for all”, as it may well enable the performance of integrated learning experiences and the overall promotion of student motivation, without requiring vast investments, which may not be possible in the public universities of developing countries.

Regarding the future, we would like to expand the study to count with the opinions from students and colleagues, both at ETSI Industriales – TU Madrid, and even at other universities and centers involved in the International CDIO Initiative, so as to find other possible relevant aspects, which may not have been considered.

CONCLUSIONS

Present study has detailed the complete development of the INGENIA initiative, the main results from the first implementation from 2014-2015 academic course and the principal challenges and difficulties faced, when trying to systematically promote CDIO and to encourage a shift from traditional teaching-learning methodologies to student centered approaches. Present analysis has been carried out focusing on the main drivers of change: students, teachers, environment and resources, taking into account the opinions from the Managing Board at ETSII-TU Madrid, which have been systematically gathered by means of comprehensive surveys and interviews. Key aspects, including: student motivation, coordination between teachers and subjects, supervision of the projects under a tight schedule, promotion of topics for all industrial engineering areas, rapid prototyping resources for reaching the implementation and operation stages, among others, have been discussed and the more relevant lessons learned and proposals for improvement have been also put forward. We have also tried to provide an analysis about the impacts of such proposals for improvement on the second implementation from 2015-2016 academic year in which the INGENIA initiative has been performing with even better results and involving more than 250 students. We truly hope that present summary of key aspects and possible good practices, for the systematic promotion of active methodologies within a whole plan of studies and based on the CDIO approach, may be useful for colleagues desiring to carry out similar experiences.

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CREATING NEW DESIGN-BUILD-TEST EXPERIENCES AS OUTPUTS OF UNDERGRADUATE DESIGN-BUILD-TEST PROJECTS

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ABSTRACT

This paper describes a methodology of using individual engineering undergraduate student projects as a means of effectively and efficiently developing new Design-Build-Test (DBT) learning experiences and challenges.
A key aspect of the rationale for this approach is that it benefits all parties. The student undertaking the individual project gets an authentic experience of producing a functional artefact, which has been the result of a design process that addresses conception, design, implementation and operation. The supervising faculty member benefits from live prototyping of new curriculum content and resources with a student who is at a similar level of knowledge and experience as the intended end users of the DBT outputs. The multiple students who ultimately undertake the DBT experiences / challenges benefit from the enhanced nature of a learning experience which has been "road tested" and optimised.
To demonstrate the methodology the paper will describe a case study example of an individual project completed in 2015. This resulted in a DBT design challenge with a theme of designing a catapult for throwing table tennis balls, the device being made from components laser cut from medium density fibreboard (MDF). Further three different modes of operation will be described which use the same resource materials but operate over different timescales and with different learning outcomes, from an icebreaker exercise focused on developing team dynamics through to full DBT where students get an opportunity to experience the full impact of their design decisions by competing against other students with a catapult they have designed and built themselves.

KEYWORDS

Design-Build-Test, Project-Based-Learning
CDIO Standards: 5 (Design Implement Experiences), 7 (Integrated Learning Experiences), 8 (Active Learning)

INTRODUCTION

The benefits of project based learning (PBL) have been evaluated in a number of studies. An international panel of evaluators of the Aalborg experiment in PBL, which began in 1974, found students were enthusiastic about this method of learning and that these students recognised their PBL experiences as the main source of professional skills developed during their degrees (Kjersdam, 1994). A later analysis (Kolmos 2010) further identified that compared to other Danish institutions Aalborg had the highest retention rates and one of the highest percentages of students finalising their studies on time. A meta-analysis of 43 PBL implementations (Dochy et al, 2003) found robust evidence supporting skills being developed by students and also found that despite some lower initial scores in technical knowledge assessments, there was significantly better retention of acquired knowledge in the longer term among PBL students. In a review of the research into active learning Prince (2004) found evidence to indicate PBL develops students' abilities to solve open-ended problems and encourage an attitude of life-long learning. Prince also found that PBL frequently resulted in increased library textbook reading, improved class attendance and studying for meaning rather than simple recall. The rationale for CDIO Standard 5 (Design Implement Experiences) aligns with these findings and has been the inspiration for increasing the number of instances of such experiences within the degree programmes taught in the School of Mechanical and Aerospace Engineering at Queen's University Belfast (Hermon et al, 2010).

> *CDIO Standard 5, Rationale:*
> *Design-implement experiences are structured and sequenced to promote early success in engineering practice. Iteration of design-implement experiences and increasing levels of design complexity reinforce students' understanding of the product, process, and system development process. Design-implement experiences also provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills. The emphasis on building products and implementing processes in real-world contexts gives students opportunities to make connections between the technical content they are learning and their professional and career interests.*

Successful implementation of DBT experiences has however proved for many to be far from straight forward. Malmquist el al (2004) found in a review of DBT projects among the founding members of the CDIO Initiative that development was more complex than traditional courses and required appropriate new learning spaces to be effective. Additionally there tend to be additional costs incurred from the production of prototypes and functional artefacts in DBT projects that are not required in more traditional lecture style courses. As well as cost the throughput capacity of any prototyping or workshop facilities also becomes an issue if the DBT projects are to be used with larger cohorts. Among 7 key factors identified for effective implementation of DBT by Elger *et al* (2000) was an appealing topic that is amenable to simple prototype construction and a means to motivate students by using competition and/or public presentation. Setting a theme which students find attractive and which works well as a competition can however be a difficult task.

While the educational objectives and rationale expressed above are strongly held and while the desire to continually improve and extend the DBT content within the School's programmes exists there are also other demands on Faculty members time that make the development of new DBT exercises challenging, given these DBT exercises are more complicated and resource intensive than lecture based courses.

Inspiration

The inspiration for the methodology described herein was a paper presented at the Engineering and Product Design Engineering Conference (E&PDE 2013) at the Dublin Institute of Technology in September 2013. The work of Leutenecker et al (2013) relates to a mechatronics Design-Build-Test challenge at ETZ Zurich based on moving items up a scaled model version of a mountain with a device designed, built and operated by the students which attaches onto a cableway. The exercise described operated successfully with 550 participating undergraduate students of mechanical engineering and emphasised the differences between simple "funky" prototypes and more complex functional prototypes in meeting the educational objectives of the course. A key piece of equipment which enabled the rapid production of many fibre board prototype components was an industrial standard laser cutter. The large number of students involved and the fast turnaround of prototype components was of particular interest not only because of the growing number of students in the School of Mechanical and Aerospace Engineering (SMAE) at QUB but also because this conference coincided with the specification of equipment for a new Student Design Centre (FabLab style facility) within the refurbished laboratory building in the School. The identification of a successful implementation in a comparative degree programme proved to be very timely indeed.

Development of the Methodology

The commissioning of the CadCam FB1800 laser cutter and the handover from the refurbishment contractors of School's new Student Design Centre was completed in October 2014; a few weeks into the start of the new academic year. There was therefore insufficient time to have a DBT project using this equipment ready and tested for that teaching period. Instead a proposal to run an individual student project with the new equipment was proposed. As this project would involve some paper based fact finding in the first few weeks the lack of immediate availability of the equipment could be accommodated within the project work plan.
It was the initial definition of this 3rd year project (full year, 15 ECTS credits) and the requirement to meet the specific learning outcomes of the module that led the author to further develop the methodology described in this paper.

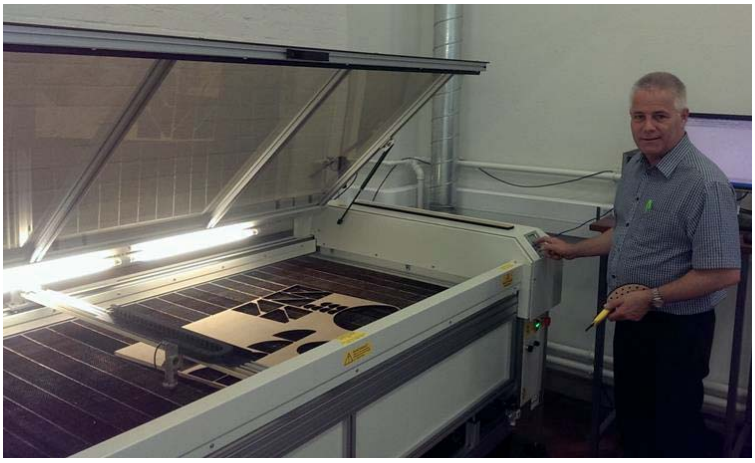

Figure 1 - CadCam FB1800 laser cutter in the QUB SMAE Student Design Centre

Case Study - DBT Challenge Development (Table Tennis Ball Catapult)

The description below is the original text from the project proposal. This was put into a pool of projects from which the students rank their preferences. Projects are allocated to individuals with the highest GPA students getting their selections considered first.

> *Aims:*
> *Using the 'Innovation Process' Course at ETH Zurich as an example of what can be achieved with a cohort of 500+ students over the period of one semester, the objective of this project will be to develop and prove the viability (time and cost) of a new "Design for Manufacture" Design-Build-Test (DBT) challenge project for undergraduate students in the School of Mechanical and Aerospace Engineering. Since ETH Zurich makes effective use of a 2D laser cutter as the primary manufacturing tool for their project it is anticipated that this challenge will be based around the use of the School's new laser cutter (CadCam FB1800)*
>
> *Outline work plan:*
> - *Literature review of existing student DFM project challenges*
> - *Familiarisation with CDIO methodology*
> - *DBT challenge theme ideation, selection and definition*
> - *Realisation of functional prototype to meet the defined challenge brief*

- *Evaluation of time, cost and resource requirements for the context of a large cohort of students.*

Project Deliverables:

- *Define a "Design for Manufacture" Design-Build-Test challenge design brief.*
- *Quantify resource requirements for a range of cohort sizes to complete the challenge over 1 or 2 academic semesters.*

The individual projects in this module run over a full academic year, carry 15 ECTS credits with students expected to spend 300 hours working towards the project deliverables. The project in question was allocated to a 3rd year BEng Product Design Engineering (PDE) student.
The student experience was essentially similar to that any other design project that would have run in this module but instead of the task being to design of a piece of test equipment for research or a widget of no future use the objective was to design an artefact that would be used as the basis of a design challenge for future teaching.

The underlying pedagogical theme of the project is one which actually is very attractive to the BEng PDE cohort in the School. A previous analysis of the destination of graduates from the programme (Hermon, 2013) identified that a significant minority (10%) of BEng graduates take a further year of study to gain a Postgraduate Certificate in Education (PGCE) and go on to become secondary level teachers of Technology and Design; an A-Level subject which the majority of applicants to the PDE programme possess. This therefore effectively utilizes what might otherwise be an underused resource of students who are inclined towards a teaching career. These students have a strong motivation to produce a good project in this subject area, since it will help them not only with their PGCE application but also with their future careers. This high percentage of BEng graduates pursuing a teaching career had been one of the more surprising results of the analysis of graduates, but one which helped identify their potential as developers of curricular content.

Over the 24 weeks of the Autumn and Spring semesters of 2014-15 the student project followed the outline work plan. During the weekly review meetings between student and supervisor it became apparent that the original emphasis on design for manufacture (DFM) could be extended to involve more design iterations. This was concluded since the initial measurements of cutting time for sample parts demonstrated that extremely fast turnaround of drawings to components could be achieved. It is worth noting at this point that the total cutting time for one set of components for the catapult device is under 20 minutes. While the focus of the challenge moved away from DFM and more to DBT the manufacturing tolerances and cutter compensation (required due to laser beam width) still needed to be considered when modelling the CAD components in the design phase (if operated in that mode).

The supervisor had a significant influence in the direction of project but with minimal time input of around 1 hour per week, mostly the review meetings. The student was the principal hands-on investigator. All of the design details and CAD modelling was done by the student, as was the production of drawings (DXF files mostly), the measurements of manufacturing tolerances, the assembly of components, the experimentation and alteration of parameters, iterative design modifications and liaison with the production manager. In total for a 15 ECTS credit module like this the expectation at QUB is that the student spends around 300 hours in total. While an experienced Faculty member might reach the same outcome faster than this there are some aspects such as the experimentation, testing and iterative changes which are necessarily time consuming and cannot be skipped.

One benefit to the student is that this type of active learning develops experimental and practical skills which are often absent on university entry.

One benefit to the supervisor is that the student is much closer to the target audience (in this case summer school / first year undergraduate / prospective undergraduates) in cognitive development and more able to provide valuable feedback on aspects such as the level of challenge or on the suitability, enjoyment and motivational aspects from a student perspective. Often an expert or senior academic forgets what it is like to not know something or to remember how some fundamental concept was learnt. In this respect the student had a major influence on the choice of theme. A catapult was chosen because the underlying mathematics on the trajectory of projectiles is part of the A-Level syllabi students entering the School will have studied previously. The application of mathematical modelling into DBT projects was another of the key success factors identified by Elger *et al* (2000) so the selection of a theme with a close link to fundamental mathematics opened up the possibility of getting students to justify design decisions on the basis of mathematical modelling. To assist with this an Excel spreadsheet (Figure 2) developed previously for an introductory course in the School was supplied to the students undertaking the design challenge mode.

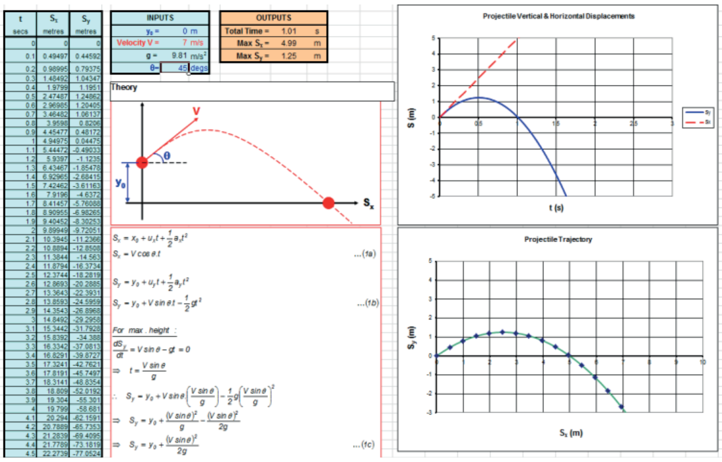

Figure 2. Excel spreadsheet for parabolic trajectory (credit CD McCartan)

Operational Modes

Three modes of operation have been developed and tested which use the same catapult design and components. In all 3 modes of operation the objective of the competition is the same; to propel a standard table tennis ball a range of distances (not precisely known in advance) of between 1 and 5 metres into a bucket (Figure 3).

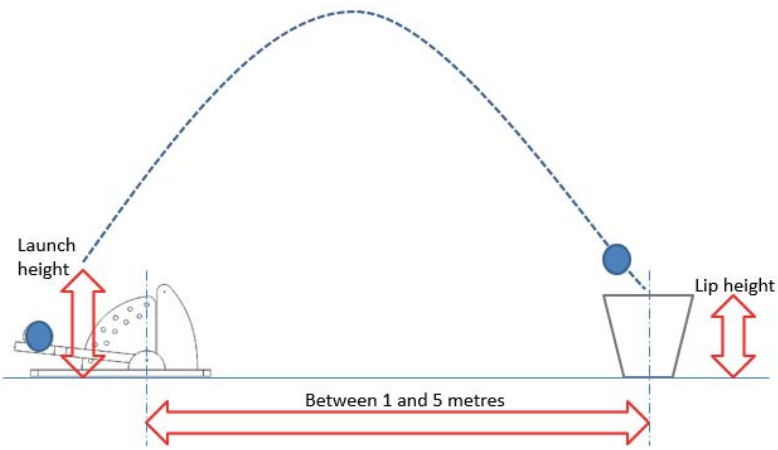

Figure 3. Table tennis ball catapult competition objective

Mode 1:
8x 3 hour sessions (summer school): Build-Test-Redesign-Build-Test-Compete
Note - This mode presumes the students have previous CAD experience sufficient to be able to modify existing parametric 3D models and / or create new components and assemblies.

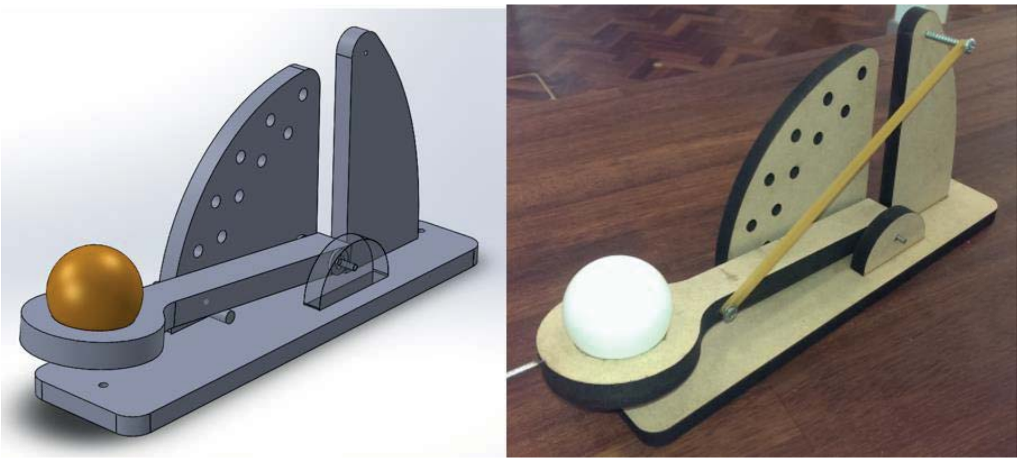

Figure 4. Mode 1 basic catapult (CAD model and MDF assembly)

In this mode the students get the full experience of designing their own device and then building this for a competition against their peers.

Initially the basic catapult is provided as a kit of parts. The students assemble and then proceed to test the device, characterising its performance for different launch angles and launch velocities. This is done by altering the number of elastic bands and the position of the pin which stops the arm rotating, hence launching the ball. The basic design however is deliberately flawed and when trying to throw the ball 5 metres can often break either about the pivot pin or where the arm strikes the stop pin. Some students like to immediately see how far they can throw a ball and quickly damage their device. In anticipation of this it is wise to make a few spare arms as replacements. The handover of these however can be delayed to simulate delivery time, as it would be in the real world. This also gives time and opportunity to discuss methodical test approaches with the students to improve their experimental practice. This aspect of this mode of operation was identified from a failed early iteration of the design. This highlights the benefit of having a sufficiently long test period to prove out the design, as is accommodated for in the undergraduate project schedule. A second design flaw in this initial design relates to the fact that the vertical sections are simply glued into slots in the base. The main quadrant with the holes that locate the stopping pin does over repeated testing tend to move up and out of the base. This provides another area of the device in which the students have scope to make and test their design improvements.

After a period of range finding and experimentation with the Excel file the students are made aware of the competition challenge and given a time schedule for design and manufacture of their components.

After all drawings have been submitted for manufacture the lecturer shares the details of an improved design (Figure 5) and runs a debrief session discussing the design rationale and the relationships to the mathematical theory. This provides the students with an example of how technical details of a design might be effectively communicated. They also receive instruction at this point on manufacturing tolerances and cutter offset compensation (due to laser beam width) that need to be taken into consideration when producing models and related DXF files for their designs.

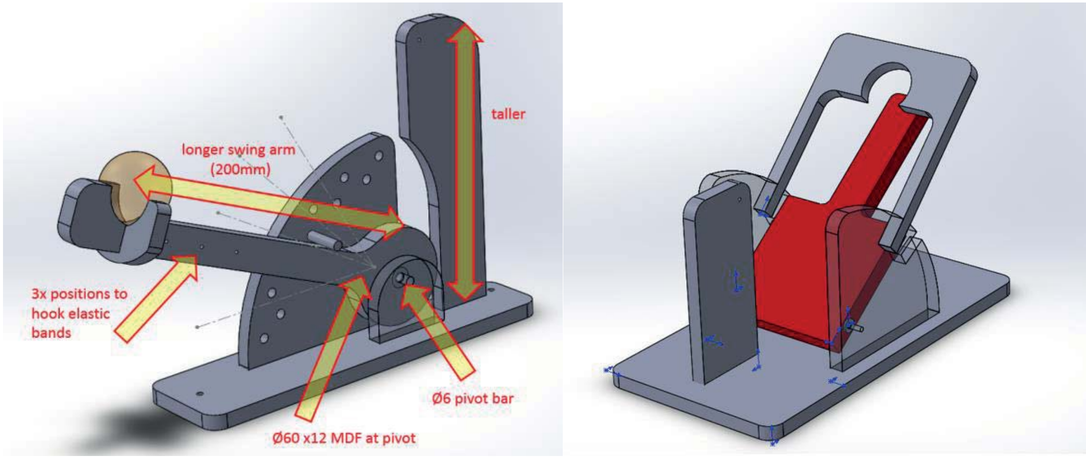

Figure 5. Mode 1 lecturer's improved catapult design (left) & summer school student design

After a scheduled break in the sessions (hours or days, depending on the cohort size) to allow all components to be manufactured the students next assemble their own designs and start experimental testing to characterise their own device. The sessions end with a competition which both keeps the students motivated to do well against their peers and also provides a nice climax to the sessions.

Optionally the students can be asked to make a short presentation explaining their design, the rationale for how it was developed, and reflection on how their device performed in the competition.

Mode 1 Learning Outcomes:

- Use of mathematical modelling to drive design decisions
- Use of DFM guidelines with respect to manufacturing tolerances
- Application of CAD skills
- Development of experimental practice and team working skills
- Development of communication skills (optional final presentation)

Mode 2:
2x 3 hour sessions (secondary school outreach): Build-Test-Compete

This mode is intended to give prospective students an enjoyable experience with an introduction to the active learning approach used in a cdio-centric degree programme.
The improved design shown in Figure 5 is provided in kit form for assembly by the students. This design is used because it is more robust and should not break if operated with the intended projectile range. The students assemble and test their device in the first 3 hour session with little instruction. The parts simply slot together and are fixed with wood glue. It is possible that these students might never have made anything so it is considered important to let them get hands on experience and then get to experiment with something to which they feel a sense of ownership. After lunch they are given a short presentation about experimental practice, and a brief introduction to manufacturing tolerances with respect to assembly fits, before being allowed some further time to perform more structured testing. The day ends with a competition, prize giving, photographs and a short debriefing session to highlight the active learning approach and the learning outcomes.

Mode 2 Learning Outcomes:

- Experience of basic component assembly
- Development of experimental practice and team working skills
- Introduction to engineering tolerances, limits and fits
- Awareness of cdio and active learning approach

Mode 3:
1x 3 hour session (team working icebreaker): Test-Compete
This shorter single session can be used as an icebreaker at the start of an undergraduate team project. The emphasis is on getting the students involved in something which requires co-operation. The students are provided with a pre-assembled catapult (improved design type) and given the competition objective information (Figure 3). They are then told to get started to test and characterise the device. After about 30 minutes, of usually aimless and unorganised "play", the lecturer(s) who have been observing the students attempts call a halt and give a presentation about experimental best practice (Figure 6), and advised on appropriate roles for team members.

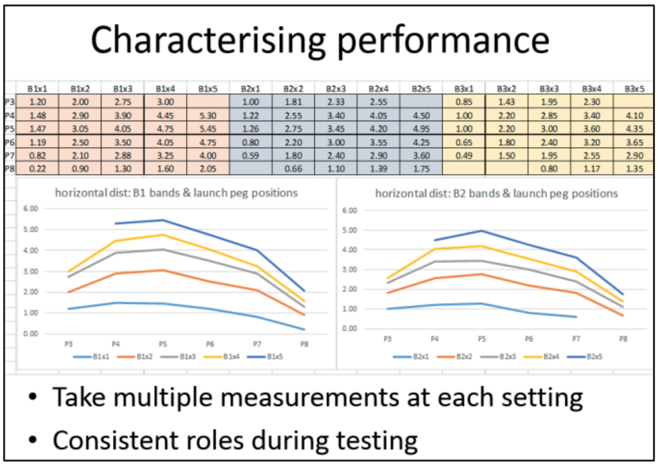

Figure 6. Slide from presentation on experimental best practice

The students then have about 90 minutes to conduct a more structured investigation before the session finishes with the usual competition.

Mode 3 Learning Outcomes:

- Development of experimental practice and team working skills

Examples of Operational Modes
The 3 modes have been operated successfully on live student groups. The longer format Mode 1 with a group of 28 Chinese summer school students as one of 4 accelerated modules studied over a 4 week period in August 2015. The shortest icebreaker session (Mode 3) with a cohort of 82 year 3 MEng Mechanical and Product Design Engineering students in week 1 of their major year-long group DBT project in September 2015. The Mode 2 outreach version was used with a group of 38 "high flying" secondary school students as part of an initiative to attract more of these high caliber students into engineering subjects at degree level, also in September 2015.

Anecdotal evidence and feedback sheets gathered at these events were overwhelmingly positive but no formal evaluation was done as part of this paper.

Current Projects in Progress
In academic year 2015-16 the author is currently supervising 2 new projects using the same methodology with the objective of generating new equipment and DBT design challenges:

1. Design and build a test device to explore the parameters influencing the flight of table tennis balls, particularly how spin affects trajectory.
2. Design of an undergraduate Design-Build-Test experience which integrates engineering science from the stage 1 modules in the School of Mechanical and Aerospace Engineering.

In both cases the laser cutter is again the “workhorse” for manufacturing components but both projects are also seeking to extend the links to other modules in the curriculum by including elements of fluid mechanics, machine elements such as bearings and gears, electric motors and control systems.

CONCLUSIONS

The case study described herein demonstrates that student projects can produce outputs that are suitable for use as teaching resources in DBT design challenges and experiences. Effective use was made of a previously untapped resource of BEng Product Design Engineering students, with in interest in following a teaching career, as developers of curriculum content appropriate to their peers.

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The hard work and perserverance of both of these individuals has contributed to the development of a valuable resource.

BIOGRAPHICAL INFORMATION

J Paul Hermon, is a Senior Lecturer (Education) in the School of Mechanical and Aerospace Engineering at Queen's University Belfast, is Programme Director for the Product Design Engineering degrees and Co-Chair of the CDIO UK & Ireland region.

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MOBILE PHONE PHYSICS LABORATORY

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ABSTRACT

In an attempt to increase the part of practical work in a first year physics course at the Faculty of Business ICT and Chemical Engineering we have introduced mobile phone laboratories for one group of students. Mobile phones have a large number of sensors to measure changes in the orientation of the device, acceleration, light conditions, sound levels etc. These sensors can also be used for measuring physical phenomena. This paper reports a short study of the feasibility of open, less guided, experiments in the field of mechanics. The study was done during a part of the Engineering Physics course given to our international information technology students. At the same time we studied the effect of activity based assessment and compared it with the results from an exam like exercise. As a result from this study we can conclude that introducing mobile phone laboratories made the course more attractive. But, the activity based assessment is in need of an update.

KEYWORDS

Physics Education, Laboratory, Active learning, Assessment, Standards: 5, 7, 8, 11

INTRODUCTION

Changes in the university funding drives the development of the education towards larger student groups and less contact hours in an attempt to cut costs. This makes it more and more difficult to give all students enough time for practical laboratory exercises. At the Degree Programme for Information Technology the amount of credits in physics have been cut from 15 ECTS credits down to 10 ECTS credits when the curriculum changed 2014 (Turku University of Applied Sciences). At the same time the resources given to the teachers for development of courses and lecturing were decreased.

The current set of physics courses at the degree programme consists of two separate courses, Engineering Physics and Measurements in Physics, worth 5 cr each. Both courses are given during one semester. The first course covers the theoretical part including mechanics, electricity and optics. The second course is as the name indicates focused on measurements and presentation of measurement data. From the student perspective the first course has been considered theoretical in the sense that the part where students actively participate has been limited to traditional problem solving. On the other hand, the second course is mainly based on student activating practical work. Due to the restrictions in the laboratory, regarding space and equipment, not all students can do the same laboratory work at the same time. This makes it difficult to connect the laboratory works in the Measurements in Physics course with the theory in the Engineering Physics course. Students may be forced to do an experiment before they have the corresponding theory.

To solve these problems we have tried to introduce experiments as home work for the students in within the Engineering Physics course. As almost all of our students have smart phones, we decided to use mobile phones and the sensors in the phones as measurement tools. In this way no extra resources was needed to build the mobile phone physics laboratory.

DEVICES AND SOFTWARE

Most smartphones are equipped with motion sensors such as accelerometers and gyroscopes. The main purpose for these sensors is to sense changes in the spatial orientation of the device. But they can also be used as sensing elements for mechanics measurements (Kuhn et al., 2013). In this test our students used their own phones. As a consequence different brands, models and operating systems were used.

To be able to read the sensors and get the data in a form that allows us to analyze it a dedicated software is needed. There are several different possibilities available on the market. However, few of them are available for all operating systems. In this study the students were recommended to use the Physics Toolbox (Physics Toolbox) if they use an Android is IOS device. For Windows phones the Sensor Emitter (Sensor Emitter) is one option. The drawback with the latter software is the data transferring that requires an in situ contact with a computer.

THE ENGINEERING PHYSICS COURSE

The Engineering Physics Course is a 5 ECTS credit course. The course was given to our first year international students at the Information Technology programme during their first semester. The early intake for the programme is 40 students and this year 42 students registered for the course. The content was divided into 12 weekly topics and two week time for an individual final project. The weekly topics were:

Week 37: Introduction, fundamental laws of motion and the SI system
Week 38: Independent exercises
Week 39: Force and motion, Newton's laws of motion
Week 40: Independent exercises
Week 41: Application on Newton's laws of motion
Week 42: Independent exercises
Week 43: Work, power and energy
Week 44: Electric fields
Week 45: Magnetic fields
Week 46: Electric circuits
Week 47: Optics
Week 49: Temperature and heat transfer
Week 50 - 51: Independent final project

The students had 3 contact hours every week of which two were dedicated for theory and one for exercises. As an addition to normal physics exercises the phone physics laboratory was introduced week 41 and 43. The students formed groups of 3 to 5 persons for the laboratory exercises. The course was assed based on the student activity and returned exercises and reports. The reports exercises were marked with scores on a scale from 0 to 2, 0 = no report or not acceptable, 1 = acceptable or late report and 2 = good report. The impact of the individual final project was larger than the impact of the other exercises and reports. It was graded on a scale from 0 to 6. The last traditional exercise was held in the same way as a final exam but with the difference that the impact on the final grade was as small as for an ordinary exercise. However, it was also graded as a traditional exam to enable a comparison of the activity based assessment and a traditional exam. Feedback was collected after the course to evaluate the effect of introducing experimental work to the theoretical class.

Mobile Phone Physics Laboratory Exercises

The main idea with the Mobile Phone Physics Laboratory Exercise was to introduce more hands on experiences of physical phenomena for the students. They should also get a feeling of how to design an experiment and analyze collected data. To facilitate the learning of the latter two themes the given tasks were open in the sense that the students could decide within the groups how to measure the phenomena and how to analyze the data. However, some leading questions were given. Students were also supposed to build their own measurement setup using items that they find “at home”. All groups should report their work with a video recording and a theoretical calculation of a similar simplified problem. As an example a problem could be;
“Study a pendulum using you your mobile phone. What useful data can be measured? What happens if you change the pivot point, i.e. the length if the suspension? What happens if you increase or decrease the deviation from the position where the pendulum is at rest? Make a video showing your experiment and give a theoretical explanation of your findings.”

RESULTS

The overall student activity during the course was higher than during earlier versions of the same course. One reason is clearly the assessment system that was based on continuous assessment and student activity.

The idea that the students should do the experiments on their own time outside the school did not work as planned. Is seem that it was too demanding to ask them to design their experiments without help. To overcome this problem we used some of the lecture time to do the experiments.

Another problem was the data analysis part. Not all groups were able to analyze the data in a way that connected it to theory. This was to some extent a problem that we expected to have, the students are first year students and they haven’t had courses in data analysis. However, some of the problems arise from using the software in the phone, saving data and transferring it to a computer. This was a thing that we expected them to learn easily as they are information technology students.

Looking at the outcomes from the experiments we found that the students did participate actively in this part of the course. Almost all participated in the experiments and all groups returned a report. Doing the work in groups is of course one to activate individuals as the group members push each other. However, it can also be a way to enable free riders. But comparing the in class activity in the course Measurements in Physics, were the same group did traditional guided physics experiments, with the in class activity during the more open experiments in the Engineering Physics course the activity was much higher in the latter. In the best cases the groups developed their experiment setups during the process to get better data e.g. one group started to use two strings as suspension to eliminate rotation of mobile phone that was used as the bob.

In a comparison with previous years the overall through put of the course was better than before. The reason for this may be that the dropout rate during the course was lower. A comparison between the grades from the activity based assessment and the last exercise shows that the grades in many cases are close to each other when the grades are low or on an average level but there are huge differences when the activity assessed grades are high. In some cases an exam would have given a better grade, see Table 1.

Table 1. Differences between activity based and exam based assessment

Stud. ID	Activity based	Exam based	Stud. ID	Activity based	Exam based	Stud. ID	Activity based	Exam based
ID 10	5	1	ID 35	4	0	ID 17	2	0
ID 16	5	0	ID 39	4	1	ID 24	2	2
ID 18	5	1	ID 40	4	1	ID 5	1	3
ID 22	5	2	ID 1	3	3	ID 14	1	2
ID 26	5	1	ID 2	3	2	ID 19	1	0
ID 33	5	2	ID 6	3	2	ID 38	1	0
ID 36	5	3	ID 7	3	5	ID 4	0	0
ID 41	5	1	ID 15	3	4	ID 8	0	0
ID 21	4	1	ID 25	3	2	ID 12	0	0
ID 23	4	0	ID 27	3	3	ID 13	0	0
ID 29	4	2	ID 31	3	1	ID 20	0	0
ID 30	4	2	ID 3	2	2	ID 28	0	0
ID 32	4	3	ID 9	2	1	ID 37	0	0
ID 34	4	2	ID 11	2	1			

Most of the students that got a good grade form the activity based assessment did put down a lot of work on the course but were not able to write a good exam. It could be that that the activity based assessment leads students to learn to find solutions to problems but not to solve problems by them self. It is worth thinking on what we want to assess.

The collected feedback was overall good. Open comments about the mobile phone physics laboratory experiments were encouraging. The students liked the experiment as they shed light on the theory. The most negative comments were given on the amount of feedback given on returned exercises. The quick grading on the scale 0 – 2 did not give enough feedback and the evaluation was late. The quick evaluation was introduced to speed up the evaluation process to enable fast feedback. This did not work, the process required still too much work and was too slow. Some students would have liked more traditional teaching with more guided examples solved in class.

CONCLUSION AND FUTHER RESEARCH

The attempt to introduce mobile phone physics laboratories in a first year engineering physics course to increase the active learning and hands on experiences was partly successful. Most of the students enjoyed the experimental part and participated more actively in the learning process. However, the learning out comes were not as good as we expected. There was clearly a need of more support in the experiment design and data analysis part. This problem could be overcome by a deeper integration of the two courses Measurements in Physics and Engineering Physics.

The increased student activity during the course and the activity based assessment gave a higher trough put. However, the assessment based on activity and returned reports in need of an update. It is of great importance that the assessment leads the students to gain the skills that we want them to have. The activity based assessment lead students to seek solution to problems but not learn how to solve them independently.

There is clearly a need of further research concerning the learning outcomes. Another interesting topic would be to study the effect of usage of the accelerometers in mobile phones for visualizing coordinate transformations.

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BIOGRAPHICAL INFORMATION

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EDUSCRUM – THE EMPOWERMENT OF STUDENTS IN ENGINEERING EDUCATION?

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ABSTRACT

The students are not all alike. It is one of the characteristics of the human species that makes it especially adaptable to the formation of communities: people complement each other. So, if students have different characteristics, a rigid “one-size-fits-all” approach will not be successful. It may be achievable, if you try to find a lowest common denominator, but we all know what that means: wasting most of the students' potential.
In this paper we describe the application of a Scrum based pedagogical approach to several courses of the Informatics Engineering bachelor program of ISEP (LEI-ISEP). eduScrum is a framework where much of the responsibility for the learning process management is delegated from teachers to students, both in terms of time and effort management. This flexibility allows for multiple student profiles to actively participate in the learning process.
eduScrum builds on top of the Scrum project management methodology and active learning best practices, such as peer learning and embrace correction.

KEYWORDS

eduScrum, Active learning, Learning Assessment, Standards 8, 11

INTRODUCTION

Instituto Superior de Engenharia do Porto (ISEP, School of Engineering - Polytechnic of Porto) is the largest polytechnic engineering school in Portugal with more than 6500 students and over 400 teachers. It is located in Porto and lectures 12 first cycle and 10 second cycle Bologna programs. 11 of this programs are EUR-ACE accredited.

Licenciatura Engenharia Informática (LEI-ISEP) is a Bologna1st cycle Informatics Engineering program (3 years – 180 credits) created in ISEP in 1985, but extensively improved in 2006/07 with the adoption of Bologna declaration in Portugal. The new structure is based on ACM Computing Curricula (2005), namely a combination of the Computer Science and the Software Engineering curricula, and structured along the CDIO principles.

The program is structured in 6 semesters:

- Semesters 1 to 5 have 12 weeks of ordinary classes (4 or 5 courses per semester) followed by a 4-week long design-build course.

- The last semester has some 3 semester-long courses, but it is mainly devoted to an internship/capstone project (18 ECTS).

In all, in the 2015/16 school year, there were 1323 students enrolled in LEI-ISEP, 415 in the 1st year, 421 in the 2nd and 487 in the 3rd. These numbers are not enough to characterize LEI-ISEP, as the student population is far from being homogeneous. For example, most students attend daytime classes, but there are 346 students enrolled in nighttime classes (18:00 to 23:30), usually because they have full-time jobs. Also, most students are enrolled as ordinary students (5 or 6 courses per semester), but there are 304 students enrolled as partial students, which have half the number of courses per semester of an ordinary student (maximum of 3 courses), thus taking at least 6 years to graduate. Most of these students attend nighttime classes.

Such a heterogeneous environment is the direct result of the massification of higher education and is not by any means exclusive of LEI-ISEP. Governments are a driving force in this process, using higher education as a fast paced social engineering tool, especially in southern Europe countries, which trail northern Europe countries in most education indicators. LEI-ISEP has a key role in this process of upward mobility, as roughly 25% of the students need to have a full time job to pay for their studies.

As students are not all alike and have different expectations regarding their higher education experience, the school should provide different learning processes somehow adapted the students' profiles. Nevertheless, there are several constraints:

1. School's internal pedagogical regulations, which strongly limit the existence of different assessment paths in a course.
2. Outcomes-based program accreditation processes, which require that a minimum set of outcomes must be the same for every student. Thus, different learning processes must have the same outcomes.
3. Working students class attendance is not mandatory by Portuguese law, though most regularly attend classes. Nevertheless, many working students have sometimes to skip some classes due to their jobs.
4. Not all students are enrolled at the beginning of the 1st semester, especially 1st year students. There are several different national application processes for 1st year students, so it's possible for a student to be enrolled one month after the beginning of the semester.
5. Lecture attendance is quite low (on average), as it is not mandatory. Still, some courses' lectures do have a high attendance (e.g. over 70%), which shows that students value lecture quality.
6. Students usually prioritize their effort, so coursework that does not contribute to the course's grade is usually given a very low priority or left undone.

Active learning (standard 8) must be dominant in a CDIO program. Active learning means different things to different people, so that it would be useful to have a reference/catalog for active learning methods. The Pedagogical Patterns Project (PPP) has the produced the book "Pedagogical Patterns Advice for Educators" (PPP, 2012), to try to capture the expertise of teaching practice/learning in a compact form that can be easily communicated to those who need the knowledge. Many of the pedagogical patterns in the book are focused on active learning. Figure 1 provides a mind map of the active learning patterns on the book.

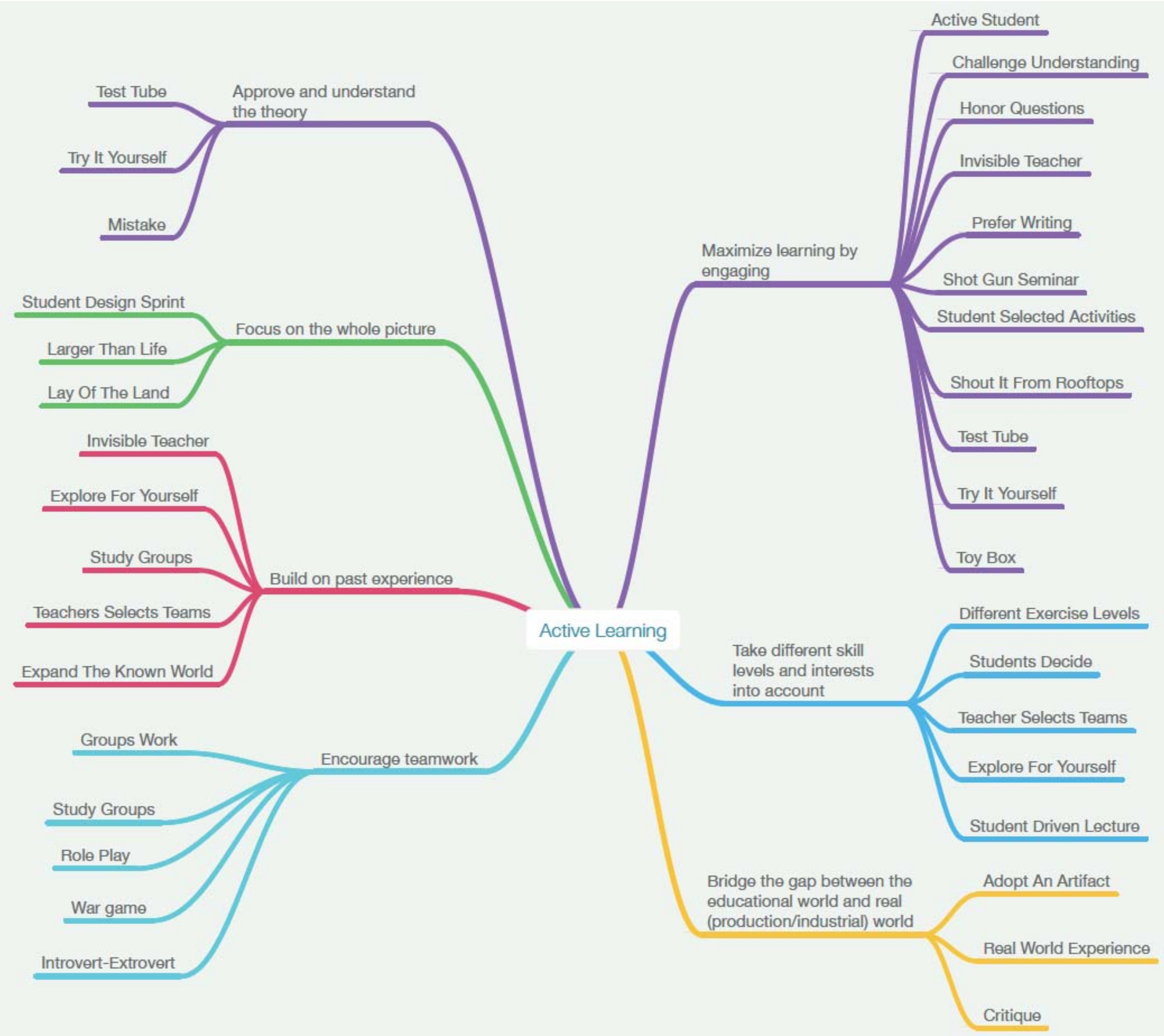

Figure 1 Active learning pedagogical patterns

ACTIVE LEARNING IN LARGE PROGRAM

One important aspect of active learning is student engagement and this can hardly be achieved by applying a standard “recipe” to all students. Flexibility is paramount. The teacher must continuously adapt its approach and select the appropriate methods in order maximize the effectiveness of the learning process. This is quite achievable in a course with one or two teachers and a small number of students, but quite hard in a course with 400 students and 10 teachers. It is quite difficult o providing a consistent learning experience to all students with a large teaching staff team, especially in courses with a strong practical component, lab classes and group work.

Lab classes are especially challenging, as students have different learning and working speeds. Groups help mask some differences, but they will hardly work at the same rhythm. A “forced march” approach may be used to achieve intra and between class synchronization, but it will hardly result a productive learning process for the students. Worse, experience shows that students will organize themselves in order to ease their march, creating two types of groups: the best students and the left behinds. This is the recipe for disaster.

To force the creation of heterogeneous groups may look to be a solution, but in a “forced march” scenario it will move the rupture forces inside the group. Working in a heterogeneous group is not easy, because of different working and learning speeds, background knowledge, work ethics, individual objectives, etc. (Martins et al., 2013). But this is what happens in real life, in the workplace, where heterogeneous teams are the norm, not the exception. The program should prepare students for real life, so its learning processes should encourage good teamwork practices. That’s, where eduScrum can be very helpful.

TEAMWORK USING SCRUM

Scrum (Sutherland, 2014) is an agile project management methodology widely used by software companies worldwide, but applicable to any area. The main concepts behind Scrum are:

- Team empowerment – the team manages its own work (task allocation) and periodically reviews its internal processes in order to continuously improve.
- Sprint based scheduling and planning – at the beginning of each sprint, a set of tasks are chosen form the project’s backlog, i.e. work to be done, and a work plan is defined for the sprint. Fixed length sprint are used (e.g. 2 weeks) and the tasks not finished at the end of the sprint go back to the backlog.
- Periodic client feedback – the project has a client, be it internal or external to the organization, which provides feedback at the end of the sprint. Work not accepted by the client it is not finished and goes back to the backlog.

eduScrum (http://eduscrum.nl/) is an adaptation of Scrum to education. It was created and first applied in secondary education (forms 7 to 12) in the Netherlands, but it can easily be applied in higher education and professional training. It can be used in any class context where teamwork is dominant.

Engineers work in teams. In the context of LEI-ISEP, a software engineering program, teamwork and interaction with a client are paramount. Thus, the application of Scrum to the classroom of one of the most widely used agile software development methodologies looked quite natural. There is no single educational approach that can be successfully applied to all courses, but the approach proposed by eduScrum (with minor customization) seems to applicable to most LEI-ISEP courses’ practical and lab classes. Until now, the exceptions are mostly courses where a major overall of the course’s classes are required, thus resulting in stiff resistance from the teaching staff. Change does not come easily…

Scrum’s flexibility and team empowerment make it especially useful in an active learning environment and we have found it to answer to all 6 constrains presented before. For example, a group of students beginning classes a few weeks later in the semester can be easily solved by shortening the duration of the first sprints, until they reach the level of peers. Regarding working students, a multi-week sprint gives (e.g. 2 or 3 weeks) gives them the ability to manage their work, even if they have to skip a class during the sprint.

Heterogeneous teams pose a special challenge in a teamwork classroom environment, but not when a Scrum based approach is used, as it naturally encourages peer-learning and peer-assessment. Better yet, scrum also allows for students to negotiate with their teammates their tasks and workloads, thus allowing for both over and under achieving students to fit in the same group. Scrum provides simple, yet robust tools for activity planning and monitoring.

And it has an essential aspect: it does not grade incomplete/wrong work. It is better that a student provides half of the tasks/work well done than most of them with defects! It promotes work quality in a natural way and the students are also stimulated to develop themselves into valuable team member (Linders, 2013).

eduScrum

eduScrum is based in the Scrum framework, but especially tailored for the education environment. A brief explanation is provided below, but more information can be obtained from the eduScrum website.

Roles

The main roles are (Figure 2):

- Product owner – teacher who manages and defines the product backlog.
- Scrum Master – teacher or team member who coaches the teams in order to correctly follow eduScrum rules.
- Development team – group of students who delivers the product.

Groups can be formed by students at the beginning of the semester and for the whole semester, unless unfortunate events (e.g. element quitting) or poor teamwork performance require changes. It is also possible to be teachers to form the groups, but they must be aware that it is a significant overhead and a responsibility. It is always better for the students to organize themselves. It is also possible to have temporary groups (e.g. for a single assignment), but one must be aware that team needs some time to start being productive.

It is a good practice to create balanced teams, at least in number of elements. 4 or 5 elements are common choices, but it can go up to 7 in large projects. Bigger teams are not productive, even in a professional environment.

Sprint

A sprint is a period of work in which the group has to develop or solve a set of tasks or user stories related to the course's objectives (Figure 3). It ends with a sprint review, where the sprint results are assessed. At the end of the sprint there may also be an integrative individual or group assessment activity. Sprint duration is the same for all sprints and it should be 2 or 3 weeks, maximum. A module can be composed of several sprints, so there is no need for longer sprints, which are quite ineffective.

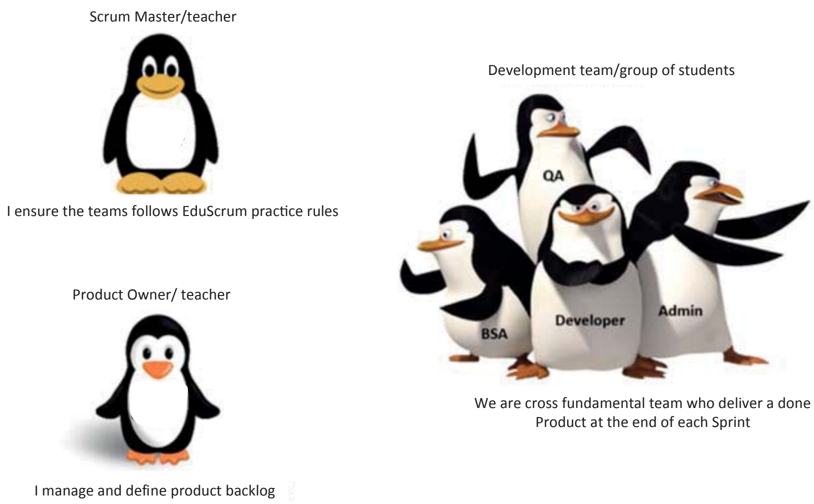

Figure 2 Scrum team (adapted from http://www.123sfdc.com/2015/03/scrum-framework.html)

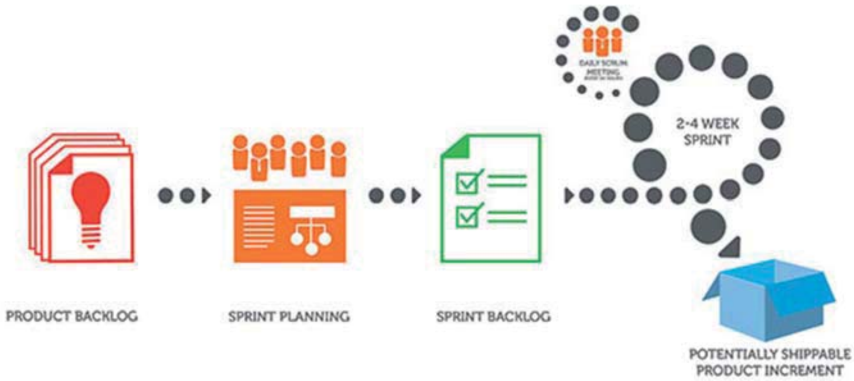

Figure 3 Sprint

Each sprint must have:

- Objectives – subset of the course outcomes
- To-do list – could be exercises, problems, user stories, monographs, etc.
- Acceptance criteria – for each activity there must be a set of criteria for accepting and assessing the activity.

During the sprint students develop their activities, dividing responsibilities among the team members. Activity can be further decomposed into more than one task. The task allocation mechanism requires an estimation of the effort of each task. A common solution is using the Fibonacci series (1, 2, 3, 5, 8, 13, 21, ...) to assign weights (complexity and time to implement) to each task. The students then choose the tasks accordingly. In the team's first sprints, while students are not used to this process, teachers may suggest weights for the activities/tasks. The team decides when and how they execute the activities/tasks during the sprint.

Task management is achieved is a Scrum board, i.e. a simple board with 4 columns:

1. Not started
2. In progress
3. Finished
4. Accepted

At the beginning of the sprint, all tasks are on the “Not started” column. The distinction between “Finished” and “Accepted” is quite important for the methodology, as only work accepted by the product owner should be graded. There is also the possibility to include mandatory peer review tasks, so that only tasks reviewed can be declared “Finished”. This is especially advantageous because it encourages work reviewing and peer learning by the students and also alleviates some work on the teaching staff. A task that fails the peer reviewing process or is reject by the product owner/teacher returns to 2nd stage, “in progress”. The acceptance process by the teacher may include asking some questions to the team related to the task/activity.

Sprint review

The sprint assessment usually has 3 components:

- Assessment of tasks performed - usually calculating the weighted average of accepted activities. Activities not accepted have a 0.
- Assessing students’ individual contribution by analyzing the team’s scrum board (photo submitted in moodle).
- Integrative sprint review (optional) – the students have to answer a quiz or solve and exercise/practical problem related to the sprint, individually or in groups. A simplified grading mechanism scale (e.g. 1-5 scale) should be used.

The sprint assessment corresponds to the weighted average of the two components.

Sprint retrospective

The group should write a brief analysis (e.g. paragraph) on 3 questions related to the team performance during the sprint:

- what went well;
- what went wrong;
- what should be improved in the next sprint.

APPLICATION AND FEEDBACK

The eduScrum methodology has been applied in in two Math, one Physics and four Programming courses of LEI-ISEP. There was some initial reluctance from the teaching staff regarding its “by the book” application, so that some courses used a customized version of eduScrum. This was a mistake one had to endure in order to bring faculty onboard.

Math courses used variable duration sprints (2 to 4 weeks) aligned with the course syllabus’ sections. These courses have 4 hours/week of practical classes and sprint related activities were only included in half of the classes. The remaining followed the traditional approach: teacher provides a list of exercises, the students solve them and the teacher helps the students individually or by solving the exercises on the board. There was an integrative sprint review at the end of each sprint in the form of a quiz. Teams of 4 or 5 students were used. Due to school regulations, the sprint assessment was only formative on Math courses. The courses’ assessment was by a final exam. In the following semester, sprint assessment was both formative and summative..

The Physics course used the methodology only on lab classes. The students have to plan, implement and report the results of an experience; and that was the scope of application. There were 3 sprints with increasing weight on the lab grade. Only the last sprint had an integrative sprint review in the form of presentation and discussion of the experience's results. Teams of 4 or 5 students were used.

The programming courses have several group assignments, so that would be fairly easy to apply the eduScrum approach to those. The objective was to apply the process "by the book", using teams of 4 students. Unfortunately, not all courses followed the standard approach and several questionable "customizations" were introduced. One course used groups of 2 students, which is not a team. This resulted in an increased workload for the teaching staff, which had to provide feedback to about 8 or 9 groups in each class, instead of 4. Teaching staff feedback on the pseudo-eduScrum application on this course was overwhelming negative.

It is always very difficult and dangerous assess the application of a new methodology in terms of the students' academic results/grades. Also, one school year is not enough to have a solid assessment, especially because students change every year. Nevertheless, there is strong evidence that the students were more engaged in practical and lab classes, even on Math courses where the sprint assessment was only formative. Overall results were also better in most courses, but not in all. We were not able to derive a strong correlation between the improvement in the programming courses lab classes results and the final exam grade.

CONCLUSIONS

In this paper we describe the application of the eduScrum methodology in several courses of a large Informatics/Software Engineering program (over 1300 students). We believe there is a strong correlation between the Scrum project development process and CDIO, as depicted in Figure 3. Thus its adoption as the reference methodology to foster active learning adoption in the program.

The first conclusion is that students were more interested and engaged in lab classes, though there is not enough evidence to assert that this had a positive impact on final exam grades. But exams' grades were not the prime objective for eduScrum adoption, anyway.

On the other hand, there is strong evidence that some teaching staff is still reluctant to use active learning and to allow the students some freedom in choosing their own learning path. Some teachers also seem to focused on student individual grading by the teacher, ignoring the positive effects of peer learning and peer reviewing by the students. Nevertheless, the application of eduScrum is being expanded to more courses. A special effort is being taken on training teaching staff on the methodology.

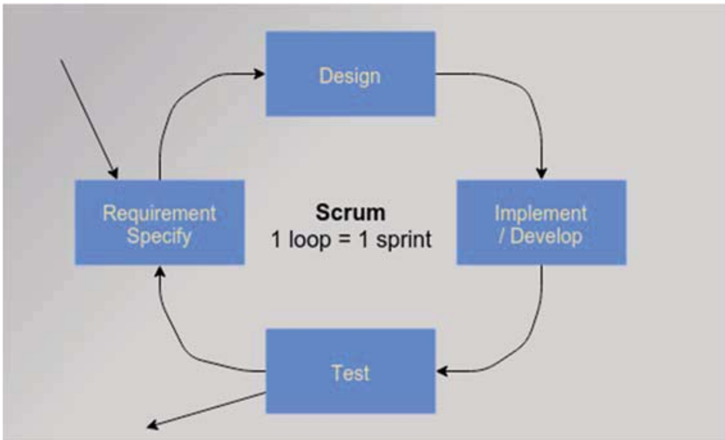

Figure 3 Workflow during the sprint (Marler, 2015)

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CDIO IMPLEMENTATION IN SWEDISH UPPER SECONDARY EDUCATION

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ABSTRACT

In 2010, the Swedish agency of education was given the duty of introducing a new educational programme at upper secondary level in the Swedish school system. In autumn 2015, it became possible for Swedish upper secondary schools that offer the Technology programme (preparatory for higher education) to start up a one-year vocational educational programme. This engineering programme is an additional course for students who have a degree from the three-year Technology programme.
This additional fourth year gives them the opportunity to obtain *Qualified Graduate from Upper Secondary Engineering Course* status. After graduation, students are qualified to work as an upper-secondary engineer (Swedish National Agency for Education, 2015).

When introducing this new educational programme, the Swedish National Agency for Education also took the opportunity to introduce new, hopefully more modern, pedagogical concepts. CDIO, a concept of thinking when conducting engineering education, is one of the pedagogical tools introduced in this additional year of engineering education.

To facilitate this implementation, support material was handed out to teachers during conferences arranged by the Swedish National Agency for Education in autumn 2015.

In this study, we wish to explore how teachers have embraced the teaching material and how they use it in their daily tuition. This paper presents a pilot study, which analyses the perspectives of six selected informants.

A questionnaire was sent to all teachers who participated in the conferences and, based on their answers, six informants were selected for further interviews. The analysis was performed using the Repertory Grid Technique (RGT) along with semi-structured interviews. RGT derives from George Kelly's (1963) understanding of how we perceive the world around us. Utilising RGT, this study examines teachers' expectations on teaching material that supports students' development of engineering knowledge and skills.

The results reveal that teachers' views on CDIO are largely positive and that it is perceived as something that offers a new description of something they have always used. However, they have not used the material in any significant way, despite the fact that, to some extent, the material is consistent with what they believe to be good support materials for teachers.

KEYWORDS

CDIO, upper secondary school, technology education, engineering education, Educational development, standards 1-12

BACKGROUND

Sweden is a country with an extensive educational tradition and with many high-technology companies. Therefore, engineers are widely needed and this has long been a popular profession (Berner, 1999). In accordance with this, the way engineers are educated has also been an on going topic for discussion. The old tradition of engineering education in Sweden has been that it is possible to take a diploma degree in engineering, i.e. undergo a four-year upper secondary education (Sveriges Ingenjörer, 2011), or to take a Master's degree, i.e. a five-year programme at university level. This will provide a "civilingenjör" as the engineering degree at university level has been termed since 1915 (Sveriges Ingenjörer).

In the late 1980s, the Government submitted a bill to parliament concerning the reorganisation of the four-year engineering education at secondary level. The education seemed out of date, due to the rapid technology development and the design of equivalent educations in Europe. The engineering education on secondary level was proposed to be a two-year education within higher education and a one-year technician training would be organised by adult education (Sweden. Government of Sweden, 1988. Sweden. Government of Sweden, 1991).

This new organisation of engineering education was run for almost two decades, albeit without the success for which the government hoped. In 2008, former Minister of Education Jan Björklund declared that the abolishment of the upper-secondary engineer degree in 1992 was a mistake. He concluded that there was a need to reintroduce of this form of schooling (Vene, 2009, Nilsson, 2008). In April 2010, the Swedish National Agency for Education received an assignment by the Government to investigate and propose the design of one-year upper-secondary engineer education (Swedish National Agency for Education, 2010).
This new education was supposed to be a supplementary year to the Technology Programme and it began as a pilot project in autumn 2011 (Swedish National Agency for Education, 2011) and became permanent in autumn 2015 (Sweden. Government of Sweden, 2014a).

After graduation students obtain Qualified Graduate from Upper Secondary Engineering Course status. The Swedish National Agency for Education cites project manager, production engineer, designer and site engineer as examples of possible vocation for an upper-secondary engineer (in Swedish gymnasieingenjör) (Swedish National Agency for Education, 2015a).

As the period of education is short, only one year, upper-secondary engineers rapidly become available on the labour market. In the diploma's goals it is stated; "After graduating from the education, students should be well prepared for professional work as upper-secondary engineer in their technical area." (Swedish National Agency for Education, 2015b, p. 2).

From this, emerges the question: What does it mean to be well prepared for professional work as an upper-secondary engineer?

Education is realised through political initiatives. Organisers and stakeholders influence the education and therefore the characteristics of an upper-secondary engineer. Teachers and supervisors (in workplace-based learning) lay the foundation for students' views on what it means to be an upper-secondary engineer.

The Swedish Agency for Education decided to look at how engineering education at university level has evolved during the last decades and uncovered the CDIO concept – a concept of thinking regarding engineering education that sets strategies for both content and pedagogic methodology (CDIO Standards 2.0, Crawley et.al. 2011).

Accordingly, teachers now have the responsibility to prepare students to become upper-secondary engineers with support from CDIO. The Swedish National Agency for Education states that the student "[…] shall have the opportunity to develop engineering skills with help from the internationally recognised CDIO model (Conceive, Design, Implement, Operate)" (Swedish National Agency for Education, 2015a).
In addition, in descriptions of diploma projects in the three-year Technology Programme, CDIO is emphasised as a method to develop an engineering approach and an engineer´s way of working (Swedish National Agency for Education, 2012).

The Upper-Secondary Engineering Education has four profiles and studies are combined with workplace-based learning, the education is presented as an opportunity for students to gain employment immediately following graduation. The profiles are: Design and Product Development, Production Engineering, Information Technology and Urban Planning.
This can be compared with the five orientations that fall within the Technology Programme years 1 to 3: Design and Product Development, Information and Media Technology, Production Technology, Community Building and Environment and Technology Sciences. Students graduating from any of these orientations can apply to any of the four profiles on *The Upper-Secondary Engineering Education*. (Swedish National Agency for Education, 2015a, Sweden. Government of Sweden, 2014b).

The Swedish National Agency for Education organised in autumn 2015 conferences for teachers involved in *The Upper-Secondary Engineering Education*. CDIO was presented during the conferences through presentations, discussions, workshops and support material.

The *Support material* from the Swedish National Agency for Education is designed to help organisers and teachers to develop and implement a technology education inspired by the CDIO. The CDIO model is presented as a toolkit to develop an engineering education and engineering skills.

RESEARCH QUESTION

This study focuses teachers' views on how to support students' development to upper-secondary engineers. Since the students will be active engineers for decades, teachers' ideas about this knowledge field will affect society in the future hence it is of particular interest to study this field in light of further development of technology education on secondary level.

The overall questions posed in this paper are:

How do teachers use support material for their education and what teaching materials do teachers, in *The Upper-Secondary Engineering Education*; think would promote an engineering approach in the students?

Three questions, in line with the overall questions, are posed to the informants in the interviews.

- Have you used the *Support material* from the Swedish National Agency for Education?
- In the diploma goals for *The Upper-Secondary Engineering Education,* it is stated that, after graduating from education, students should be well prepared for professional work as upper-secondary engineer. What do you think characterises such a student?
- Describe a project - is the CDIO model used?

A complementary assignment is given to the informants where they are asked to grade different teaching materials.

METHOD

A mixed-method approach is undertaken in this study. This begins with a quantitative section, where all participants at the Swedish National Agency for Education conference are asked to fill in a questionnaire. This approach is followed by a more qualitative approach. A Repertory Grid Technique (RGT) is used along with semi-structured interviews. The method derives from George Kelly's work, and is based on his theory of personal constructs (Fransella, Bell & Bannister, 2004; Jankowicz, 2004; Kelly, 1963). Although it has a quantitative structure (Jankowicz, 2004), RGT is primarily a qualitative method, the main purpose of which is to understand other people.

The questions in the questionnaire are generated from experiences with similar questions in a previous study (Isaksson Persson, 2015) and in discussions with the Swedish National Agency for Education. It is produced and published with help from KTH.

Questionnaire

The purpose of the questionnaire is to obtain an overview of the conference participants' experiences and to obtain a sample of informants. The questions concern the participants' own education and experiences of teaching and other work.

The choice of informants is made based on their interest in participating along with whether they teach the course *Practical upper-secondary engineering*. Every student studying to upper-secondary engineer takes this course, and it is of central importance to her or his education. The aim of the course is for the students to develop an engineering approach.

Of the 98 participants at the Swedish National Agency for Education's conferences in autumn 2015, 89 received a questionnaire. This has resulted in 43 participant responses. Because the number of responses to each question varies, the aim of the presentation of data is provide an illustration of the participants, rather than to provide a statistical analysis.

All four profiles of *The Upper-Secondary Engineering Education* are represented among the respondents.

- 22.7% of the respondents are female, 75% male and 2.3% preferred to be gender neutral (Out of 43 participant responses).

- 36.6% have 0 to 9 years of experience in teaching. 41.5% between 10 – 19 years and 22% indicated 20 – 34 years of experience (Out of 40 participant responses).
- 56.8% hold an engineering degree and 43.3% do not (Out of 43 participant responses).
- 31.8% have taught at *The Upper-Secondary Engineering Education* pilot project and 68.2% have not (Out of 43 participant responses).
- 37.2% teach the course *Practical upper-secondary engineering* and 62.8% do not (Out of 42 participant responses).
- 50% supervise diploma projects at *The Upper-Secondary Engineering Education* and 50% do not (Out of 43 participant responses).
- 62.8% teach year 1– 3 at the Technology Programme and 37.2% do not (Out of 42 participant responses).
- 27.9% teach at other programmes at secondary level and 72.1% do not (Out of 42 participant responses).

In summary: a majority of the respondents are male, often between 10 to 19 years teaching experience and are a holder of an engineering degree. Moreover, 'he' not participate in the pilot project of *The Upper-Secondary Engineering Education* before autumn 2015, teaches at the Technology Programme year 1-3 but not in other programmes at secondary level. He does not teach the course *Practical Upper-secondary Engineering* but may supervise the diploma project in *The Upper-Secondary Engineering Education*.

Interviews

Of the 36 conference participants who were interested in participating as informants, seven were contacted by e-mail. They were chosen on the basis that they teach the course *Practical Upper-secondary Engineering*. All seven were initially interested, but later one declined due to heavy workload.

The informants consist of four men, one woman and one person who prefers to be gender neutral and their experiences as teachers ranging from 2 to 21 years. They work in different cities in central and southern Sweden.

- Five have an engineering degree and work experience as engineers.
- Three have taught at *The Upper-Secondary Engineering Education* pilot project before autumn 2015.
- Five supervise diploma projects at *The Upper-Secondary Engineering Education*.
- Four teach other courses in addition to *Practical Upper-secondary Engineering* at *The Upper-Secondary Engineering Education*. These courses are CAD, Computer-controlled production, Mechatronics, Production equipment, Production knowledge, Production philosophy and Technology-specialisation.
- Four teach year 1 – 3 at the Technology Programme. The courses are Automation technology, CAD, Construction, Entrepreneurship and Technology.
- Three teach at other programmes at secondary level - these programmes are Industrial Technology Programme, Natural Science Programme and Social Science Programme.

In comparison to the rest of the participants at the conference, the informants in this study are representative as male engineers that teach, in addition to *The Upper-Secondary Engineering Education*, years 1 – 3 at the Technology Programme. The woman is distinct from the other informants and the other conference participants due to gender and that she is not an engineer.

All six interviews are conducted at the informants' workplaces and recorded. The informants are initially given the opportunity to check and change their answers from the questionnaire. Following this, three questions are posed to the informants.

- Have you used the *Support material* from the National Agency for Education?
- In the diploma goals for *The Upper-Secondary Engineering Education,* it is stated that students after graduating from the education should be well prepared for professional work as upper-secondary engineers. What do you think characterises such a student?
- Describe a project. Is the CDIO model used?

The interviewees discuss issues freely and later the answers are transcribed and analysed.

Procedure using RGT

The last part of the interview was performed using the Repertory Grid Technique (RGT). Principal components analyses and Cluster analysis generated with WebGrid Plus (WebGrid Plus) has been evaluated.
The procedure for the RGT results in a number of two-dimensional constructs. RGT derives from George Kelly's (1963) understanding of how we understand the world around us. Kelly claims that we base our worldview on the way in which we construe our experiences. When we interpret our world, we use multi-dimensional attributes, which Kelly calls constructs (Kelly, 1963). The construct depicts two things about how we define a certain topic: what we consider to be characteristics and what we think is opposed to, or contrasts with, this. This renders constructs bipolar. Fransella, Bell and Bannister (2004) summarise Kelly's view on how we construe the world as "[...] we never affirm anything without simultaneously denying something" (Fransella, Bell & Bannister, 2004, p. 7).

Constructs are elicited regarding a certain topic. The topic for this study is *Teaching materials that promote an engineering approach*.

In the part where RGT was used the informants were given the assignment to suggest, at most, eight different teaching materials. The researcher herself also supplied two forms of teaching material as the basis for the interview. The ones supplied by the researcher are the *Support material* from the National Agency for Education and a mental picture of good or ideal teaching material.

The teaching materials are noted on a grid sheet and are presented three at a time by the researcher. Not all are present in physical form, such as digital materials. The informant picks two of these that share characteristics. The shared characteristic is noted in the grid and is a construct's first pole. The opposing characteristics possessed by the third teaching material is the construct's second pole. The first pole has the value 1 and the second pole value 5. All other teaching materials are then rated according to the construct on a scale from 1 to 5. The procedure is repeated until ten constructs are elicited or the informant wants to stop.

FINDINGS

Questionnaire

Reflections have been made on some of the relevant questions for further analysis of the research questions.
On the open question “Other work experience you consider relevant to you as a teacher?” 29 answers were given. Of these, 22 respondents referred to work in industry, engineering or technician assignments or work with IT, support or electronics. Three respondents refer to school related assignments.
On the open question “Education you have undergone relevant to your work as a teacher?” 33 answers were given. Of which, 25 respondents refer to education concerning engineering, IT or courses concerning the technology area. A further 13 of these respondents also referred to teacher training or other pedagogical studies. Five referred to teacher training alone or other pedagogical studies and other kinds of education.

Interview
Before compiling this paper, six informants have been interviewed and the transcripts have been analysed. The answers are compiled and presented in summary and/or with quotations to demonstrate common traits.

In the diploma goals for The Upper-Secondary Engineering Education, it is stated that students, after graduating from education, should be well prepared for professional work as an upper-secondary engineer. What do you think characterises such a student?

An upper-secondary engineer should possess basic practical skills and be able to participate in projects. But above all see the production/technology process as a whole and have ability to acquire the knowledge needed to solve problems.

> Informant: Yes, it’s a student who is independent in the sense that he can, if he is facing a problem, knows how he will act to solve it. That’s the engineering approach. Not that one possesses all knowledge about a certain specific area, but that one can find out, turn against it and be open and see the possibilities, try in ones area of expertise.
> (Teacher Te402, 08.12.2015, p. 1)

> Informant: […] an engineer is the one who has a systems approach, sees the big picture, understands that what we have is a social construction.
> (Teacher Te403, 13.11.2015, p. 3)

Describe a project. Is the CDIO model used?

Summary: All teachers use projects as a pedagogical method and describe the projects’ different phases. These are in line with CDIO. The teacher works with integrated learning in the projects and the results, ranging from 3D models, prototypes to usable products.

Have you used the Support material from the National Agency for Education?

Summary: The informants did not use the *Support material* in teaching explicitly but recognised the CDIO concept. The following quotes illustrate this. They describe experiences from engineering and teaching that they consider similar to CDIO.

> Informant: It’s obvious that it comes from University [...] in practice, it goes much faster. [...] We try to show that these types of models are available, but in practice, you do not make it as comprehensive.
> (About the CDIO model. Teacher Te404, 14.12.2015, p. 3)

Informant: Yes, I did briefly [...] Nah, I have not read it but focused on the Agency's curricula and then on [...] what the companies here want.
(About the *Support material*. Teacher Te404, 14.12.2015, p. 1)

Informant: And then I have already read the materials available online. So I have not looked so much on the Agency's support material. I have, just quickly looked it through but cannot say that I've used it, and I want to state that I recognised a lot of the CDIO concept. […] I think this is, it's vocational didactics to the very highest degree.
(About the support material and the CDIO model. Teacher Te402, 08.12.2015, p. 1)

Informant: I have read it. I have discussed it in class. Very similar to the one I used when I worked at [...]. [...] but there are some other names and things like that. But [...], the concept is pretty much the same.
(About the *Support material* and the CDIO model. Teacher Te401, 18.11.2015, p. 1)

Findings from the RGT study

Ratings 1 and 5, and constructs linked to them, have been taken into account in order to get an overall picture of the informants' thoughts about the *Good teaching material* (the mental picture of good or ideal teaching material) and the *Support material*. According to RGT indicates similarities in ratings, either between constructs, or elements representing the topic of the interview (in this study teaching materials), similar meaning to the informant (Jankowicz, 2004). With this reasoning in mind we suggest that the elements presented in table 1 represent the teaching material that the informants believe promotes an engineering approach.

Table 1. Teaching materials with similar ratings as *Good teaching material*.

Teaching materials with similar ratings as Good teaching material
PDF booklet with mechatronics assignments (Informant Te401)
Internet (for example web pages about Agile methods) (Informant Te402)
Teaching materials produced by the teacher (Informant Te403)
PowerPoint about organisational theory (Informant Te404)
Web page about entrepreneurial learning (Informant Te406)

Informant Te404 is not represented in table 1 because there is no high similarity in the ratings between the teaching material and the *Good teaching material*. He rates good teaching materials mostly to the value 3. In his view, there is no good teaching materials, he creates his own from different sources, he comments on this with the following quote.

Interviewer: And then we have the Good teaching material.
Informant: Yes, it is. All of it together is good.
Interviewer: Then it is a 3?
Informant: Yes [...] this is proof of that we have no good teaching materials, alone. We have no course adapted teaching material, but we can knock it together with what we think is good from various books and own expertise, lab equipment that we have and so on.
(About the CDIO model. Teacher Te404, 01.03.2016, p. 9)

Table 2 shows examples of constructs describing informants' views on the nature of a good teaching material. The informants' constructs reveal different perspectives on a good teaching material. It poses questions about why and how becoming an engineer rather than specific questions about engineering skills [1]. It has a pedagogical approach [2]; it promotes a dialogue between teachers and students and is adapted to students and situations. It facilitates teacher's work [3]; it is easy, accessible and ready to use, and does not require a great deal of preparation. It has an element of creativity [4]; it is diversified, has endless possibilities; it is flexible, easy to modify and/or use for various purposes.

Table 2 shows constructs describing the *Good teaching material* and the teaching materials shown in table 1

Constructs	
Pole describing *Good teaching material*	Opposed Pole
Easy to find level for the students.	Hard to find level for the students.
Have parts that are adapted to teaching, to students' level.	Reporting of research. The students do not see the use of the book.
Follows specific models. Clear plan, common thread.	Aimless
Up-to-date	Rapid development, books become outdated
Dynamic	Static
Diversity	Limited
Endless possibilities.	Specific in its function.
Educational idea.	Not good teaching materials. Good content, poor structure.
Linked to reality.	Overall support. Steering documents.
Useful knowledge for the upper-secondary engineer.	Frameworks and guidelines
How and why learning the profession.	Skills needed in the profession.
Dialogue, discussion teacher – student.	Hard to discuss.
Whole	Part
Comprehensive	Based on subject area

Informants' views on the Support material

Two informants do not know the *Support material* well enough to include them in the RGT study. The other informants associate the *Support material* as a contrast to engineering practice and the industry and more linked to science, theory, guidelines and steering documents. On the other hand, they give examples of teaching in line with the guiding principles promoted by the *Support material*.

Summary: The *Support material* is considered to be a model or a working method. It is characterised by being easy to adapt to the students' level. It gives an overall picture of engineering. It is associated with theory and steering documents.

DISCUSSION

Shaping an upper-secondary engineer

In the findings we see that the *Good teaching material* poses questions about why and how to become an engineer but, surprisingly to us they do not suggest that it includes specific questions about engineering skills or project work, which is often suggested in other advices on how to improve teaching in technology (Skolinspektionen, 2014).

The informants value a holistic view on the technology process and think it is important for an upper-secondary engineer to have this ability as well as skills to solve problems in an engineering way. We claim that the informants think the *Good teaching material* supports the possibility to achieve this.

The *Good teaching material* also reflects issues of teaching. Teaching materials should be dynamic with a pedagogical idea. They shall facilitate the teacher's interaction with students and the process of selecting and presenting subject knowledge.

The technological-profession knowledge in focus

The *Good teaching material* and the *Support material* have similarities; they are easy to customize and have broad rather than specific approaches towards engineering. One interesting reflection is that the informants do not use the *Support material* in their everyday teaching. Some have only read the material briefly. But they express appreciation for The Swedish National Agency for Education's conferences where CDIO was presented and they use the CDIO in their teaching.

However, the *Support material* is associated with steering documents in a way that the *Good teaching material* is not. To us it appears as though the teachers have a very strong professional identity and that it is somewhat difficult to reach them with new directives.

When the conference participants consider what work experiences and education they find relevant to them as teachers, the dominance of technological-profession knowledge is colossal. It appeared as though the conference participants value this knowledge more than teaching experiences and education. They may not specify their teacher training, as they take it for granted, but this still shows the conference participants' homogeneous approach to what counts as important in the teaching profession. This findings are in line with another study were it was shown that teachers with no teaching degree used steering document to lesser extent than teachers having a teacher degree (Hartell et.al. 2014). We can argue that The Swedish National Agency for Education's conferences are initiatives towards teachers' professional development. Clark and Hollingsworth (2002) have identified six perspectives on teacher change. The results of this study emphasise that teachers' change is best achieved through participation in learning communities rather than by change through imposed external initiatives.

Conclusion and further research

The conference participants and the interviewees were predominantly male. It seem like they regard their experiences from work and education within the technology field relevant to their assignments as teachers. They value and appreciate teaching materials that promote a broad rather than a specific approach to engineering.
Is it harder for the informants to mediate a holistic perspective on technology than specific technology knowledge? Isaksson

ersson (2015) has previously examined work active engineers' views on their vocational knowledge and experiences from technology education. These engineers regarded it as a deficiency in their education that they did not learn much about general skills such as leading teams, communication, collaboration and so on. Another perspective, which needs to be examined, is students' perspective. What are their experiences of The Upper-Secondary Engineering Education, what is engineering knowledge to them?

The informants do not seem to appreciate the *Support material* very much, even though it is about CDIO, with which they are familiar. Is there an issue of pride from the teachers/engineers when the authorities impose their view on how to educate upper-secondary engineers? In addition, it would be interesting to dig deeper in the question about if it is a disciplinary conflict between a strong identification with a knowledge/professional field and demands from the pedagogical field?

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FOCUSING ON CREATIVITY: FACULTY MOTIVATION IN TEACHING BRAIN-STORMING AND CREATIVITY IN AN INTRODUCTORY COURSE

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ABSTRACT

At Reykjavik University (RU) we run an introductory course for all engineering students in two phases: a two-day „brain-storming“ event focusing on creativity, early in the first semester, and a three-week intensive course focusing on design at the end of the semester. In the brain-storming phase, almost all faculty members in the School of Science and Engineering (SSE) take part and act as tutors. Their role is to stimulate and encourage the students. Participating in this course puts many of the faculty into a new role and their reaction has ranged from very enthusiastic and interested to reluctant, critical and even drudging. A survey on faculty opinion shows that they are very supportive of introducing creativity into the engineering programs, as implemented by the brain-storming days. On the other hand, a significant fraction of the faculty considers their time not well spent in participating in the course. The SSE has two options, firstly to continue in a similar way with all faculty involved or to ask only those interested to take part in the course next time. We conclude that it is important that participating faculty become more involved and are given the opportunity to influence the course's development as well as training in relevant teaching methods.

KEYWORDS

Creativity, brain-storming, introduction to engineering, educational changes, standards: 1, 4, 8, 10.

INTRODUCTION

CDIO (Conceive-Design-Implement-Operate) is a widespread model for improving engineering education. Implementing CDIO into an already established teaching program calls for a number of changes in the education process, e.g. faculty adoption of the CDIO context (standard 1), an introductory course that provides the framework for engineering practice and introduces essential personal and interpersonal skills (standard 4), active experiential learning methods (standard 8), and enhancement of faculty competence in providing integrated learning experiences (standard 10).

Creativity in engineering

It is a demanding responsibility of universities to educate engineers for the future and the unknown challenges they will face later in their career. Many of them will be put in positions were they need to think globally, be open to new ideas and opinions, and will be expected to work efficiently in diverse teams to come up with new creative solutions facing different societies. All too often, engineering education focuses mostly on the technical expertise, which is of course fundamental to engineering, but their education also needs to provide them with the mind-set to be creative and work in multidisciplinary teams (Crawley, Malmqvist, Östlund, Brodeur, and Edström, 2014, Kamp 2014).

To generate ideas is the foundation of creativity, and brain-storming is a well know technique for fostering creativity, whereby a group of people create ideas as a part of problem solving. Brain-storming techniques have been used successfully in various industrial and educational settings, i.e. sciences and engineering (Fang, 2013).

Commitment of faculty to changes in education

Changes in education are a complex process that builds on work carried out at many different levels, e.g. in the classroom, the teacher's work outside the classroom, at the school management level and state policy. Fullan (2000) emphasises that large-scale changes must be implemented in cooperation with, and supported by, all stakeholders, including teachers and school authorities, and everyone needs to take an active part. To implement changes in education as CDIO calls for can be difficult and demands that both the institution and faculty react efficiently and successfully. The burden of changes affects not only administration, but also teachers, because their roles are crucial and their abilities and attitudes are important (Maskit, 2011). The experience of implementing CDIO can be different at different universities. Lee et al. (2015) compared the experience of five universities in four countries, and stated that the change of faculty's mind-set is one of the biggest challenges, as well as achieving "buy-in" of the faculty. Quite a few sceptical reactions were revealed.

Fullan (2007) lists three perspectives to reflect on when introducing new things in education: "(1) the possible use of new or revised material (i.e., instruction resources such as curriculum material or technology), (2) the possible use of new teaching approaches, (i.e., new teaching strategies or activities), and (3) the possible alternation of beliefs (i.e., pedagogical assumptions and theories underlying particular new policies or programs)" (p.30). Changes initiated by implementing CDIO are related to all three perspectives. The faculty's reactions can range from being positive and eager to take part in the new pedagogy, to negative and critical attitudes and even fighting against the changes. Based on the above studies, positive and supportive attitudes among faculty are essential and extremely important for the successful implementation of CDIO.

A COURSE ON CREATIVITY THROUGH BRAIN-STORMING

SSE at RU has been adopting the principle of CDIO is the context of engineering education. There are many things to consider when planning an introduction to engineering course and creativity and engineering design are certainly among the issues that should be in the curriculum. SSE runs an introductory course for all first-year engineering students in two phases: a two-day „brain-storming" event, early in the semester, focusing on creativity i.e. the "C" in CDIO; and then a three-week intensive course, at the end of the semester, focusing on engineering design (Audunsson, Saemundsdottir, and Matthiasdottir, 2015).

In this paper the focus will be on the first phase of the course, i.e. the brain-storming event, as it was run in the fall of 2015. One of the main objectives of this course is to give students a chance to become acquainted with other students and faculty, making them more comfortable in their study environment and thus hopefully lowering the drop-out rate. The learning outcomes (LO) all focus on personal and interpersonal skills, i.e., at the end of the course the student should:

1. Have experienced teamwork and understand the importance of cooperation and diversity in a working group.
2. Have experienced an organized approach to brain-storming.
3. Have experienced diversity in the presentation of solutions.

The brain-storming days started in the fourth week of the fall semester in 2015, on late Wednesday afternoon, when the students got a brief presentation of the project they were supposed to work on the next day, and exhibit their solutions the day after that. The project was kept a secret until Wednesday afternoon and was presented to students and faculty at the same time. The next morning, Thursday, 208 first year students were divided into groups of five to six students each and introduced to the basic rules of brain-storming, followed by a brain-storming session and selection of ideas to continue to work with during the day.

Most students are used to well-defined assignments that all too often have only one solution. To prepare the students for the challenge of the upcoming studies, as well as to change their mind-set into thinking that there can be many solutions to a problem, the method of brain-storming was utilized. The aim was to teach students how to approach the idea phase of a project in an organized manner, as well as to demonstrate to them the advantages of working in a group.

Brain-storming has been a popular method used by the industry in different fields for some years. It is normally used in the initial phase of a project or during the project duration to solve a specific problem. One of the reason for its popularity within some industries is for example due to the creativity aspect of the method. By using brain-storming, many new ideas are generated by different types of stakeholders and the most valuable one is then chosen to continue to work with.

By introducing this method to students in the beginning of their engineering studies they are taught a method they can use throughout their studies. Brain-storming makes sure that all ideas are considered, for those students that are not as talkative as others this can be beneficial since all voices are heard. The group will have to reach an agreement on which idea to continue to work with so the method brings the group together and is a perfect way to start group work.

The brain-storming process

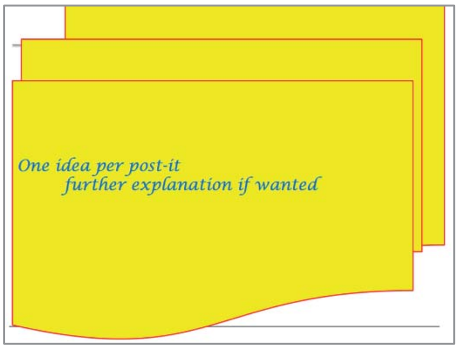
The brain-storming session was divided into the four following steps:

1. *Defining the problem or the project*

   The project in the last year´s course was a national stadium in Iceland, a much discussed and disputed topic at that time. The year before, the project was a bridge across the bay where the university campus is situated. Both projects were related to current issues that had been widely covered in the media, and most students related to these projects as relevant issues.

2. *Brain-storming*

At this stage, the students were encouraged to generate as many ideas as possible regarding the topic for 15 minutes. They wrote each idea on a single post-it note and it was greatly emphasised that all ideas were welcomed – no idea is too "stupid". The purpose of this step was to allow each student to speak his or her mind and to participate, since it is often a problem in group work that only one or two persons dominate the idea phase. The main rules during the brain-storming process, originally from Osborn (1953), are:



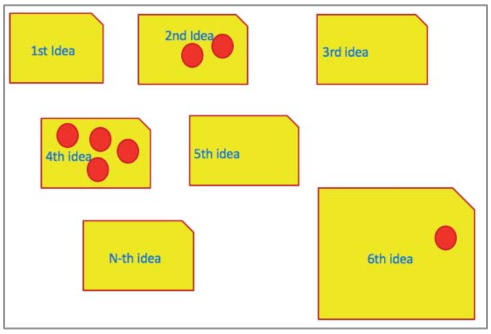
- No criticism, all criticism of the ideas that are generated should be put on hold.
- Quantity is desirable, the more ideas the more likely an effective solution will be found.
- Think "up", wild ideas are especially welcomed; generating a good and long list of ideas is preferable.
- Combine and improve ideas (1 + 1 = 3 rule).

3. *Collecting and classifying*

One student per group got the role of table manager, he or she should classify similar ideas. The purpose of this stage was to narrow the focus, and to combine and improve ideas.

4. *Prioritizing and selecting*

The ideas were prioritized in two ways, with the aim of finding the "best" idea to continue to develop and promote at the exhibition the last day of the course. Firstly, all group members received three circular stickers and were asked to put them on the idea or ideas they liked the best. They could either put all three stickers on one idea, or divide their stickers between ideas.



Secondly, a graph had been put on each group´s table with the X-axis labelled as "Complicated", meaning how easy or difficult it was to implement and promote the idea; and Y-axis labelled as "Cool and Original", to encourage the students to think outside the box.

In this final step of the brain-storming, criticism was welcomed. The students, who had gotten to know each other a bit better at this point, were encouraged to speak up for the ideas they preferred and present the group with arguments for evaluating the pros and cons of each idea.

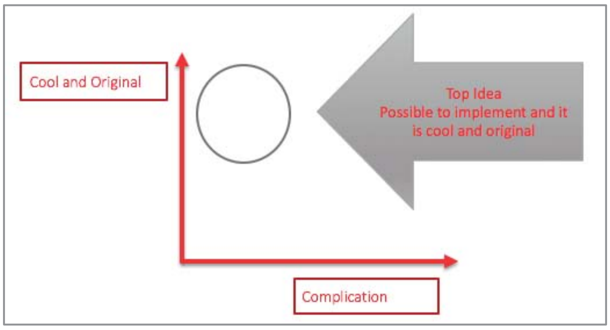


Figure 1 shows students working in the brain-storming session.

Figure 1. Group work in the brain-storming session.

5. Further work

Thursday afternoon, after the brain-storming session, students worked in groups on developing the idea they had decided on, to some extent guided by faculty. They presented their solutions at noon on Friday, mostly by showing models, posters and/or videos. The students did not get any formal feedback on their work but a committee chose and rewarded the “best” three projects. The students gave feedback on the course and the course evaluation was rather positive, or 4.12 (on a scale from 1 to 5).

Almost all SSE´s faculty took part in the brain storming days and acted as tutors, each teacher responsible for one to three groups. Their role was to guide students through the project without “to much” support, not at all to solve the tasks or give them the “right” ideas. The faculty acted both as facilitators and activators and the students took responsibility for setting goals and for the results of their work. Many of the faculty were placed in an unfamiliar situation, they were no longer teachers in the role of leading student´s work in the classroom and guiding them towards well-known solutions, instead their new role was to stimulate and encourage students to seek their own new solutions. The reactions of the faculty to this new task, based on a discussion at an informal meeting held after the course, ranged from being very enthusiastic and eager to being reluctant and passive.

SURVEY ON FACULTY ATTITUDES

It was decided to run a small survey among the SSE faculty, with the objective of gaining a better understanding of the faculty’s attitudes toward the brain-storming days. From now on the two-day brain-storming phase will be referred to as the course.

Method

A total of 50 faculty members at SSE were approached and 23 (46%) of them participated and answered a questionnaire. When asked how often they had participated in the course, 17 (74%) had participated twice, three (13%) once and three (13%) never.

A questionnaire was designed especially for this survey and consisted of 22 statements on a five point scale (from totally disagree to totally agree) about attitudes towards the course and its implementation. At the end of the questionnaire there were three open questions, two about what the participants considered to have been successful and not so successful, and one open space for any other comments. The survey was online in a system called FreeonlineSurveys (http://freeonlinesurveys.com/) and the faculty received an e-mail from the SSE office asking them to participate. The survey was conducted in January and February 2016 and was open for three weeks, a reminder was sent to all after one week.

RESULTS

Table 1 shows the faculty's attitudes toward four of the statements in the survey. Majority (86%) of the respondents claim that creativity is important in the engineering programs at SSE, and just over 62% feel that the current implementation of the course is acceptable.

Table 1. Faculty's attitudes towards teaching creativity and towards the course in general.

	Totally agree and agree N (%)	Neutral N (%)	Totally disagree and disagree N (%)
Creativity should be an important factor in the engineering programs at SSE	19 (86%)	2 (9%)	1 (5%)
It is a good initiative by SSE to run this course	14 (67%)	3 (14%)	4 (19%)
I believe that this course is important for SSE	13 (62%)	3 (14%)	5 (24%)
The projects in the courses are encouraging and provided scope for creativity	13 (65%)	4 (10%)	3 (15%)

Table 2 shows the faculty's attitudes toward six statements regarding students and LO. Overall, the majority of the faculty is of the opinion that the LO of the course were fulfilled. A few faculty members are of the opinion that students do not benefit from the course.

Table 2. Faculty's attitudes towards the objectives and LO of the course.

	Totally agree and agree N (%)	Neutral N (%)	Totally disagree and disagree N (%)
Students have the opportunity to get to know each other well in this course	15 (75%)	3 (15%)	2 (10%)
Students learn about teamwork in this course	17 (85%)	3 (15%)	2 (10%)
Students learn about the importance of cooperation in this course	13 (65%)	4 (20%)	3 (15%)
Students are introduced to an organized way of gathering and assessing ideas in this course	13 (65%)	5 (25%)	2 (10%)
Students learn about a variety of ways of presentations in this course	10 (50%)	6 (30%)	4 (20%)
I believe that students do not benefit from this course	3 (15%)	3 (14%)	15 (72%)

Table 3 shows the faculty's attitudes towards twelve statements about their own involvement in the course. A majority (62%) of the responding faculty are happy to participate in the course, feel it is well organized (70%) and do not feel it is a failure (71%). Just under half (47%) of the participants wants to take part in further development of the course.

Table 3. Faculty attitudes towards their own involvement in the course.

	Totally agree and agree N (%)	Neutral N (%)	Totally disagree and disagree N (%)
I participate happily in the course	13 (62%)	4 (19%)	4 (19%)
I find this course well organized	14 (70%)	3 (15%)	3 (15%)
I feel excited not knowing anything about the project until it begins, just like the students	7 (33%)	7 (33%)	7 (35%)
I find this course rewarding for me as a teacher	6 (30%)	7 (35%)	7 (35%)
I want to participate in developing this course further	7 (47%)	2 (13%)	6 (40%)
I find this course to be a failure	5 (24%)	1 (5%)	15 (71%)
I find the course too long	4 (19%)	5 (24%)	12 (57%)
I need more guidance about my role as a facilitator in this course	6 (29%)	8 (38%)	10 (48%)
I believe this course support to the courses I teach	5 (24%)	7 (44%)	6 (38%)
At first I had doubts about this course but not anymore	2 (13%)	8 (38%)	8 (38%)
I feel we need a formal assessment in this course	3 (15%)	6 (29%)	12 (58%)
I think my time is poorly spent as an instructor in this course	8 (38%)	2 (10%)	11 (52%)

Nine participants answered the open question about what went well in the course. The remarks emphasise how well the students worked, and that the first-year students had the opportunity to get to know each other and the teachers. This quote is representative of their comments: "Overall a very good course and necessary to break up the semester. This course helps me definitely to give students the idea that they are in an exciting study program". The respondents liked the emphasis on creativity and one said that the initial introduction to the course on Wednesday had been convincing and inspiring, and that the course was well organized. One especially praised the brain-storming session and said it was fantastic.

Nine of the participants gave their opinions on what had not been successful in the course. Many comments were related to how faculty's time was wasted, especially in the introduction at the beginning and at the students' exhibition at the end. One criticized the lack of formal feedback to students at the end of the course.

When asked if they had something to add, 12 answered and the comments were both positive and negative. Four were very positive and thought this was a great initiative. As before the negative comments were that faculty time was not well spent and the evaluation of the students work could be better. This quote is representative of their comments: "This course is good, but it should take into account that the staff has many other things to do and it is not acceptable to let them sit long lectures they benefit nothing from".

DISCUSSION

Faculty's motivation and support is always important, especially when offering a course which is supposed to inspire students to be creative, such as the brain-storming days. The faculty must be prepared to teach a curriculum emphasising personal and interpersonal skills and active learning with problem solving activities, team work, brain-storming and discussions. Overall, the survey indicates positive attitudes towards the course, LO, the organisation and students' experience. A vast majority of the respondents in the survey supports the idea of stimulating creativity in the engineering programs, as implemented by the brain-storming procedure, although, firm conclusions cannot be drawn from the results due to the relatively low response rate.

Despite this faculty members were not as positive towards their own roles in the course, and too many felt that their time was not well spent. One possible reason for this was reflected in the participants comments; they see themselves principally as researchers and specialists; research leads to promotion and, as researchers, they regret anything that takes time away from their research. As specialists, they find it more rewarding and feel most comfortable teaching specialised courses within their own field of specialization. For many, teaching personal and interpersonal skills, is neither within their field of interest nor their field of competence. This is something the organizers of the course need to address.

It is disappointing that a relatively large proportion of the respondents seem "neutral" regarding their own involvement in the course. This can mean that they are not interested in their roles in the course. Only on third said they found the course rewarding to themselves as teachers and one fifth said that the course supported other courses that they taught, although the LO address skills that should could apply to many courses. The organisers of the course clearly need to put more effort into stimulating active interest among faculty and possibly by more involvement in implementing the course.

In short, the faculty seem to like the idea of stimulating creativity among first year students by the brain-storming days, but they are not as keen on being active in running and developing the course.

From the survey it can be concluded that there are two options for the organisation of the course:

- All faculty members participate in the course each year, each member tutoring one or two groups. If so, then a campaign to motivate faculty is necessary.
- Only a part of the faculty participate in the course each year, teaching "full-time" during the two days, i.e. each tutoring four to six groups.

Either way, the SSE needs to prepare faculty for teaching personal and interpersonal skills and coach them for teaching in these new circumstances. It is important to give all faculty an opportunity to influence and participate in the development of the course in order to give them a sense of ownership in the course and make them more engaged in their roles as tutors.

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MIXING DESIGN, MANAGEMENT AND ENGINEERING STUDENTS IN CHALLENGE-BASED PROJECTS

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ABSTRACT

The aim of this work is to describe and discuss the benefits and limitations that have been detected along two iterations of a learning experience that has been carried out by three institutions located in Barcelona: Istituto Europeo di Design (IED), ESADE Business School and UPC-Telecom BCN. Design, management and ICT engineering students are mixed together in multidisciplinary teams to face a design challenge along a semester. The framework of these projects is the Challenge Based Innovation (CBI) program, a structure promoted by CERN in which students from different disciplines and countries are challenged to design solutions to social needs following the Design Thinking approach. The international and multidisciplinary teams perform several stays (3-4 weeks in total) at IdeaSquare, a creative environment built at the CERN Meyrin site, in Switzerland, where the students can consult with scientists and knowledge transfer experts about their challenges and about the possible use of CERN technologies in the proposed solutions. They also devote a weekly working day in their home institutions along a semester. The challenges are quite open and, according to the Design Thinking methodology, the students follow several divergence-convergence phases: they devote approximately one third of the time identifying relevant needs into the challenge scope and choosing one of them; another third identifying possible solutions for the chosen need and converging to a single one through low-resolution prototyping and testing. Finally, the last third is spent exploring the business aspects and possible technological implementations of the solution and developing a functional prototype, able to provide a proof of concept of the idea. The main goal of this paper is not to describe the CBI course but to compare the Design Thinking approach with the analytical design currently employed in the engineering school involved in this course using the CBI course as a study case. While the technical complexity of solutions is higher in the standard design-build projects performed at Telecom-BCN, the degree of awareness about the user needs and the ability of developing disruptive and high-impact solutions and of promoting the entrepreneurial skills of the students is higher with the approach used in the CBI program.

KEYWORDS

Design Thinking, Multidisciplinary projects, Challenge-based projects, Standards: 5, 7, 8, 9.

INTRODUCTION

“Conceive” is the first of the four phases in the product lifetime defined by the CDIO paradigm. CDIO Standards clearly state that the Conceive stage includes defining customer needs, considering technology, enterprise strategy, and regulations and developing conceptual, technical, and business plans. On the other hand, CDIO Syllabus 2.0 refers to the conception phase taking into account the customer and societal needs in points 4.3.1 (Understanding Needs and Setting Goals), 4.4.2 (The Design Process Phasing and Approaches), 4.4.5 (Multidisciplinary Design) and 4.7.8 (Innovation – the Conception, Design and Introduction of New Goods and Services).

Nevertheless, most points of the Syllabus section 4 and most engineering curricula put more emphasis in “Design” and subsequent phases and students’ projects often start from requirements or even directly from specifications, even if an external stakeholder stated them. This is because usually the interlocutors in the companies that specify the product are also engineers. On the other hand, this allows that projects can reach a high technical complexity and that students would learn how to deal with it.

Product designers and designers from all disciplines devote more time and put more emphasis in the user needs. It is often assumed that engineers need that another agent (product design, marketing, management…) states the requirements. Although our students feel comfortable with this role distribution, it limits the capability of graduated engineers on participating in the concept creation.

In the recent years, new terms like Co-Creation or Design-Thinking (DT) have arisen as ways of dealing with the uncertainty involved in the conception phase. A few references can be found in the CDIO knowledge library about this approach, most of them from Singapore Politechnic - (Kim, 2011)(Yang et al., 2014) (Ping et al., 2011) which has included specific courses in their curricula. There are also references in Taajamaa et al. (2014).

Following points describe the DT approach and compare it with the classical analytical design approach, more widespread in engineering education and practice. Then, a learning experience that has been carried out by three institutions located in Barcelona: Istituto Europeo di Design (IED), ESADE Business School and UPC-Telecom BCN in which design, management and ICT engineering students are mixed together in multidisciplinary teams is described. The framework of these projects is the Challenge Based Innovation (CBI) program, a framework developed and promoted by CERN in which students from different disciplines and countries are challenged to design solutions to social needs following the Design Thinking approach. Part of the course is performed at IdeaSquare (http://ideasquare.web.cern.ch/), a creative environment built by Aalto and CERN at the CERN Meyrin site, in Switzerland. The main goal of this paper is not to describe the CBI course in detail but to use it as study case to compare the Design Thinking approach with the analytical design currently employed in the engineering school involved in this course. The learning outcomes of the engineering students, compared with those obtained in the regular design-build courses at Telecom-BCN, are compared and discussed. The description and outcomes of other challenge-based projects developed in the CDIO environment can be found in (Malmqvist et al., 2015)

DESIGN-THINKING VS ANALYTICAL DESIGN

Design-Thinking - a methodology to guide exploration in innovation

In order to come up with innovative solutions to meet the market needs, a product development team needs to be skilled in exploration. Exploration is fundamental for innovation, and refers to the innovative behavior involved in risk-taking and experimenting with unfamiliar alternatives. This search for new ideas, markets, or relations inevitably faces uncertainty; it has less certain outcomes than the further development of existing ones. (March, 1991, p. 73) At the outset of and exploration project, there is no clear predefined target, nor a known route to achieve it - certainly no requirements nor specifications, while classical engineering student projects often start from requirements or even directly from specifications. Therefore, exploration activities need to be supported by an appropriate methodology that is able to deal with the uncertainty, support the creation of the information required, and flexibly modify the direction of the project as new information becomes available.

Design Thinking is an iterative and human-centered approach to innovation, originating from the design disciplines and drawing from the tools and methods utilized traditionally by designers. This methodology has been credited for its specific support for reflective reframing, integrative thinking, abductive reasoning, and dealing with uncertainty and ambiguity - all conditions for successful exploration (e.g. Hassi and Laakso, 2011 a; Dunne and Martin, 2006; Dym, Agogino, Eris, Frey, & Leifer, 2005). The foundations of DT were laid around the mid 1970’s and late 1980’s within design research (Hassi and Laakso, 2011 b), focusing on understanding “the way designers think as they work” and drawing from the practice of professional designers, for example architects (Johansson and Woodilla, 2009). While design research keeps building on its broad research history on DT, the concept has gained increasing interest in other fields, such as engineering (e.g. Fai, 2011; Ping, Chow, and Teoh, 2011; Dym et al, 2005) and management (e.g. Kolko 2015; Dunne and Martin, 2006), where it is regarded as a methodology for innovation, problem solving, and value creation. (e.g. Brown, 2009; Johansson and Woodilla, 2009)

There is no single predominant definition for Design Thinking. The notion of Design Thinking is broad and there are even debates over what exactly is meant by it (Cooper, Junginger, & Lockwood, 2009). Following Brown’s (2009) description, DT begins with skills designers have used and developed over many decades, while aiming to match human needs with available technical resources, and within the practical constraints of business. The tools from the “designers toolking” are put into the hands of people who are not professional designers, and they are being applied to a vast range of problems. (Brown, 2009, p. 4) DT is essentially a human-centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping and concurrent business analysis. It is not a substitute for professional design, but rather a methodology for innovation in the early stages of the innovation funnel. (Lockwood, 2010, p. xi)

Despite the lack of a consensual definition for Design Thinking, the definitions seem to have some key tenets in common, such as, human-centricity, rough prototyping, iterative knowledge creation, and reflection (Hassi and Laakso, 2011 a; Lockwood, 2010 p. xi). Perhaps the most prominently emphasized issues in DT is its inherent and thorough *human-centred approach* (e.g. Brown, 2008; Porcini, 2009). Deriving from long practical experience and research, Meinel and Leifer (2015) argue that successful innovation through DT will always bring us back to the human-centric point of view: “This is the imperative to solve technical problems in ways that satisfy human needs and acknowledge the human element in all technologies and organizations.” (Meinel and Leifer, 2015, p. 2) All depictions of DT are extremely consistent in emphasizing developing empathy towards the user, to have a deep understanding of their motivations, needs, and fears (e.g. Lockwood, 2009; Clark and Smith, 2008; Dunne and Martin, 2006). In order to achieve the deep and empathic understanding of the user, DT employs observational and ethnographic methods (e.g. Beckman and Barry, 2007; Carr, Halliday, King, Liedtka, Lockwood, 2010), as well as collaborative design with the user (e.g. Boland and Collopy, 2004; Brown 2008).

The Design Thinking process can be viewed as an exploration of a problem space and solution space, i.e. within the scope of the challenge, identifying and evaluating alternative problems to be solved and different solutions to address the chosen problem. In terms of cognitive processes, it is a combination of divergent and convergent thinking, where a set of choices is first created, and only then are choices made between the alternative options (Brown, 2009, 67). Ratcliffe (2009) describes DT as a six phase, iterative process involving back-and-forth movements between the different phases (Figure 1).

The process begins with *understand*; forming a general understanding of the situation and challenge at hand, and formulating an initial problem statement. During this phase, a product development team speaks with experts, conducts background research on the topic, and develops their understanding of the challenge to a level that allows them to identify ways to address the design challenge. While developing solutions to design problems is a well-recognized skill of designers, the ability to think up new ways of looking at the problem in the first place is key as well (Dew, 2007). This ability is referred as reflective reframing of the problem or situation. Design thinking encourages questioning the way a problem is represented (Boland and Collopu, 2004), looking beyond the immediate boundaries of the problem to ensure the right question is being addressed, and identifying, framing, and reframing the problem to be solved are seen as equally important as solving the problem or finding an appropriate solution (Beckman and Barry, 2007; Drews, 2009).

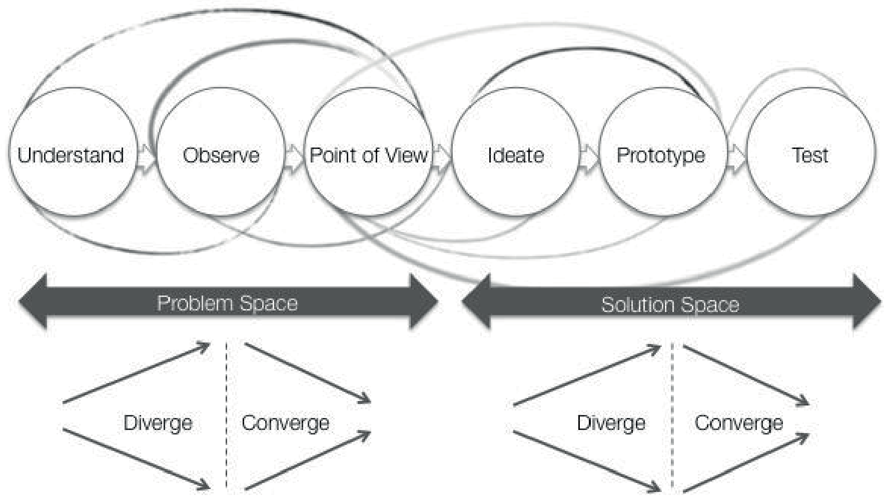

Figure 1. *Steps in a Design Thinking process (adapted from Ratcliffe, 2009)*

One of the outcomes of the understand-phase is the identification of key stakeholders and potential users. This gives the team an entry-point to the second phase, *observe,* where the objective is to learn how people behave and interact in the context of the challenge. This phase is also called *needfinding,* as the aim is to develop a deep understanding about the needs and problems of the user. At this phase the ethnographic research methods come to play, and where empathy for the user is developed. In addition to observation, the methods deployed here, include for example interviews, shadowing, “living the life of the user” i.e. immersing to the experience the user goes through.

When defining *a point of view*, the team analyses and draws conclusions from the findings of the previous phases: are there patterns, surprises, meaningful details that could give direction to the following phases. This phase is essentially about reflecting on the information created and collected so far, and interpreting that into a new, better focused and defined problem statement. Here, an often used model for the reformulation of the problem starts with the question “How might we….” which is followed by the description of the user, his/her need and a specific insight that gives clues for a possible solution. This point of view statement becomes the starting point for idea development (e.g. Ratcliffe, 2009).

When *developing ideas*, quantity is encouraged (e.g. Brown, 2009, p. 67, 77-79). The challenge is to cover as much of the potential solution space as possible, and to do so the team must suspend judgement. Ideation it itself is an iterative divergence and convergence, where idea generation is followed by their analysis and selection, and then a new ideation round is done to either increase variety amongst the existing idea, or to produce detail to the already existing ones. Selected idea(s) are then prototyped and tested.

Early, rough, and quick prototyping is a central part of the iterative and highly tangible approach favoured by designers - and a cornerstone of DT. Early – “from day one” – and continuous prototyping is considered necessary and beneficial throughout the entire process (e.g. Brown, 2008; Fraser, 2007). *Quick prototyping* refers to creating many inexpensive and rough conceptual artefacts, to promote reflection and the generation of new ideas (Fai, 2011). Prototypes are, in fact, primarily seen as a tool for stimulating thinking and exploring ideas, not as representations of the products (Boland and Collopy, 2004). They are created to facilitate thinking and knowledge creation, to make concepts concrete, and to help the exploration of numerous possible solutions (e.g. Fraser, 2007, 2009; Lockwood, 2009). They are low-cost representations of the idea: sketches, cardboard models, or rough digital mock-ups, that are created with the purpose of receiving early feedback from the users with minimum investment of resources. The less is invested, the easier it is to modify the direction of the project if the received feedback so requires.

Testing the prototype with users shows what works, what doesn’t. Reflection on the information gained from testing gives direction for the next iteration, i.e. how the idea and the prototype need to be modified. The process of challenging the original problem is not limited to the beginning of the process, but is ongoing, incorporating the findings already gained to re-phrase the problem (Drews, 2009)

Analytical Design

In the classical product development process, we can define a project as a connected sequence of unique and complex activities, with a single goal or purpose that should be completed in a specific time and with a given budget, according to a specification (Ulrich-Eppinger, 2008). This type of process assumes a certain level of knowledge upfront and during the project development. It consists generally on a sequence of steps or activities, usually six or more, that the designer or company employs to conceive, design and manufacture a product (Figure 2). The concept development is the key activity that demands more coordination among the other functions. It includes the following activities depicted in the lower part of Figure 1. In practice this activities may overlap in time and iteration is often necessary.

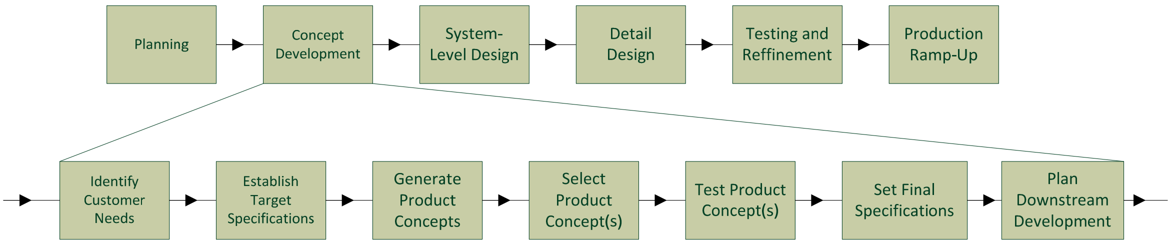

Figure 2. *Phases of product design and detailed phases of Concept Development. Adapted from* Ulrich-Eppinger (2008)

It is probably not needed to provide a detailed explanation of the classical approach. Most engineering schools teach and use a given variation of this approach. If we had to cite three references, we would choose the already cited (Ulrich-Eppinger, 2008) as a modern view of classical design, (Elder, 2008) as a reference book and the Lips model (Svensson, 2011) as an educational project model developed in Linköping University as a result of its participation on the CDIO initiative.

Model Comparison

If we look at the block diagram that describes the phases of design according to the Design Thinking approach (figure 1) and compare them with those depicted in the diagram of the "Concept Development" phase (figure 2, lower part), it may look like both are describing the same process. Apparently both start with understanding (needfinding) the customer needs, both stablish target specifications (Point of View), both develop several product concepts (ideate) ant test them through prototypes, to finish with a single product concept defined through final specifications. Where is then the difference? When engineers start dealing with "Identify Customer Needs", they usually know that the product is a given device, e.g. a wheelchair, and the needs are defined around the use of this device and the alternative analysis is performed on variations of this device or their parts. The same alternative analysis in the DT approach is not even in a preliminary phase of the solution but in the different needs identification in a given, broad environment e.g. elder mobility.

The design process assumes a certain level of information upfront and during the project development. According to Loch, "*Main reason for project failure is that organizations do not recognize the fundamental difference between project novelty and project risk…Novel projects pose unforeseeable uncertainty*." (Loch et al. 2006, pp. 2-3). In today's projects, complexity is increasing and the risk of product failure in the market is extremely high. Companies have to deal with a high level of uncertainty in innovation projects. In many cases there is not enough information and it is not possible to precisely describe and define neither the current state nor the expected outcome. Moreover, in innovation projects there could be (and usually is) that one problem has many possible and different outcomes. Loch et al. (2006, p. 74)) identify three fundamental project risk management approaches in face of uncertainty: the planning approach, iterate-and-learn approach, and selectionist approach.

The planning approach (with contingency and residual risk) could be considered the most classical approach, and is deployed when entering a known solution space. In this approach, the important problem solving occurs at the beginning of the project and then the emphasis shifts to executing the plan. There is a relatively high level of certainty and plenty of information at the outset. The outcome depends on the input at the beginning of the project, which proceeds with a pre-made plan with strong organizational pressure to support it.

The iterate-and-learn approach is well suited for projects in unknown solution space. It starts by planning and moving toward one outcome, which is the best that can be identified, with the information available upfront. The project team must remain prepared to repeatedly and fundamentally change both the outcome and the course of action as the project proceeds. This is due to the high level of uncertainty and lack of information available when starting the project. As new information becomes available, better-informed decisions can be made. This may force to iteratively modify the outcome.

The selectionist approach is characterized by pursuing multiple paths; independently of one another, and picking the best one ex post characterize this approach. As the “iterate and learn approach”, this approach is well suited for unknown solution space, where the level of uncertainty is high at the beginning. As the project moves forward, more information is generated allowing deciding which paths to follow and which ones to discard.

In a simplified analysis, the first and more systematic approach is the one usually employed in classical engineering design, and this allows using modeling and analytical tools to optimize both the design process and the design results. Systems of Systems approach (Keatinget al., 2011) or Complex Systems Architecture (Crawley et al., 2015) provide focus and analytical tools to deal with very complex systems in a known environment. However, in uncertain environments, such as for example the creation of novel products, services or processes, the project outcome or the means to reach it are unknown at the outset of the project. Here, the iterate-and-learn, and the selectionist approach provide a more suitable support for the development process. Design Thinking is essentially aimed at creating information and knowledge. Hence, it bears strong resemblance to the iterate-and-learn approach, that relies on creative problem solving and reframing as the project proceeds.

The design-build project courses in the ICT degree curricula of Telecom-BCN at UPC mainly follow the classical approach. Although near half of the projects are specified by external companies or institutions, very few (one or two per year) involve a real contact with final users (e.g. medical doctors, nurses or patients), while the usual contact with companies is through R+D staff, usually engineers. The Telecom school has however had the opportunity of participating in a singular experience the last two years, a Challenge Based Innovation course promoted by CERN in which students from different disciplines and countries are challenged to design solutions to social needs following the DT approach. It is described in the following point.

THE CBI EXPERIENCE: MIXING DESIGN, MANAGEMENT AND ENGINEERING STUDENTS IN CHALLENGE-BASED PROJECTS

The European Organization for Nuclear Research, CERN, has been carrying out groundbreaking fundamental research in particle physics for over 60 years, and has made numerous important discoveries in the field - latest being the Higgs boson in 2012. It’s current research gathers over 12 000 scientists from around the World in a collaborative effort in scientific experiments, developing new hardware and software solutions for their instruments. Over time, some of the research discoveries and instruments have found their way to wider audiences and have had significant impact on our everyday life, as in case of the World Wide Web.

IdeaSquare

The process of discovering the relevant societal applications is nevertheless slow, sometimes taking even decades, and many good applications so far have been adopted through serendipitous coincidences. In order to shorten the time gap between the research and its application in a structured way, a new innovation experiment called IdeaSquare was set up by CERN in 2013 in collaboration with Aalto Design Factory, a multidisciplinary teaching and development unit inside Aalto University in Finland. The main purpose of IdeaSquare is to explore new ways to demonstrate the value of applying fundamental research concepts to societal challenges. For this effect, IdeaSquare is hosting long-term research projects on detector R&D, promoting different innovation-related events and hackathons and facilitating multidisciplinary student projects like the Challenge Based Innovation (CBI).

Challenge Based Innovation

CBI is an experimental, human-centric product development project structure hosted by IdeaSquare. In CBI, multidisciplinary student teams start from a societal need and obtain relevant end-user needs to be addressed. Together with CERN mentors, teams draw inspiration from relevant novel technologies and create tangible prototypes to e.g. help autistic children in their learning process or developing methods for longer food storage. The CBI structure is a prototype itself and its purpose for IdeaSquare is to find out whether these kinds of design methodologies can bring value in the highly technological context of CERN. In the mission of CERN (Figure 3), CBI is focused on Collaboration and Education, with slighter focus on Technology and Research. To ensure a strong connection to CERN, all the teams have an assigned CERN mentor or research group they collaborate with throughout the project. They also have a coach in their home university with whom they have weekly sessions and who facilitate the team's advancement (Table 1)

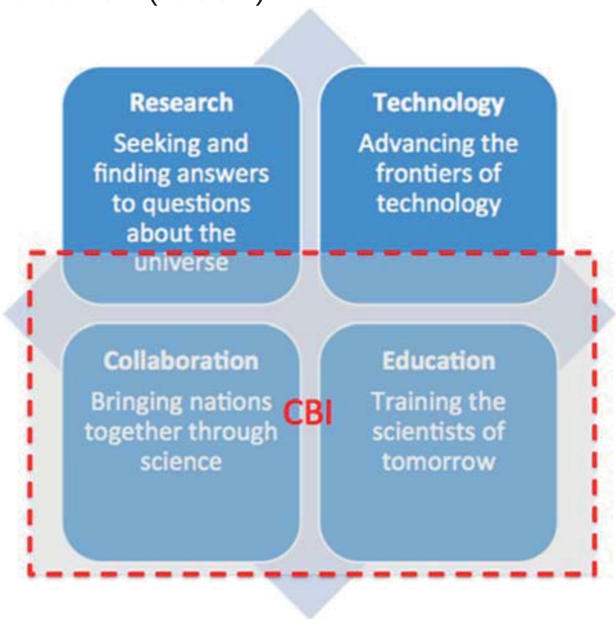

Figure 3. *CBI's focus within the mission of CERN (source: CERN website)*

Aligned with the DT approach, the basic structure of CBI is divided into three parts: Discover, Design and Deliver. The three phases of CBI are similar to e.g. the Design Council's double diamond model, composed of four phases, and the ME310 model, which has three main phases (Carleton & Leifer, 2009; Design Council, 2005).

In the Discovery phase, the student team does a deep dive into the societal need which they are given, and seeks to understand the fundamental constellation of the project. Need-finding, benchmarking and basic research about the project context are done with the goal of understanding the user and the field of operation. The phase ends with the team defining a specific need or a problem they aim to tackle. In the Design phase, multiple solutions for the discovered need are quickly prototyped and user feedback is gathered. Through learning from the prototypes, a final concept is chosen. In the Delivery phase, this concept is made higher in its resolution, and technical, design and user interface parts of the solution are implemented and integrated in a tangible prototype. The projects are finally presented in a gala event to the CERN and university audiences.

Table 1. Learning objectives and practical arrangements of CBI course

Learning objectives for students	**Practical arrangements**
• Develop highly futuristic, technologically feasible ideas that have the potential to challenge the status quo in socially and globally relevant human challenges. • Develop skills applying design thinking tools and methods and product design in a practical, real world project. • Develop skills in moving ideas into testable, tangible prototypes quickly. • Develop skills in interdisciplinary teamwork and communication.	• Each team will have 7-9 students coming together from two or more different universities. The team will be a multidisciplinary combination of students who have their background in engineering (mechanical, electrical, ICT), business and design. • The project topics will be confirmed and assigned during the kick-off week. Each team will be paired with a dedicated CERN mentor. • Project budget will be allocated for the teams for their exploratory prototypes during the process and for building the final, high-resolution prototype.

The topics for the course would be optimally formulated together with a societal problem owner and an expert institution e.g. an NGO working on the field. So far, some of the topics have been inspired from the CERN side, some from the collaborating universities' side and also from companies working on relevant areas. The topics are open rather than tightly framed, and the outcome is aimed to be educational for the participants beyond the pure project outcome.

The final deliverables for the CBI course were designed to give each project clear goals and to ensure that the most relevant learning objectives (Table 1) would be covered. Usually in a project, user testing is one of the things that is not often done to the full extent. To emphasize this point together with the impact calculation, they were separately mentioned.

1. Proof-of-concept prototype
2. User test results
3. Impact demonstration
4. CERN connection
5. Final presentation with relevant materials
6. Final documentation describing the project and process
7. Final video

Examples of projects developed into the CBI course

The last two academic years, design, management and ICT engineering students from Istituto Europeo di Design (IED), ESADE Business School and UPC-Telecom BCN were mixed together in multidisciplinary teams and also together with students from another international universities and similar disciplines. Being the three mentioned institutions located in Barcelona, the local student teams (5-6 students each) could work together at least one full day per week when they weren't at CERN, and could contact via Skype with the international partners. Examples of the challenge statements and the resulting solutions are described in Table 2. Other four challenges not described in this table were also completed.

Table 2. Examples of the challenges in the two last editions of CBI course

Challenge statement	Solution developed and prototyped
How can we design a wearable system that allows the users to access information about their effect on others around them by deepening the understanding of these interactions?	A wearable system that helps people with Asperger's syndrome to learn about how close come to another person and how fast and loud has talked to him/her.
How can we design a viable system that allows people to restore or enhance their ability to move?	A flexible skirt with an "airbag" and a set of sensors and algorithms that triggers it when a fall is detected to prevent hip fracture in elder women.
How might we improve public health by providing safe access to water?	A low-cost sensor set-up that detects if a given well in Africa is working and a network to inform users about the well state and to manage the repairing if needed.
How might we home deliver food in a new way that maintains the food cold, at a selected temperature, ensuring its safety?	A food transportation box that combines a special isolation material, partial vacuum and RFID active tags to reduce the cooling needs and to give information on the order state to both the customer and the provider.

A description and a report of the projects performed in the academic year 2014-2015 are available at http://2014.cbi-course.com . The reports of the projects performed the current academic year will be soon available in the same site. This last fall semester, 19 students (5 from ESADE, 6 from IED and 8 from UPC) coming from 9 different countries, have been distributed in four teams to face four challenges: "European Labour Mobility", "Food Safety in Home Delivery", "Creating a Literate World" and "Water Safety". The teams that carried out the first two challenges joined with two four-people teams from UNIMORE, in Reggio Emilia, Italy. Because of this the course was called CBI@ Mediterranean. These two first challenges were partially specified and sponsored by companies while the other two were defined by the teaching team. The schedule of the course is shown in table 3:

Table 3. Schedule of the 2015 edition of CBI course

Week	Location	Phase	Seminars	Deliverables
1	ESADE	Research	Introducing CBI challenges. Design Thinking methodology. Project Management approaches	CERN Workplan
2	Idea Square	Research	Understanding CERN. CERN technology macro domains. Case presentations	Research plan for 3 weeks. 1st Checkpoint presentation
3	UPC	Research	Design&user research. Trends research and analysis	
4		Research	Intellectual property and patents	Research results
5		Research/ Ideation	Ideation process Conceptualization / Moodboards	Preliminary list of relevant technologies and contacts at CERN
6		Research/ Ideation	Lego Serious Play	3 rough prototypes
7	Idea Square	Ideation/ Proto&Test	Concept testing & validation. User tests	Mid-term presentations
8	UPC	Ideation/ Proto&Test	Business Models and experimentation	
9		Ideation/ Proto&Test	Distribution strategies for entrepreneurs	First draft of the business plans & uncertainties identified. Results from testing
10		Proto&Test/ Convergence	Financial Plan: How much money is needed?	
11		Convergence /Design	Funding the new venture: How do you get the money?	Financial Plan
12		Design	Hardware and software prototyping. Storytelling & Visual communication	Work and research plan for CERN
13	Idea Square	Design		
14		Design/ Presentation		Final presentation
15	UPC	Final deliverables		Final reports and models, project video, personal reflection

The students from the three institutions in Barcelona joined a first full-time week at eGarage, a space for co-creation located in ESADE, then a second week at IdeaSquare at CERN, followed by a period of five weeks in which the teams met a whole day per week at Espai Emprèn, a co-creation space located at UPC campus. During this weekly day, the students followed a series of seminars and workshops (1-2 h per week), presented the deliverables of the previous week and worked on the successive phases of their projects. Then the students stayed along a week at IdeaSquare where they meet CERN scientists and continued with the ideation phase. After that, five more weekly days at UPC, completing the solution convergence and starting the final prototype design, which was completed and integrated during the last visit to IdeaSquare (10 days), which finished with the final presentation in front of the IdeaSquare community, CERN scientists and invited stakeholders. Student’s assessment is based on the evaluation of the team performance and the result of the project (relevance, originality, impact): 50%, the individual performance (the process and quality of work done, the application and adaptation of specific prior knowledge in a multidisciplinary project, the adaptation to a multidisciplinary environment): 30% and peer evaluation through a rubric: 20%.

DISCUSSION AND CONCLUSIONS

The overall result has been outstanding in both editions. Feedback from students in general and from engineering students in particular has been more than positive. Most of them have qualified CBI course as a key step in their curriculum. Several aspects which are not usually found in the regular courses can be found together in this one: Multidisciplinary and international composition of teams, which not only enriches the points of view taken into account when analyzing the challenges but also forces the students to negotiate in a wider environment than its usual class group; contact with CERN scientists as consultants and coaches and with CERN technologies, which raises the horizon of possible solutions to levels unforeseen by the students; singular workspaces, mainly at IdeaSquare, where the students work together and intensively during several periods in an environment that boosts the creativity; challenge-based projects with very open initial statements, which drive to the use of a methodology like Design Thinking, which takes the students out of his comfort zone and forces them to interact with end-users and stakeholders in several phases of the projects.

Although all students from the different disciplines are playing out of their field with the interdisciplinarity and the user-driven approach, the engineering students are probably the ones that experience the biggest perturbation respect to their previous training. One of the biggest tasks for coaches is to keep them calmed when they tend to apply technological solutions in the low-resolution prototyping phases during needfinding and ideation (two thirds of the project duration), where they are still not needed. They need a strong justification to participate in these phases exactly like the design or management students. Including engineers in the teams has the added value, set apart the enrichment of viewpoints, of allowing the implementation of true functional final prototypes, which could provide a realistic proof of concept to users, stakeholders or potential investors. A minor drawback of the involvement of engineering students is that they (and even the engineering teachers and coaches) use to reveal the technology limitations in the ideation phase, where disruptive solutions that go beyond the currently possible solutions could appear.

If compared with the capstone projects performed by the regular students at Telecom-BCN (Bragos et al., 2012) the results would be the following:

- The human resources allocated to the projects is quite similar. Although the local teams in CBI courses are smaller (5-6 students vs 8-12 students), they devote more time to the project thanks to the intensive weeks at IdeaSquare.
- While the CBI course students devote four-five weeks to needfinding, four more weeks to ideation (including low resolution prototyping and testing) and only four weeks to final solution prototyping, the usual structure of capstone projects at Telecom BCN is two-three weeks to fix specifications from initial requirements, six weeks to subsystems design and implementation and five weeks to system integration and refinement.
- As a consequence, the technical deepness and complexity of solutions is higher in capstone projects than in CBI projects, but the degree of awareness of what the product is and what does the user expect from it is clearly lower. Even some students in the team can be only devoted to technical tasks and miss the user/market orientation of the product and the business aspects. There are some exceptions in capstone projects, when interlocutors are not engineers or technicians but end users (only 1-2 projects out of 6-9 per semester).
- In capstone and other design-build projects following the classical approach, the need of having all sub-systems working and of integrating them before the product delivery adds a real need of solving practical issues, dealing with unexpected problems (technical issues, delivery delays, discontinued parts, …) and of negotiating the solutions into the team. On the other hand, the concept statement is usually set from the beginning and the requirements and specifications are frozen in the first weeks. In opposition, in CBI projects, although a given technical development level of the final prototype is required to provide a proof of concept, the relevance and impact of chosen needs and solutions are more critical and most conflicts and issues appear in needfinding and ideation phases, when validating chosen alternatives with stakeholders.
- Related with the previous paragraph, the planning and documentation needs are different in both cases. In the Telecom-BCN capstone projects, a strict planning and documentation method is followed, including risk analysis and contingency plans to cope with delays and incidents and to ensure the traceability of the design process. The creative phases of the CBI projects however, need a more dynamic approach and the documentation is intended as an aid for understanding the different steps and for communication with stakeholders. Videos and other visual representations often substitute the formal reports. Final reports and presentations also enhance the technical achievements or the user/market orientation in the two approaches.
- Multidisciplinarity in Telecom-BCN capstone projects is understood as the mixture of communications, electronics and networks or audiovisual systems engineering students, which is wider than having only students from a single discipline but is still limited to the ICT engineering field. In opposition, in CBI course, engineering students should learn to discuss with people that has a very different point of view, which is a relevant experience. CBI course has also been a great learning experience for the engineering teaching team. The user-driven approach is being introduced with a limited extent in the regular project courses by the faculty that has participated in CBI. Also coaching the engineering students that have been taken out of their comfort zone has been a great experience that has modified our way of thinking in engineering project education.

Albeit perhaps unintuitive, multidisciplinary learning experiences also support the development of the students' professional profile, and deepen the professional expertise in a respective field. In a learning context such as CBI, the successful development of the project depends on the specialized input delivered by each student, from his field of expertise.
Open-ended and problem-based projects allow the students to learn how to manage projects with uncertainty: how to proactively create information, reflect on it as a group (collaborative sensemaking) and adapt the direction of the project respectively. The experience develops the entrepreneurial skills and abilities of the students.

The benefits in the learning outcomes of the participants in CBI courses are cumbersome and, at least from the engineering students' point of view, cannot be foreseen before participating in the course. Design Thinking is a methodology that can only be learnt by doing. An immersion in that methodology like the one described in this work cannot be provided to all students, and even a large amount of engineering students would prefer projects with more technical content, but a basic knowledge of the basis of this methods would be very positive for everyone, and the possibility for the students more inclined towards innovation and entrepreneurship to participate in a learning experience like the one described is highly desirable.

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INTEGRATING AND INNOVATING METHODOLOGICALLY AN INTRODUCTORY ENGINEERING COURSE: USING SERVICE LEARNING

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ABSTRACT

This paper describes the new design and implementation of the Introduction to Civil Engineering course at UCSC in 2015. With the previous course structure students were not acquiring the intended personal and interpersonal learning outcomes and showed very low interest and motivation for the communication skills. An interdisciplinary team composed of civil engineers, a Spanish professor, a therapist in Psychogenealogy and an Industrial Engineer/organizational coach with expertise in positive psychology, was put together to re-design and implement the course. The result was a course that integrated all the disciplines (engineering role, communication and personal/interpersonal skills) by means of a service-learning project that was developed during the whole semester. This project sets the context and the purpose for the other learning outcomes that are addressed in the course, which were planned out in the semester in a way that they were delivered just in time when the students needed them for a specific part of the project. The project requires them to conceive, design, implement and raise funds for its implementation. The students were assigned 8 hours/week, which were distributed among the different disciplines that were taught by the same faculty that participated in the course design. As a result, students were highly motivated and learned more than previous years. Faculty were able to perceive changes induced by the experience and the self-awareness process that was intentionally provoked and that resulted in positive changes in their attitude and behaviour.

KEYWORDS

Service Learning, introduction to engineering course, personal and interpersonal skills, leadership skills, teaching community, Standards: 1, 4, 5, 7, 8, 11.

INTRODUCTION

More engineering schools are acknowledging the benefits of an introduction to engineering course in the first year (Johns, 2006) & (Crawley et al.,2007). According to the CDIO Standards, an introductory course not only provides a framework for engineering practice, but also “introduces essential personal and interpersonal skills” (Crawley et al., 2007).

When receiving first year students, it is important to shape them from the very start in order for them to meet the profile by the end of their program. Therefore, learning outcomes related to attitudes, teamwork, leadership and communication skills are of the essence. But developing these skills is not easy, especially in an engineering program.

In 2011, the School of Engineering of the Universidad Católica de la Santísima Concepción (UCSC), began the implementation process of a CDIO based curriculum for 5 of its undergraduate programs (Loyer et al., 2011). As part of the changes, each program incorporated a first year *Introduction to Engineering* course using as guidelines CDIO standards 1, 4 and 8 (Loyer et al., 2011).

In the case of the Civil Engineering program, the introduction course had good results in terms of motivation and knowing more about civil engineering, but not regarding the other learning outcomes. With this in mind, the school's authorities entrusted the redesign of this course to an interdisciplinary team, with the interesting results that will be presented further on.

INTRODUCTION TO CIVIL ENGINEERING COURSE

Original Introduction to Civil Engineering Structure

The Introduction to Civil Engineering course focuses on developing engineering, personal and interpersonal skills, as well as on having the students understand the role of Civil Engineers in the world. The CDIO skills considered are presented in the following table:

Table 1: CDIO syllabus skills associated with the course

Technical knowledge and reasoning	1.2. Core engineering fundamental knowledge
Personal and professional skills and attributes	2.1. Analytucal reasoning and problem solving
	2.4. Attitudes, thought and learning
	2.5. Ethics, equity and other responsibilities
Interpersonal skills: teamwork and communication	3.1. Teamwork
	3.2. Communication
Conceiving, designing, implmenting and operating systems in the enterprise and societal contex	4.1. External, societal and environmental context
	4.1.1. Roles and responsibility of engineers
	4.3. Conceiving, systems engineering and management
	4.4. Designing
	4.5. Implementing
	4.7. Leading Engineering endeavors

The course was assigned 8 hours/week. It was originally dictated by civil engineers and a professor of Spanish who was in charge of the communication skills (written reports and oral presentations). Students would have 2 hours/week of oral and written communication (OWC) classes and 6 hours of "engineering". In the last quarter students developed a final project related to an engineering area. The original course structure is shown in figure 1.

As a way to develop communication skills, the original oral and written communications course was incorporated inside the Introduction to Engineering course, under the presumption that by putting the together it would somehow add context of engineering and students would learn these skills better.

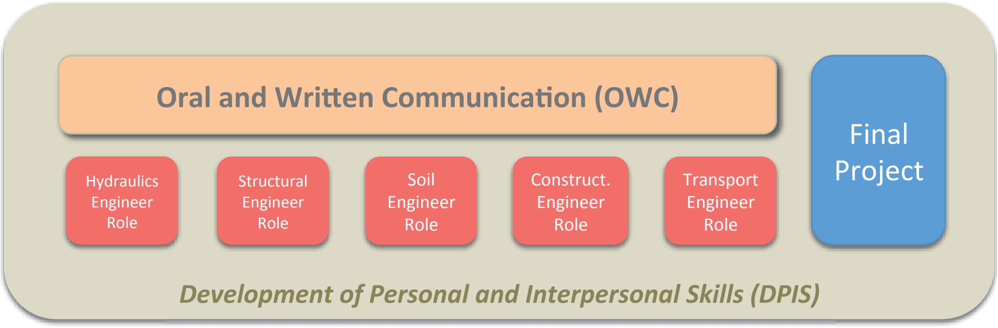

Figure 1. Original Introduction to Civil Engineering Course Structure

Students were motivated by this course, especially with the active learning engineering experiences. But the communication skills and the other personal and interpersonal learning outcomes were not being satisfactorily achieved.

We believe that one of the reasons was the lack of integration of the activities designed for the course. For example, students complained about the OWC classes, because they did not see their purpose in the course, since they were not integrated in a proper way. Another reason was that no one was taking charge of the other personal and interpersonal learning outcomes. They were declared in the syllabus, but they were not being properly or sufficiently addressed in the course. And finally, there was not sufficient communication and coordination between the faculty involved.

New Introduction to Civil Engineering Structure

An interdisciplinary team composed of civil engineers, a Spanish teacher/actor, a therapist in psychogenealogy and an industrial engineer/organizational coach with expertise in positive psychology did the new design of the Introduction to Civil Engineer course. This group was set up and headed by a civil engineering professor with experience in engineering education, the CDIO framework, and teaching communities.

Although the original task was to integrate the different disciplines keeping the basic structure of the course, the final product was slightly different. As a result of the interdisciplinary work, the new course structure integrated all of the disciplines in a very innovative way. In the course three disciplines are identified, in response to the learning outcomes: Engineering Role (ER), Oral and Written Communication Skills (OWC) and Development of Personal and interpersonal Skills (DPIS). The main innovation is that these disciplines are integrated through a Service Learning Project (SLP), as is seen in figure 2.

During the first three quarters of the semester, the students' weekly schedule would be structured in the 4 modules described below, while during the last quarter, all 8 hours would be destined to the service-learning project.

- Module 1: 2 hours of "Engineering Role" (ER)
- Module 2: 2 hours of Oral and Written Communication (OWC)
- Module 3: 2 hours of Development of Personal and Interpersonal Skills (DPIS)
- Module 4: 2 hours of workshop for ER or for SLP (depending on the schedule).

Each module is under the guidance and supervision of a specialist in that field. Each discipline has a specific syllabus, but everything is planned out or synchronized during the semester in a way that the topics are addressed *just in time* when the students will need them for a specific part of the project. This was considered important in the integration of the different disciplines in the course, because not only is it more effective, learning-wise, but it also gives each issue addressed a sense of purpose for the students.

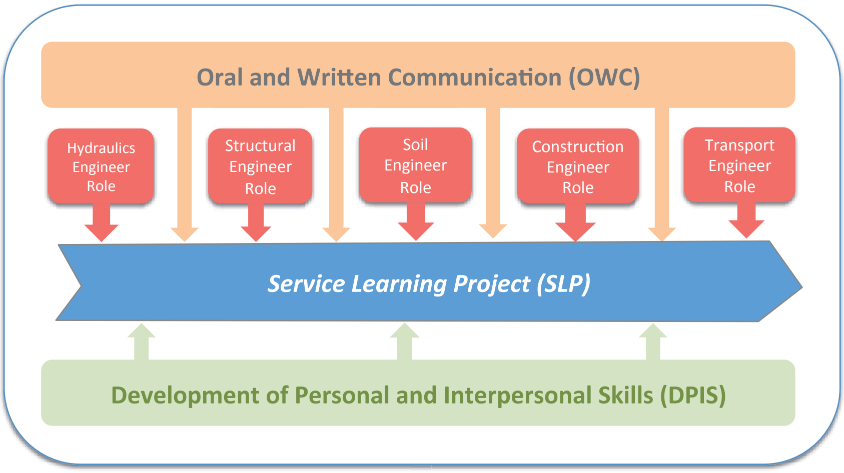

Figure 2. New Introduction to Civil Engineering Course Model

Service Learning Project (SLP)

The project is developed for a social organization or community (called community partner) and it should focus on something that students can design and build in order to solve the problem or requirement that they had previously identified, but related to civil engineering. Students get to conceive (C), design (D) and implement (I) their project, so it complies with CDIO standard 1. The different stages of the service learning project are shown in figure 3. The *first phase* considers four stages and is carried out in small groups of 5 students. The second phase consists of only two stages but with bigger teams that must interact with each other.

The first stage is to identify the community partner's needs. This stage requires students to visit the facilities, meet with the different actors and research regarding that specific type of organization or community. Once each team has identified the problem that they will address, they go on to stage two and design their solution. The third stage is a formal presentation by each team where they get to present their proposal in front of all the faculty and class. Faculty choose the three best projects which will be formally presented to the community partner (stage four). Together with the community partner, the best project is selected and leading to phase 2, where the whole class must work on the same project.

Phase two starts by regrouping the students in teams that have to carry out the different activities needed to develop the project (planning, budget, design, construction, etc.). First stage is redesigning, planning, etc., and the final one is the construction.
In terms of budget, the school puts a part, and the rest of the funds had to be raised by the students, so there was a team assigned for this task. This activity started with phase two, but it definitely has to start at the beginning of the semester as is illustrated in figure 3.

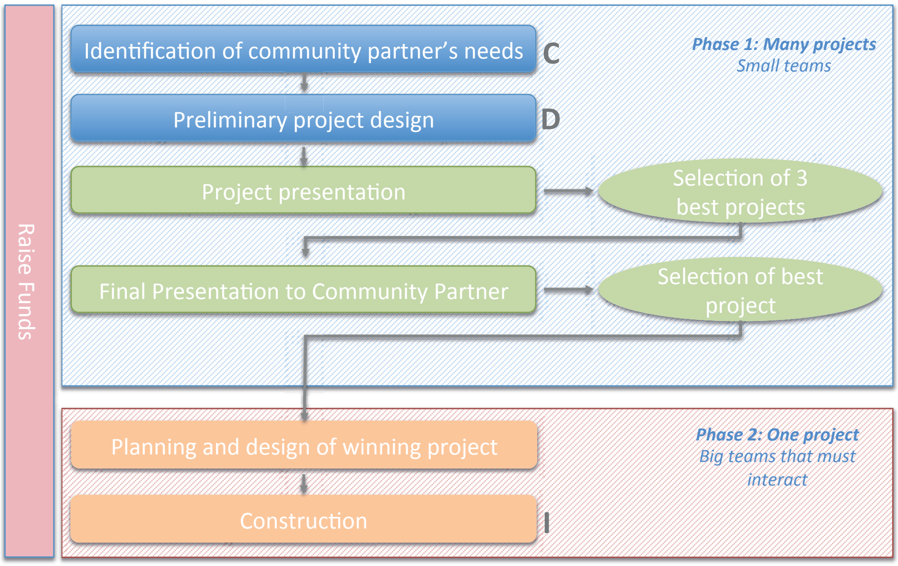

Figure 3. Service Learning Project Scheme

For the first phase, students work on their project during specific workshop hours (module 4), which were planned for this purpose. The working space was appropriate for developing team work, and the engineering professor and a teacher assistant were present at all times to guide and aid the work that the students were developing.

For the second phase new teams were assembled and they had to select their team leader. This part of the project was supervised and guided by an engineering professor. The reasons were basically three: a) To insure the proper development of the project, since it was a real project that was going to be built for a real community partner. b) As a way to coach students on how engineering teams were assembled and work together in big projects, so the engineer professor's experience is very important. c) To give the students a certain ease. This was a big project so it can be very scary for first year students, so the professor also plays a father/mother role and encourages them and helps them build their confidence. Not just any engineer professor can work with these students. Certain personal characteristics are needed in order to play the role that is needed.

Engineering Role

This part of the course was not modified from the previous course design. It consisted of two main activities:

- Lectures, seminars and presentations by faculty, engineers from the industry and alumni (Module 2). The purpose is for the students to understand the different areas of civil engineering (structural, hydraulics, soil, transportation, construction), and their role in society, but from different points of views.

- Small engineering projects. For each engineering area, there was an active learning activity that was developed during the workshop hours (module 4). In some cases it would be to build a structure and test it, others they would have to go out on the street in wheel chairs, crutches, blindfolds and/or strollers and diagnose the transportation infrastructure facilities for people with mobility disadvantages. These are very hands-on experiences that students appreciate.


Figure 4. Small engineering projects for Engineering Role Module

Oral and Written Communication (OWC)

In terms of communication skills, students are expected to learn how to write reports and make oral presentations. The main difference with previous years is that now all the reports and presentations are necessary for the project, so students now see a purpose. Also, since there is a competition (only one project is finally selected), students value more the importance of having a good report and presentation. They are assigned 2 hours a week (Module 2), where they have traditional lectures and active learning activities. Also, the teacher films their presentations so students get to observe themselves, which is very helpful.

Personal and Interpersonal Skills

This module was designed using the Cocrea model (Silva, 2016), which presents the development of these skills as a continuous learning process that must begin with the development of self-knowledge, after which it is possible to develop interpersonal skills, such as leadership. Students work 2 hours every week (module 3) with two specialists. During the first half of the semester they focus on developing self-awareness and self-knowledge through a psychogenealogy approach. This is done through different active learning activities that are designed by the therapist. The final goal of this part is for the students to know themselves and be able to lead themselves. During the second half students focus on personal skills such as emotional intelligence, self-discipline, tolerance to frustration, among others, and interpersonal skills like effective communication and empathy, all based on the Delta Leadership model (Jordán & Garay, 2014). All of these skills are necessary for the Service Learning Project; therefore they experience teamwork with transcendental goals.

Course Assessment

Each module had its own set of assessment instruments. In spite of having several instruments, there was not an overall strategy and not all of the learning outcomes were properly assessed. Five assessment instruments were used for the *personal and interpersonal* module: a) Faculty perception of students' achievement of learning outcomes; b) Students' perceptions of learning outcomes; c) Self-esteem test; d) Leadership skills test; e) Motivation towards leadership test. The last three were applied at the beginning and at the end of the semester. For the *engineering role module* the small engineering projects were assessed using a rubric. The assessment of the *communication skills* strategy was through a written report and an oral presentation of the projects. The instrument used for both cases was a rubric. There wasn't a specific strategy for the *service learning project*, and it was indirectly assessed through the reports and presentation.

RESULTS

All of the results presented in this section are preliminary, since the new course design has been implemented once, so some results could only be compared to one previous year.

Regarding the communicational skills, there was an interesting improvement compared to previous years. The grading scale used in Chile is from 1 to 7, being 4 the passing grade. In written reports there was a 9% increase in the average grade respect the previous year. But when analyzing how the grades were distributed (figure 5), this number does not say much. There is not a clear pattern, and the results for 2014 are very strange but interesting. There is a large group of students that had very low grades (over 35%), and then an almost equally large group of students that had a very good grade (over 30%). This polarized result is not observed in 2015, where student results are more spread out. The only explanation that we found for this has to do with the level of students' motivation. As was stated before, in previous years students were not very motivated for the oral and written communication classes, since they saw no purpose in them. Therefore, we interpret the low OWC grade results in 2014 as students that were not motivated, and therefore did not put much effort in the work. On the other hand, the over 30% high grades of that same year, we interpret as students with intrinsic motivation (Fischman, 2014).

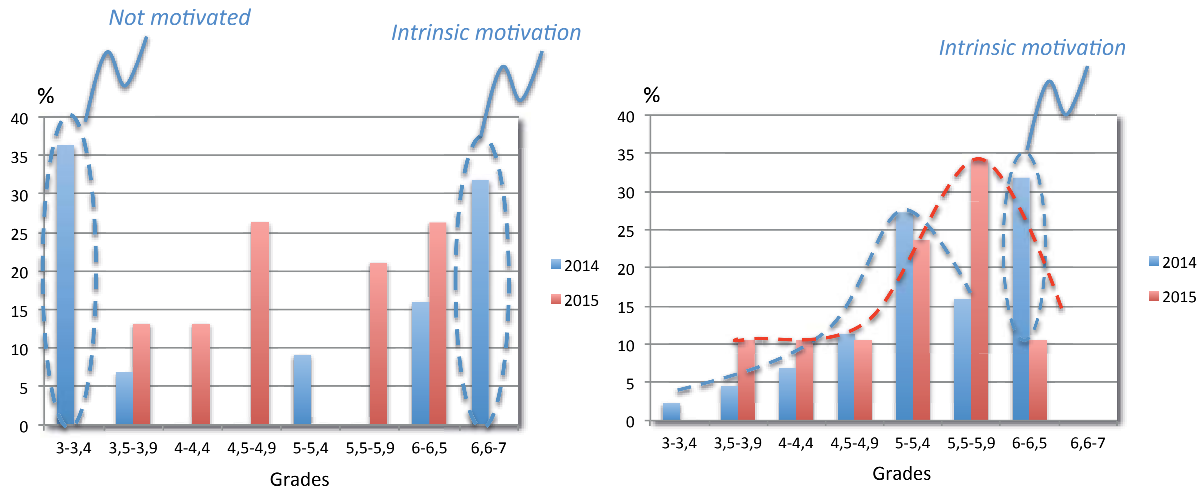

Figure 5. Final grades of written reports (left) and oral presentations (right); 2014 and 2015

The results of the oral presentation grades are also presented in figure 5. Here it is possible to see a pattern that is illustrated by the blue (2014) and red (2015) segmented lines. There was a shift towards the right (higher grades) of the grade distribution in 2015 compared to 2014. However, there is a high number of students (around 30%) that got a high grade in 2014 and not fitting in the distribution. This is the same percentage of students that got a very high grade in the written reports that same year; therefore we interpret this once again as students with intrinsic motivation. As opposed to the written reports, in the year 2014 the grades weren't as low for the oral presentation. One possible explanation is that this might have to do with the fact that these were presentations in public, and students don't want to be embarrassed in front of others, therefore they are willing to make some effort, as opposed to written reports where the only one that sees their work is the teacher. Another possible explanation is that students master more oral communication skills than written, but at the moment we don't have evidence to support this. Another interesting result is that in 2014, 20% of the students had a failing grade in the OWC module as opposed to only 3% in 2015.

When asked, the OWC teacher said that students were more willing to work compared to previous years. He also noticed that students now got a better understanding of what a report at a university level is like, compared to previous years where they still wrote reports like they did in high school. He also observed a greater sense of commitment from the students and they established relations with him, something that hadn't happened in previous years. Another interesting fact is that they asked him questions about other modules of the course (which did not happen in previous years also), which may be interpreted as students conceiving the course in an integrative way, therefore they could ask any of the teachers.

Regarding the Engineering Role modules, there was not any change compared to previous years in terms of motivation, quality of the students' work or motivation. This was expected, since this module did not change in the new design, and students had always been highly motivated for the active learning/design activities that are carried out.

An instrument was used to measure faculty perception of students' achievements of learning outcomes (personal and interpersonal). The high level of detail of the learning outcomes as well as the high number of students made this task very difficult, therefore resulting in a not very good assessing instrument. In average most of the learning outcomes were assessed at level 4 on a scale from 1 to 5 (4: skillful in the practice or implementation of), but the answers among the faculty were very disperse. The same instrument was applied to the students at the end of the semester in order to measure their perception of their proficiency level. 72 of the 120 students (60%) registered in course in 2015 answered the instrument. The results presented in Table 1 show that students in general perceive high levels of proficiency in most of the CDIO skills. These perceptions are consistent with the instructors' opinions of the same students during the same and following semester, which are detailed further below.

Table 2. Students' perceptions of their learning outcomes by the end of semester, 2015

CDIO Skills	1	2	3	4	5
2.1. Analytical reasoning and problem solving	2%	10%	39%	27%	20%
2.4. Personal skills and attitudes	3%	11%	25%	38%	21%
2.5. Proffesional skills and attitudes	0%	10%	28%	38%	25%
3.1. Teamwork	3%	10%	29%	36%	20%
3.2. Communications	3%	15%	35%	30%	15%
4.1. External and societal context	1%	7%	25%	37%	28%
4.3. Conceiving, system engineering and management	1%	7%	25%	37%	28%
4.4. Designing	0%	13%	25%	40%	21%
4.5. Implementing	6%	11%	42%	30%	7%

Note: 1) To have experienced or been exposed to; 2) To be able to participate in and contribute to; 3) To be able to understand and explain; 4) To be skilled in the practice or implementation; 5) To be able to lead or innovate in

Detailed results of the other three instruments are a matter of another article being presented in this conference (Silva, 2016), but some results are presented. 50% of the students showed an improvement of their leadership skills by the end of the semester. Also, 55% of the students had an increase in their motivation towards exercising their leadership. Regarding self esteem, the general self-esteem had a 38% increase.

All faculty involved in the course agreed that the students were highly motivated and they perceived that they were learning more. They also observed a positive change in the attitude and behavior of the students during the semester and also compared to previous years. There was a greater respect for the faculty and greater commitment. We believe this is because of the self-awareness process that the students were exposed to.

Faculty that had these students in the following semester expressed that they perceived a difference in comparison to other years. Students were more focused and “present”. They didn’t seem like freshmen students, but rather like older students. When asked about the civil engineering students to professors who taught other courses in the same semester, they said that they observed a difference in their behavior in contrast with students of other engineering programs; ours behaved better and paid more attention.

CONCLUSIONS AND FUTURE WORK

With the new course design students were highly motivated and learned more than previous years. Faculty were able to perceive changes induced by the experience and the self-awareness process that was intentionally provoked and that resulted in positive changes in their attitude and behaviour. The integrated design allowed students to see a purpose for each one of the personal and interpersonal outcomes, particularly the communication skills that had been neglected by the students in previous years. As a result of this, students were more motivated, and more conscious of their own learning processes and therefore more willing to work. Faculty that had these students during the same and following semester acknowledged this change of behaviour, expressing it as being more *focused or present*.

The main challenge that must be tackled for future experiences is improving the assessment strategies and tools. Not only for the course, but also to do a follow up in the following courses. Another challenge is how to prepare for changes in the staff that is involved in the course. There should be some kind of protocol or system in order to facilitate the transition.

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INVESTIGATION OF THE GEOSOCIAL OBSTACLES IN THE CURRICULUM DEVELOPMENT OF CIVIL ENGINEERING PROGRAMS IN VIETNAM

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ABSTRACT

After three years of the CDIO deployment in the Faculty of Civil Engineering at Duy Tan University (DTU), a number of improvements have been accomplished, namely students' flexibility and adaptability under various learning or working conditions. Most students are now more proactive and progressive in their learning approach despite of the fact that Civil Engineering is always a dull and demanding discipline. A recent survey, however, showed that while improvements are prevalent, the rates of improvement were not as fast as expected, especially in students' communication skills and creativity capacity, which are much worse compared to those of students in Western countries. Further analysis has demonstrated a number of geo-social difference reasons for this reality, namely cultural barriers in Asia, the passiveness of Vietnamese students, the non-relevance nature of certain soft-skill and career-planning courses, the gap between what is taught in school and what is carried out in the industry in Vietnam, etc. Understanding these geo-social differences is one of the many efforts in our continuous improvement of the CDIO model for Civil Engineering at DTU. And of course, our findings will offer great insights for universities and colleges in Asia, which are looking for ways to overcome traditional barriers in Civil Engineering education. A series of solutions are also proposed throughout this paper, accordingly.

KEYWORDS

Asian cultural values, CDIO Standard No. 2, 8, 9, 11, Civil Engineering, curriculum development, entrepreneurship, geo-social obstacle, soft skill development

1. INTRODUCTION

Civil Engineering career is always in high demand, and it requires a great deal of technical and professional training. In developing countries like Vietnam, most current training programs in Civil Engineering still focus on the theoretical knowledge due to the traditional training methods and the lack of training laboratories. A CDIO approach is recommended to help students develop both of their “hard skills” and “soft skills” in a comprehensively manner so as to quickly adapt to any working environment.

Since 2001, many universities around the world have applied the CDIO model for their engineering programs. For Civil Engineering, Vigild M. had reported the inspiration in creating novel Design-Build projects for the B ENG programs of Denmark Technology University in Civil Engineering, Architecture, IT, Electrical Engineering, Chemical Engineering and Mechanical Engineering (Vigild et al, 2009). A design-directed curriculum based on CDIO principles was also proposed for the program of Civil Engineering at Shantou University in China (Xiong & Lu, 2007). It is indicated that the designed-directed CDIO curriculum put students in a broad and active design environment where they learn and apply sciences, technology, engineering knowledge and non-engineering knowledge as well as to exercise their project management, communication and leadership skills. Another article by Anette Krogsbøll described four projects in the Civil Engineering study program also at Denmark Technology University along with a brief description of the entire study program (Krogsbøll, 2011). Learning outcomes, training methodologies, assessment of personal, professional and social engineering skills were described from a project point of view while progress in engineering skills was discussed from a study-program perspective. Since the CDIO model are designed and implemented according to a standard process, it needs a systematic solution for the re-investment and redistribution of resources within an organization so as to reduce any cost related to a new training scheme - this is especially relevant to a rather costly training discipline like that of Civil Engineering.

Almost every engineering study program nowadays include a mix of theoretical and practical or laboratory-based courses. The big question becomes how to adapt them with the CDIO framework and implementation guidelines with the least number of modifications. A case study for Civil Engineering programs at DuyTan University is being investigated to answer this question: Some add-on modules have been added into the current curriculum to help students develop necessary skills for the CDIO projects besides a series of “soft-skills” and career-planning courses. Several smaller projects or practical group games are also integrated into already-available courses. CDIO project courses in Civil Engineering at Duy Tan University would focus on comprehensive technical solutions for buildings and structures to cope with the natural disasters in Vietnam including floods, hurricanes, landslides and earthquake. It is also important that these solutions are at a minimal cost to fit with the economic conditions in Vietnam and at the same time, meeting the requirements of the CDIO framework.

Over the last three years of CDIO deployment, a number of improvements have been accomplished by the Faculty of Civil Engineering of Duy Tan University, namely in students’ creativity, flexibility and adaptability for various learning and working conditions. A survey was carried out to measure students’ perception about the success and failure of our CDIO deployment. Study results and feedbacks were relatively encouraging with most students now become more proactive and progressive in their learning skills and approach. Basically, the survey was based on the description of various disciplinary fundamentals in Part 1 of the CDIO Syllabus, which are necessary for any particular engineering education, as stated in the CDIO Syllabus (Crawley, 2001). As depicted in Figure 1 below, the building blocks of skills, knowledge and attitudes serve as a reminder that the development of working knowledge in technical fundamentals is and should always be the primary objective of any undergraduate engineering education.

CDIO		
1. Technical Knowledge and Reasoning	2. Personal and Professional Skills	3. Interpersonal Skills

Figure 1. Building blocks of knowledge, skills, and attitudes necessary to Conceive, Design, Implement, and Operate (CDIO) Systems in the Enterprise and Societal Context (Crawley, 2001).

The remainder of the CDIO Syllabus is arguably common to all engineering professions: That is, engineers in any field use approximately the same set of personal and interpersonal skills, and follow approximately the same generalized processes. Therefore, our survey questionnaire took after the sample survey in the report of Edward Crawley in 2001 with some modifications that focus on Part 2 and 3 of the CDIO Syllabus (Crawley, 2001).

2. CDIO APPROACHIN CIVIL ENGINEERING PROGRAMS AT DUY TAN UNIVERSITY

2.1. Objectives:

The modifications made to our Civil Engineering curriculum over the last three years since our CDIO adoption are to adapt to the regularly changing details of the CDIO framework, hence, we only make the least number of modifications each time, which are essential and necessary to a standard CDIO curriculum:

- Add-on modules were created to help Civil Engineering students develop needed skills for carrying out modular and comprehensive CDIO projects.
- The focus of our Civil Engineering CDIO projects are usually on dealing with natural disasters and catastrophes in Vietnam.
- The modifications accommodate for the economic conditions of a typical institution in Vietnam, which has insufficient education budget and lacks of various hi-tech training equipment and laboratories.
- Add-on courses to help students improve their soft skills and career-planning tactics.

2.2. Basic CDIO Projects:

At the basic level during the sophomore and junior years, CDIO projects help teach students about certain aspects of Mechanical Science which is the most fundamental knowledge of many Civil Engineering domains. More than often, Mechanical Science is very difficult for students to understand and apply because it integrates both applied Physics and Mathematics. The goal of the CDIO projects here is to guide students through the application of mechanical theories to solve some real-world problem like retaining walls or constructing truss bridges or maximizing load. Students may not understand all aspects of the theories at first, but through the fruitful applications, they will come to understand the theories to a certain degree.

Given the 4 different stages of the CDIO model, including Conceive, Design, Implement and Operate, a typical *retaining wall* project would be like this:

1. **Conceive stage**: Students will do research on landslides and its consequences. Then, they would search for existing solutions for retaining walls in case of landslide. They would try to understand the theoretical and technical aspects of those already-available solutions to certain extent. Based on that newly-found knowledge, students would propose some "new" and general designs for retaining walls under the requirements that they would save the most amount of materials and at the same time, optimizing the strength of the proposed structures.

2. **Design stage**: The instructor will provide students with information on various parameters of the terrain and the landslide, and students would need to propose their design structures for the retaining wall. It is important that students would integrate knowledge from various courses learned before:
    a. Surveying course: measuring, modeling and drawing skills
    b. Hydraulics course: the ability to determine the permeability coefficient and the force of flows on the ground
    c. Geotechnical Engineering course: practices in surveying various geotechnical properties and conditions
    d. Soil Mechanics course: the ability to assess the physical and mechanical properties of soil, and to apply knowledge about soil mechanics into calculating the strength of the proposed wall
    e. Statics course: the ability to design for the balance of the structures and the stability of the retaining wall
    f. Strength of Materials course: the ability to compute the bearing capacity of the proposed retaining wall
    g. Civil Engineering Software course: the ability to run the proposed structures on software such as Plaxis or Sap so as to provide analysis and evaluation of the corresponding virtual model

3. **Implement stage**: In Civil Engineering, the design on paper versus the actual construction always yield many differences. At the construction phase, there may be some inconceivable challenges of reality. As a result, during this stage, students are asked to build a small model of their proposed design of the retaining wall from the previous stage.

    In order to successfully build these models, students would need to know all the necessary calculations in mechanics plus typical designs under certain circumstances. The instructor may adjust certain parameters for each group to test their skills and knowledge, for example, making the landslide slope flatter or adjusting the moisture level of the soil, etc. Students would fix their design accordingly, and use devices like stress or strain tensor to test and verify the mechanics of their model. Essentially, students would have to go back and forth between this stage and the Design stage to eventually arrive at an actual model built by themselves. The outcome we look forward to is the knowledge that our students would learn in the process.

4. **Operate stage**: By theory, a construction is good if it can go through a series of operation trials under different conditions and ultimately, the test of time. The fact, however, is that once the construction is done it is very difficult to go back and fix

design or implementation problems. The same situation applies here, and the instructor would mostly test the qualities of the built models. With the CDIO project of retaining wall, the instructor will evaluate students based on the calculations made for their built model in terms of soil mechanics, hydraulics and statics. In addition, the ratio of the wall weight to the maximum weight that the retaining wall may withstand will be computed to evaluate students on their design and use of materials.

Another basic project usually held during the junior year is the “*O Thuoc Bridge Building*” project which helps integrate and apply knowledge from the courses of Strength of Materials and Structural Analysis. Specifically, students are asked to design and build a bridge model from wood or bamboo chopsticks with a specified span length and solid structures that can sustain certain amounts of weight and load. The instructor will grade teams based on their ideas for some new structures of the bridge as well as their choice of materials when building the bridge in reality. The ultimate evaluation criterion, however, is the ratio between the weight of the bridge and the weight that the bridge can withstand. A small competition show can be set up, in which the bridge models of students will do “weight-lifting” against each other until the last one stands as the winner.

Figure 2. Building the model of Retaining Wall from carton paper at DTU

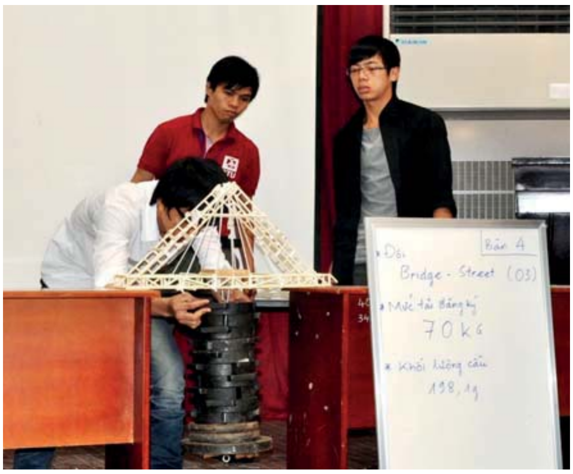

Figure 3. Testing the loading capacity of a bridge model inthe "*O-Thuoc bridge*" Project

2.3. Advanced CDIO Projects:

The topic for the senior year CDIO project is the design of some earthquake-resistant building. Students are asked to make a model of their earthquake-resistant building from wooden bars. They would need to apply knowledge from courses of Structural Analysis, Strength of Materials, Structural Dynamics, Skyscrapers, etc. Depending on the year, the actual material of the wooden bars will be chosen by the Faculty of Civil Engineering. The choice of material will have a direct effect on students' designs, and only teams who understand the implications may score high in this project.

Criteria for evaluation is taken directly from those of the Asia-Pacific Earthquake-Resistant Model Building Tournament organized every year in Taiwan. The best team in Duy Tan University is usually chosen to participate this annual tournament in Taiwan. In 2014, the team from DTU had won the championship of this tournament.

2.4. Soft-Skills and Career-Planning Courses:

Our goal in training Civil Engineering students is that besides strong technical and engineering skills and knowledge, students should also "grow" in terms of personal and interpersonal skills and should be able to present themselves at the most professional manner possible in the labour market and working environment. As a result, a number of courses were added to the traditional Civil Engineering curriculum for that purpose:

- **Professional Speaking** course: This course provides students with basic skills in public speaking including speech preparation, speech delivery, audience analysis, and the oral communication process and theory. Additional presentation and visual-aids techniques are also introduced.

- **Professional Writing** course: This course introduces students to various writing styles both for academic and corporate purposes. Academic writings consist of different types of essays like Persuasion, Compare/Contrast, Argumentation, etc. while business writing assignments include memos, reports, job descriptions, letters, emails, proposals, white papers and blogs.

- **Critical Thinking** course: This course is all about methods for collecting data, processing information, and making informed decisions from small issues of everyday life to major challenges of a life-changing nature. Students are also introduced to scientific writing methodologies like APA or MLA, or ways to effectively use library resources for their study, or problem-solving methods in typical case studies of the Harvard Business Review.

- **Career-Planning 1 and 2** courses: The first and second courses in Career Planning at Duy Tan University provide an overview about the learning environment and academic cultures of Duy Tan University. Besides academic regulations and formal procedures of various academic affairs, students will get to learn about personal development, time management, financial management, career orientation, etc. to better prepare for their four or five years in college.

- **Career-Planning 3** course: Students will learn about the core values and activities of their future career in Civil Engineering. List of all job titles and job descriptions in Civil Engineering will be provided besides bi-weekly visits or field trips to actual construction companies and enterprises.

Except for the Career-Planning 3 course, which is prepared by the Faculty of Civil Engineering, the rest of these “soft-skills” and career-planning courses are managed directly by the Board of Vice Provosts, who are in charge of General Education for the whole school. In a way, this is very fruitful because the school can set the direction for soft-skills training university-wide based on their overall studies of students’ characteristics in any one intake; but at the same time, this may be counter-productive because the materials being taught are too general and not discipline-specific.

3. SURVEY, RESULTS, AND DISCUSSIONS

It can be said that while personal and interpersonal skills are of a general nature, they are closely-tied with professional skills, which include professional behaviour at work and professional integrity codes by the industry. Professional skills, on the other hand, are tied up with technical skills and knowledge of a specific discipline or industry. This interrelated relationship may be best described schematically in the Venn diagram in Figure 4 below:

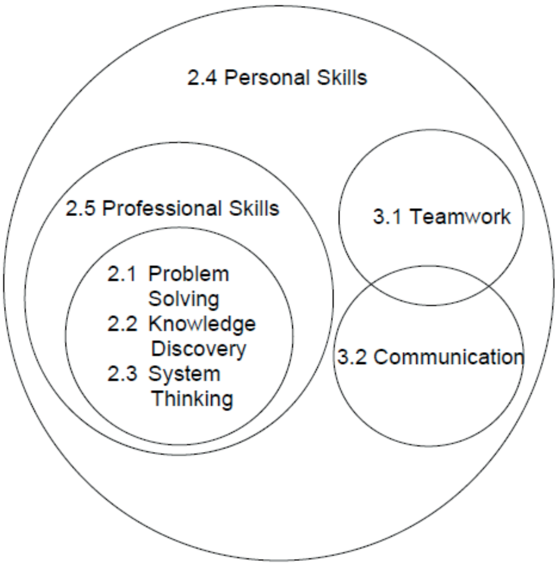

Figure 4. Venn diagram of Professional, Personal and Interpersonal Skills (Crawley, 2001)

So, in order to assess and evaluate how well our CDIO adoption and continuous improvements in Civil Engineering programs at DTU have been going on so far, we carried out a survey to study the above mentioned interrelationship based on the Venn diagram. A sample of 124 Civil Engineering students from freshmen to seniors were chosen for this study. The 7 aspects of the Venn diagram were grouped into 4 major categories of the UNESCO Framework to the Context of Engineering Education, and a Likert rating scale of 1 to 5 was adopted. As a result of the adaptation of the UNESCO framework for engineering education, the CDIO Syllabus were divided into four major categories:

1. **Technical Knowledge and Reasoning** or *UNESCO Learning to Know*: equivalent to items 2.1, 2.2 and 2.3 in the Venn diagram.

2. **Personal and Professional Skills and Attributes** or *UNESCO Learning to Be*: equivalient to items 2.4 and 2.5 in the Venn diagram.

3. **Teamwork, Communication and Interpersonal Skills** or *UNESCO Learning to Live Together*: equivalent to items 3.1 and 3.2 in the Venn diagram.

4. **Conceiving, Designing, Implementing and Operating Systems in the Enterprise, Societal and Environmental** Context or *UNESCO Learning to Do*: equivalent to all the technical and engineering skills and knowledge that students learn from our Civil Engineering curriculum.

The survey was carried out three months ago, and the survey results are generally depicted in Figure 5 below, corresponding to the 7 major aspects of the Venn diagram:

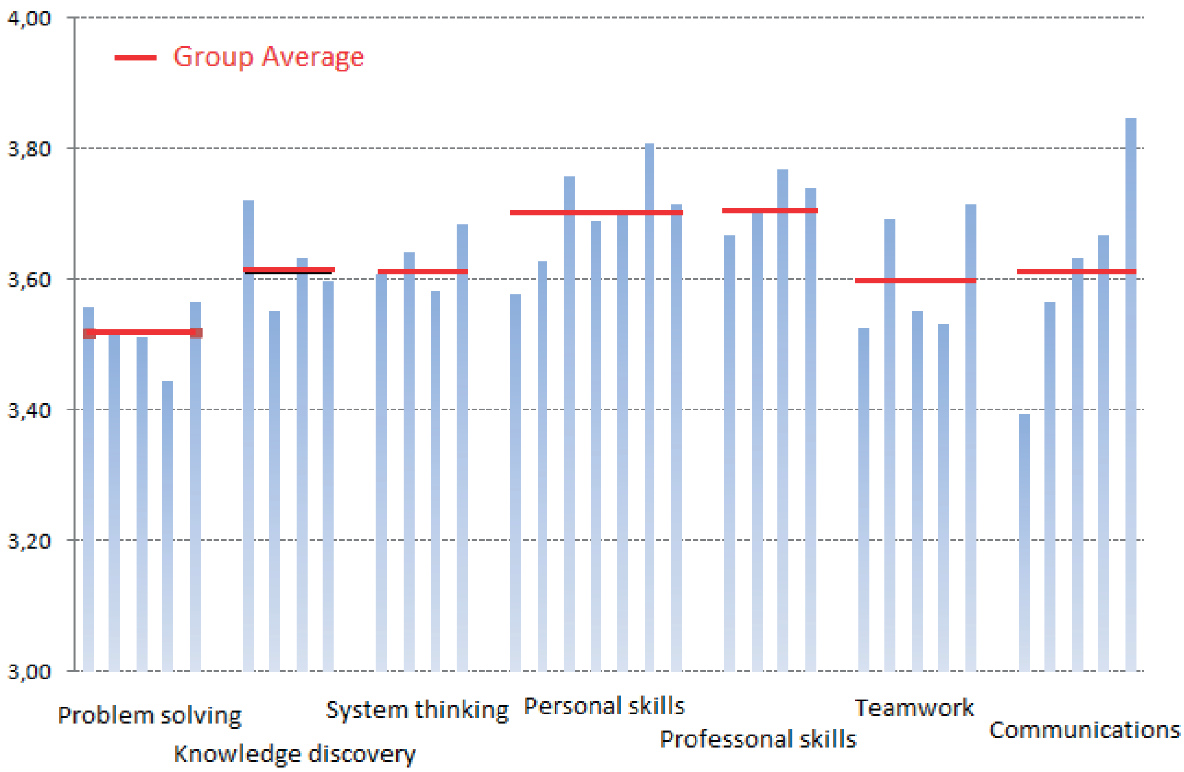

Figure 5. Survey Results about Perceived Students' Skills in Civil Engineering at Duy Tan University, following major aspects of the Venn diagram

Although we did not conduct the same surveys before the implementation of CDIO, however we collected the evaluations from other similar surveys. And we ask the lecturers to take the short survey before each CDIO course to know the level of students and help the lecturer in selecting the appropriate teaching method. Sum of these sources, we have the group average of the 7 major aspects are only range from 2.5 to 3.2 points.

The survey results in Figure 5 show our success in improving students' personal and professional skills with the highest average ratings and little variance between different results. This is a strong evidence for our success in restructuring the CDIO projects and related technical coursework. Courses like Career-Planning 2 & 3, Professional Writing and some topics in the Critical Thinking course contributed partially to this success. This may also have to do with the good qualities of Asian and Vietnamese students in that they are very hard working, have strong knowledge of natural sciences, and possess the ambition for future career development. Another aspect that showed sign of improvement is teamwork, however, its improvement level was not as significant as expected.

In contrast, survey results still showed weakness in our students' communication skills and creativity capacity. This signified the failure of many topics being taught in the courses of Professional Speaking, Professional Writing and Critical Thinking. Since these very same courses are very effective for students in business and other engineering disciplines, it can be said that they were not a good match for Civil Engineering students. There may be a number of reasons for this reality that can be further elaborated on:

- The rate of improvement in communication skills of our Civil Engineering students ever since the adoption of CDIO was not as fast as expected, especially, when compared with those of students in Western countries from previous case studies (Crawley et al, 2007). A number of geo-social reasons are responsible for this: Cultural barriers continue to be a major obstacle for open discussion and independent demonstration of new ideas by Vietnamese students. In addition, anothermajorshortcoming of Asian as well as Vietnamese students is their passiveness and warriness of new approach or ideas (Runckel, 2011). This usually leads to passive learning which is the opposite of what CDIO is asking for: Active Learning and Teamwork.

- A major source of negative effect on our students' creativity has to do with their high-school education. Indeed, most Asian and Vietnamese high-school students rarely have the chance to express their ideas about the learning subjects - they simply accept and memorize whatever their teachers have to say. High school also lack courses which help develop students' independent mindset and interpersonal skills. To compensate for this shortcoming, we have provided a number of "soft skills" courses like mentioned, however, these courses were not designed specifically for students in the field of Civil Engineering. Therefore, the new soft skills developed generally do not appear to be as beneficial as expected.

- Another shortcoming in our current Civil Engineering curriculum is that due to the focus on career-planning practices, entrepreneurship skills are mostly ignored. This is actually a major weakness of Vietnamese and Asian students when compared to Western students, and more than often, this hinders our students from thinking big or becoming creative.

- New technologies in Civil Engineering are now rapidly introduced in schools, but not all of them have been adopted by businesses in the construction industry in Vietnam. This creates a certain gap for our students in their approach when they come to work for real-world companies and enterprises because they cannot be as active and flexible as they may want to be.

4. PROPOSED SOLUTIONS FOR CONTINUOUS IMPROVEMENT OF THE QUALITY OF CDIO DEPLOYMENT IN CIVIL ENGINEERING AT DUY TAN UNIVERSITY

Many factors shape the quality of learning. These include:

- The aptitude and motivation of individual students, and their corresponding approach to learning, including their habits for teamwork and collaborative learning,
- The quality and diversity of the student body at the Faculty of Civil Engineering, which students are part of,
- The curriculum of Civil Engineering at DTU,
- The caliber and methodologies of the teaching faculties,
- The size and nature of specific Civil Engineering classes,
- The assessment and evaluation standards and/or processes,
- The learning resources (such as libraries, laboratories),
- etc.

Given the conditions in Vietnam, there are definitely many limitations at almost all of the above factors. How to effectively approach such limitations becomes the ultimate solution in improving the quality of our CDIO deployment for Civil Engineering. Below are three of the most forthcoming solutions proposed:

First of all, we have to pay attention to the teaching methodologies and practices. There is a unanimous need amongst our faculty members that we should seriously refine our teaching methodologies so as to attain specific learning outcomes. This is very much relevant to the fact that CDIO is an outcome-oriented model. In particular, we would need to engage students in Active Learning through in-class participation, discussion and debates, group games, etc. Students should also be encouraged to voice out their ideas and to be independent in their thinking and problem-solving. And yet, we need to educate our students of the advantages and disadvantages of the Vietnamese cultures to their learning habits, and how those may affect their future career in the field of Civil Engineering. This would raise students' awareness of certain pitfalls that they may run into in their current study as well as future career.

Secondly, the roles of our Civil Engineering instructors need to be restructured. It is a common knowledge that three major roles of an instructor is: Teaching, Doing Research and Providing a Service, still, it seems our instructors currently only do the teaching or worse, lecturing to be exact. As a result, the only add-on course of Critical Thinking may not help much in developing students' research capacity. Unless the instructors proactively engage students in research activities, most of the time, students will drop out halfway through some research project. Strict and formal research methodologies should not be the focus at this point because they may make students lose heart, instead, fostering the spirit of lifelong study and creativity through small research projects are two of the major things that need to be done here. As for the role of providing a service, this is actually not very much welcome in East Asian cultures. While maintaining certain distance between the instructors and their students helps create a strong level of respect, it may actually lead many of the instructors in Vietnam, no matter what discipline they are in, to believe that they are doing a favour to the students, or students come to class to learn directly from them, and not from any other sources. This mentality definitely will hinder creativity, and was the reason why so many instructors in Asia quickly announced that they had exercised everything of the CDIO model, but with no success.

Thirdly, the Faculty of Civil Engineering and its instructors need to create a healthy academic atmosphere and environment for students to grow their maturity in various aspects. At the most basic level, instructors should not always require fast answers from students on their projects or assignments. Instead, students should be given the time and step-by-step guidelines to go through the process on their own. In other words, the ultimate relationship of instructors to students is that of a guide, not of a dictator. Students should feel comfortable asking questions or arguing for their points to freely participate in any academic or professional discussion. They also need to learn that mistakes are common for progress, and even the instructors can make mistakes at any point. At a higher organizational level, the Faculty of Civil Engineering should provide students with adequate lab facilities and other learning equipment. Restructuring and renovating of individual and team learning spaces across the campus is also important in any CDIO deployment.

Last but not least, in sending students to real-world construction companies and enterprises, the instructors should have a clear agenda about what and how students may learn. Many times, these visits in the Career-Planning 3 course is an exchange of formality, and students were left out in the process. In addition, CDIO projects which are carried out with outside companies or businesses need to have a clear financial budget and plan to avoid interruptions at a later stage in the project when funding may be running out.

5. CONCLUSION

Ever since our deployment of the CDIO model for Civil Engineering programs at Duy Tan University three years ago, we have continuously run into problems and issues that need to be addressed and fixed. While various problems of technical coursework in Civil Engineering and related disciplines have been settled down to certain extent, the problem of developing students' communication skills and creativity continues to be a major challenge. Much of the reason has to do with cultural barriers in Asia as well as the passiveness of students in Vietnam due to their high school background and education. Bit by bit, we have sorted out certain problems to enhance individual students' personal, teamwork and communication skills, but there is still no general solution approach to this problem. Future studies should focus more on the Conceive stage in the CDIO projects for our Civil Engineering so as to enhance their creativity and independent study. In addition, the use academic clubs in Civil Engineering should be studied to determine if additional extra-curricular activities in Civil Engineering may help with faster maturity of our students both in their professional knowledge and communication skills.

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CDIO IMPLEMENTATION EXPERIENCE FOR THE MASTERS TRAINING AT SUAI

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ABSTRACT

This article gives an overview of the work, that was done at SUAI after the joining the CDIO Community at 2015. Firstly the paper describes the way that we chose – how to implement the CDIO in university with small steps: from the idea to the real CDIO implementation. We give an overview of a real experience that could help CDIO Community newcomers to implement CDIO Standards. Also the paper describes two important parts of CDIO implementation.

The first one is increasing of the skills assessment quality. We overview the new knowledge assessment way that we started to use at the lectures and laboratory practical works. We describe how we moved from the old assessment system, when we had just an exam in the end of the semester, to the new 100-scale overall assessment system, that consists of a number of tests, interviews, question-answer sections and so on.

The second part is about implementation of CDIO projects for the masters. We describe as a use case two joint projects, where the older and more experienced students are project leaders and the younger students are competent members of the project team. We overview the first interesting and successful projects that we ran with the supervising from the Russian space industry and specialists from our department.

KEYWORDS

SUAI, projects, assessment, masters, examples, implementation, Standards: 2, 3, 5, 6, 8, 11.

INTRODUCTION

St. Petersburg State University of Aerospace Instrumentation is a multidisciplinary research complex. Today it offers training of specialists not only for the aerospace industry, but also for other areas of scientific knowledge. University offers about 150 basic higher educational programs and 15 vocational education programs, trains highly qualified specialists, provides retraining and advanced training of scientific and pedagogical staff for 33 specialties. Nowadays SUAI trains about 15,000 students. The staff is highly qualified: 80% has scientific degrees, and 24% are doctors and professors.

The University actively develops the international cooperation and cooperates with more than fifty companies and universities all over the world. A large number of international conferences are held in the university. SUAI trains foreign students from 39 countries.

Throughout the history all the SUAI staff, students and alumni contribute to the aviation and astronautics development. SUAI staff participates in the R&D activities for the development, design and testing of instrumentation, measurement and computing systems, onboard systems for spacecraft. Also it participates in testing of new advanced rocket and space systems, on-board systems and equipment for aircraft.

In 2015 SUAI officially became the member of international CDIO Community, the 14th university from Russia.

Starting from the end of the 2014 we began to implement CDIO standards to the SUAI educational process. The paper will describe the way that we chose – how to implement the CDIO in university with small steps: from the idea to the real implementation of the Standards. We will give an overview of a real experience that could be very useful for the CDIO Community newcomers.

PILOT CDIO IMPLEMENTATION AT SUAI

As the first step, we implement CDIO Standards (Crawley et al, 2011) for the masters educational program "Embedded systems for the data control and processing" and to bachelor program "Informatics and computer technique". These programs are taught by the specialists of the Department for aerospace computer and software systems. The second step would be the CDIO implementation for System analysis and logistics department. And after that we will start the interdisciplinary projects between the students of both departments. For the pilot CDIO implementation at the Department for aerospace computer and software systems we mainly focused on six CDIO Standards. We will give you a short description of each standard implementation experience. It could be helpful for the Universities, who start to implement CDIO standards from the scratch, like we did.

Implementation of Standard 2: Learning outcomes

During the development of a new educational program firstly we defined the purposes for this program and expected learning outcomes in full respect to the CDIO Syllabus 2.0 and aligned with the Russian Ministry of education requirements. After that we defined four main groups of stakeholders for this program: current students, alumni, potential employers and staff of the department. So we prepared four questionnaires for these groups and asked some stakeholders' representatives to fill them. We think that chosen groups are mostly valuable for the questioning when you develop masters curricular and Syllabus. So there is a short explanation why.

1) *Students.* We chose three main groups:
    a. 4th year bachelors – they know what they want from the masters' education;,
    b. 1st year masters – know what they expected from the masters' education and they can compare in with what they get;
    c. 2nd year masters – know what they missed in the whole 6-years educational course and what else would be useful for them as potential employees. . .
2) *Alumni.* We chose two main groups. Both groups work in the field of their specialty – Informatics and computer technique or Embedded systems.
    a. alumni with working experience about two years – gave us the opinion on what was better to learn during the studying at SUAI;
    b. alumni with an experience more than 10 years – has the own view on the topic as the managers.
3) *Potential employers*.
    a. representatives of global high-tech companies as Intel and Nokia;
    b. representatives of Russian leading defense industry companies.

    These people also gave us a valuable vision on what do they want from the young specialists and what useful competences should they have after the graduation.
4) *SUAI Lecturers*. When the lecturers and trainers from our department filled the questionnaires, we figured out, that they prefer students to know more scientific-oriented courses. But potential employers prefer the students to know more

engineering things. So we had to find balance between these two opinions and produce the Syllabus, unifying all the results of the questionnaire.

Implementation of Standard 3: Integrated curriculum

Based on the produced learning outcomes we incorporated the list of the disciplines and combined them into a several groups (modules). So we developed a new integrated curriculum, which consists of three main phases. The first phase is implementation of curricular for the masters (department #14 for aerospace computer and software systems), then – for the bachelors, and after that – the same for the department #16 of system analysis and logistics. The first phase of curriculum implementation is shown at Figure 1, the final curricular plan – at Figure 2.

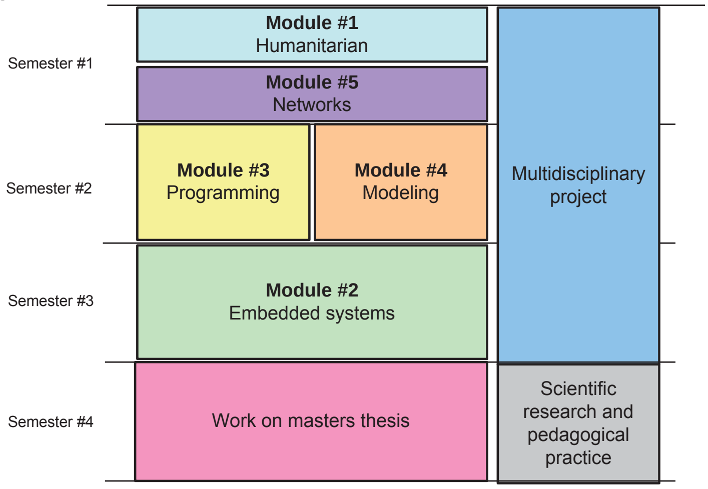

Figure 1. Integrated curriculum for the masters (department #14)

The first phase of integrated curriculum is not easy to implement, because it is hard to change the place of the disciplines in the curriculum, remove or add some new disciplines, especially when we talk about the curriculum in Russia, when it has to be aligned with a lot of other requirements. So the curriculum would be integrated to the educational process step by step.

Implementation of Standard 5: Design-Implement Experiences

The most interesting CDIO Standard is Design-implement experience. But for the implementation of this standard you need to find a space in the curriculum for the students to work on it, and time for the staff to supervise it. So we decided first to try to make a project not for the 3-4 semesters, but only for one semester in terms of one particular course. That was done to see the reaction of students for such kind of work and a real outcome of the project – would students better learn the material and get the expected skills. Each discipline at our department consists of two parts: lectures and practice. During the practice students have to accomplish a number of laboratory works specialized for this discipline. We replaced this practical works for the small project. Students have a project team, and a project leader, and the interesting task, which they have to complete till the end of the semester. The lecturer is a supervisor for each project team.

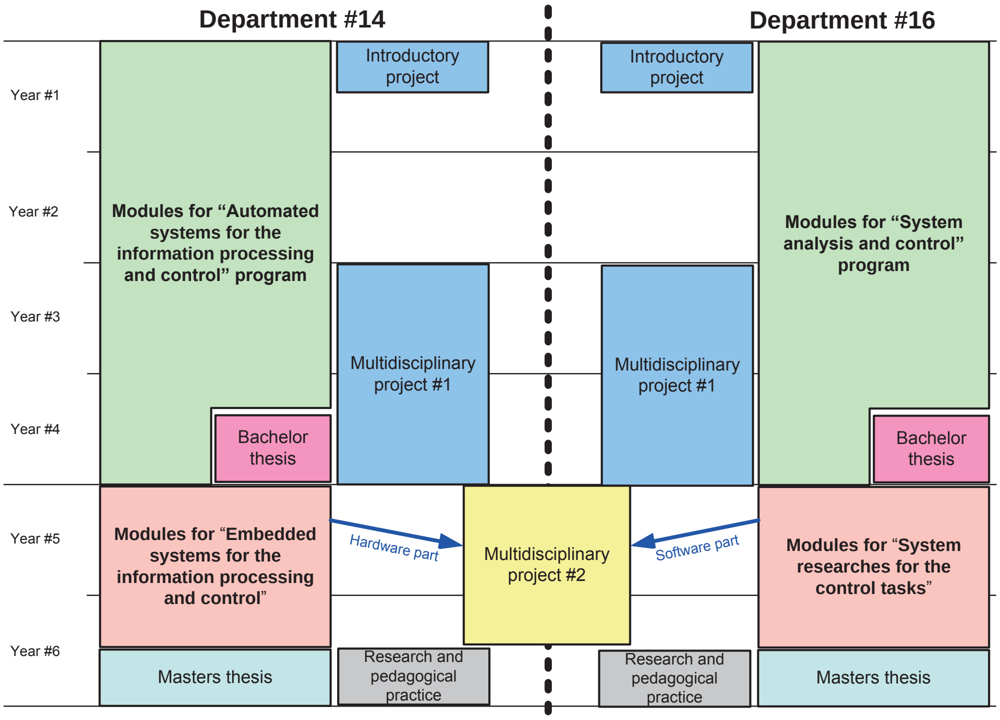

Figure 2. Integrated curriculum for departments #14 and #16.

Such kind of small projects showed the positive result – student enjoyed this practical work, they got better results. And the most interesting thing is that for last two semesters there were no students who did not successfully pass the practical work.
So in 2015 we decided to include the work on real projects (3 semesters) to the masters curricular (see Figure 1). Old curricular had one day of Research work each week. So we replaced this Research work by the Work on real projects that also could be the base for the master's thesis. The detailed description of two examples of the first projects implemented in our department is presented further on in this paper.

Implementation of Standard 6: Engineering Workspaces

If you teach students computer engineering and programming – it is easier to organize the engineering workspaces, because all you need is laboratories with PCs. So we organized laboratories and installed the software that would be needed to implement the projects: operation systems, special modeling software (e.g. IBM Rational TTCN Suite) (International Telecommunication Union, 2007), specialized embedded systems design Cadence Design Systems software. Also we provided students with an access to test equipment: logical analyzers, multichannel digital oscilloscopes Tektronix, etc.
So now working on the projects and research our students can implement the full embedded systems design cycle by using specialized professional tools and equipment and finally produce prototypes using 3D printers.

Implementation of Standard 8: Active Learning

To implement active learning methodologies we made special interviews, question-answer sessions and tests that we have several times during the semester. This gives an ability to see, do students really understand the material. In some courses, if there is some free time, we spend it to answer the students' questions. And if the lecturer sees that students did not get the material – he can repeat the most important parts of lecture to be sure that all the further material would be understood correctly. Such kind of a questions-answers part of the lecture is shown at Figure 3.

Figure 3. Questions-answers part of the lecture

Implementation of Standard 11: Learning Assessment

Learning assessment seems to be very important and useful thing to control how students understand the material and what mark should they get at the end of the semester. We moved from the old Russian 5-grade system to the 100-points system, where student can earn his points for different types of tasks, tests, answers or final exam. Less than 45 points for the whole semester is *did not pass*, 46-60 points means *passed*, 61-80 points means *well passed* and more than 81 points is *excellent*.
Current paper describes 3 different examples of the 100-points system, which was developed for the three disciplines and could be useful for the implementation in the other Universities.

Learning assessment example #1

The overall number of points consists of 3 major parts: attending of lectures, practical work (projects), exam.
For the attending of lectures student gets 0.5 point for each lecture. So in general he can get 10 points for the semester. During the lectures students perform two tests (5 points maximum for each). For the work in project student can get 20 points for the project itself and 10 for the project defense (presentation and speech). Also a student can get additional points for answering the questions during the lectures. And if a student successfully passed two tests and defended the project (so he has more than 40 points) – he can pass the exam. So 40 points are left for the exam, which consists of 2 theoretical questions (15 points for each) and one practical exercise – 10 points. Ideally if a student perfectly passed all the steps – he has 90 points plus a few points for the answering the questions.

Learning assessment example #2

During the semester student gets 100 points maximum for the 5 practical works. And the final exam success is measured in percentages. After that the overall number of points is multiplied on a number of percentages. Exam consists of 2 theoretical questions.

So if the student gets 100 points for practice, but he doesn't know the theory and he gets 20% for the exam – the total number of points would be 100*0,2=20 points, which is less than 45 (did not pass).
If a student gets only 30 points for the practical work, he can take 4 theoretical questions on the exam, and the maximum percentage that he gets is 180%. So he could extend the number of points. But in this special case the student cannot get more than 60 points, because he was not good enough during the semester.

Learning assessment example #3

The overall number of points is 60 for the semester and 40 for the exam. During the semester students get 6 tests (without a set of potential answers). Each test has 5 questions, 2 points for each question, 20 minutes for one test. On the exam student has 2 theoretical questions (14 points for each) and one sum (12 points).
At the beginning of each lecture teacher asks each student one question on the previous lectures' topics. If the student answers the question – he gets +1 point, otherwise he gets -1 point. This points are summarized with the 60 points that student can get for the whole semester. So theoretically the most active students can get more than 100 points – and this is the good reason to get the exam bonus – only one theoretical question.

These three examples proved that students are more responsible and attentive leaning this disciplines. They show better results on the exam and the better level of knowledge.

EXAMPLES OF FIRST PROJECTS IMPLEMENTED AT SUAI

This chapter describes two projects that students implemented during 2015. The supervisors of these projects were the representatives from the space industry. The project leaders are 2nd year masters and the others are 1st year masters. These projects became a base for the master's thesis for each student in the project. The projects were implemented under the control of the specialists from our department. The results would be used in the real SUAI R&D projects.
Master students participate in projects for development on networking technologies for the on-board systems of spacecraft. The project task are proposed by the leading Russian space companies like Roscosmos, TsNIIMash, JSC Reshetnev "Information Satellites Systems", international partners, like Consultative Committee for Space Data Systems - CCSDS, ESTEC/ESA, and with support from Russian Ministry of Science. In the field of Electronic Component Base elements and Systems-on-Chip students participate in projects, proposed by Russian electronic companies (JSC ELVEES, Micron) with the possibly for implementation of a system in a real chip.
In current paper we overview two projects that are successfully completed by the master students:

1. Prototype of the Ethernet-SpaceWire bridge for the onboard SpaceWire networks (Yablokov et al., 2014);
2. Workplace of the hardware-software testing of the onboard equipment (Olenev et al., 2015).

Development of the prototype of the Ethernet-SpaceWire bridge

In this project students developed a prototype of the Ethernet-SpaceWire bridge for the onboard SpaceWire networks. SpaceWire is a communication protocol for the spacecraft. In order to enhance SpaceWire link characteristics the task was to develop a special bridge SpW-Gigabit Ethernet. The bridge should be either absolutely transparent for the SpaceWire

network and can connect two SpaceWire networks into one, or could be used to connect SpW network through Ethernet interface to end user.
Figure 4 shows a prototype of Ethernet-SpaceWire bridge that was developed.

Figure 4. Development of the prototype of the Ethernet-SpaceWire bridge

For the transmission of the data the specialized protocol was developed. This protocol performs the following functions:

1. Pack the SpaceWire packets into a Ethernet frames;
2. Makes the segmentation of a packet;
3. Unpacks the packets and detects the type of a packet;
4. Performs the credit exchange mechanism.

Currently there is a plan for the next project to update the functionality of the bridge by adding the remote setting functions and implementation of the bridge functionality in SpaceWire switches.

Development of the Software-to-Hardware Tester

In this project students developed a Software-to-Hardware Tester (S2HT) for the perspective STP-ISS on-board communication protocol. The result of the project should give an ability to test the real on-board *hardware* with the *software* implementation of the protocol model (reference code). This is a software conformance tester.

Software part of the S2HT consists of the Test engine (a set of testing scenarios), STP-ISS reference model and Error generation module.

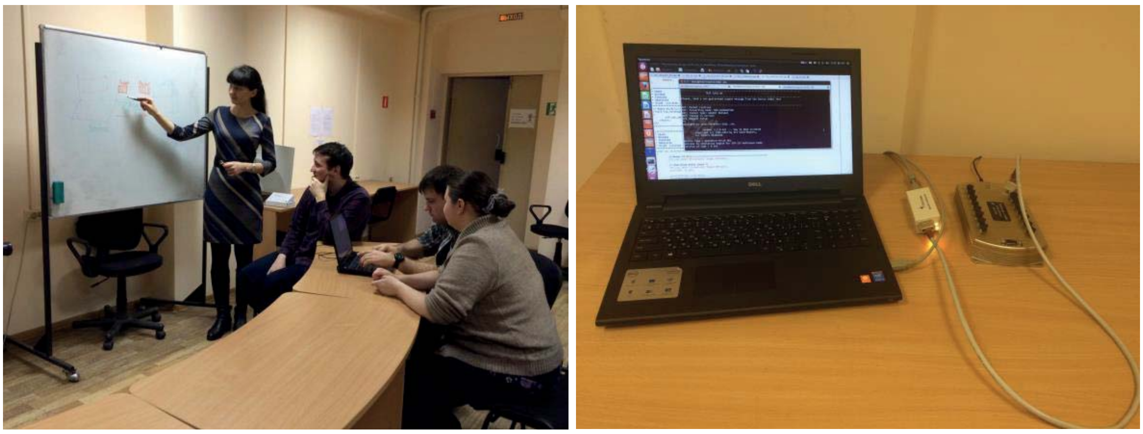

Figure 5. Development of the Software-to-Hardware Tester

This software part of the tester should be installed on the PC. PC should be connected to the device under test via the SpaceWire cable and SpaceWire Brick Mk2. Figure 5 shows the implemented testing workplace.
Current implementation, developed by the master students, is a very useful tool for the space industry.

CONCLUSION

During the CDIO implementation we faced with two main problems and difficulties.
The first one is that only a few people at SUAI knew what is CDIO. And that is a big problem when you are trying to implement the standards for the educational process of the department (not even the whole University). So firstly we organized a seminar for all the staff of the department, where we described in details all the CDIO standards and what should be done by each person to implements CDIO. And then we figured out that one seminar wouldn't be enough to answer all the questions and to explain all the plans for implementation. Also it was not so easy to prove people that what you propose would be better, then the current educational scheme, because people are used to work in the similar way. If you need to change the course and the program – that causes additional work and problems for the lecturers and other staff. We needed a few active people that can promise to try CDIO and prove to the others that it is good. So we found them and during the next semester we tried to apply CDIO standards to three courses: Communication networks, Systems' modeling and Embedded systems' interfaces. After the first semester of such a pilot testing we proved that we got better educational results with CDIO.
The second problem is aligning of the CDIO Syllabus competences with Russian Ministry of Education requirements and official indicating of the CDIO implementation in the documents. Including of new or additional subjects to the educational program is also a problem that we faced with. It is also should be aligned with Russian requirements and it leads to a huge paper work. This paper work is another point that increases the complexity of CDIO implementation. All the new things that come from CDIO standards should be indicated in the official documents also. So there should be a person that would work with these documents and update them.
But anyway we are ready to continue our work. For now the students and the staff are happy with the CDIO initiative implementation. We have the full support from the SUAI rector and our dean. We see that the number of students who did not pass exams significantly decreased and the marks are much better.
The rebuilding of the masters educational program and implementation of CDIO standards gives a good opportunity to combine the scientific knowledge with the practical experience, increase the quality of the graduates and find a new partner Universities and partners from the industry.
We hope that our experience could be helpful for the CDIO newcomers; we are ready to share our experience and implement new interesting CDIO features.

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LEARNING NANOTECHNOLOGY, BUSINESS AND COMMUNICATION BY ENVISIONING FUTURE PRODUCTS

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ABSTRACT

Optional interdisciplinary study modules were offered by the Faculty of Business, ICT and Chemical Engineering. The module “Nanotechnology - Future Prospects and Business Opportunities” was co-taught by teachers with different areas of expertise (nanotechnology, business, and English-language communication) by providing a design-implement experience. The aim was to broaden the students' views, develop their interpersonal and communication skills, emphasize the versatile skills needed in product development, and coach the students towards an entrepreneurial mindset. The module was conducted in interdisciplinary groups in English. Second-year chemical engineering, information technology and business students participated. The first week was used to produce and then group wild ideas for future products, applications or services based on nanomaterials. Based on the 10 most interesting themes, groups were formed for the rest of the module duration. After this brainstorming, activities concentrated on conceiving the future and potential new products. The design of envisaged products and business ideas was continued by gathering information while using business and innovation tools and practicing effective communication. During the final 2-3 weeks, the envisaged product and business ideas were described. Each week consisted of a Monday take-off session followed by independent and group work during the week and a work breakdown session on the Friday. In addition to tasks and group reports, the students individually reflected on their progress. Additional information was gathered by collecting feedback and by self- and peer evaluation. The students envisaged 10 future nanomaterial-based products with customer profiles and business models. Initially, many groups experienced collaboration difficulties which were, however, rapidly resolved. The feedback confirmed that most aims were achieved. While the students emphasized improvement in communication and collaboration skills, they also reported learning about business, nanotechnology, and social media and innovation tools. The word “interesting” was a common indicator of a mindset shift towards interdisciplinary team work.

KEYWORDS

Innovation process, design-implement, self-steering, group work, integrated learning, entrepreneurial mindset, standards: 2, 4, 5, 7, 8, 11.

INTRODUCTION

Innovation pedagogy (Lehto et al., 2011), developed in Turku University of Applied Sciences (TUAS), has been chosen as a strategic learning approach for all educational programs at the university. Innovation pedagogy and CDIO share many similarities and common goals (Penttilä et al., 2014) and the Faculty of Business, ICT and Chemical Engineering at TUAS has decided on CDIO as the educational framework and as the implementation method of innovation pedagogy for all students of the faculty. Most of the students of the Faculty attend BEng programs (Information and Communications Technology and Chemical and Materials Engineering), but the same principles of CDIO are also applied in the other programs, e.g., Business, International Business, Business Information Technology, and Library and Information Services. The different disciplines are also utilized in design-implement experiences by forming interdisciplinary student groups in different study modules. Nanotechnology - Future Prospects and Business Opportunities (15 ECTS) is one of the new study modules in the Faculty of Business, ICT and Chemical Engineering, where the interdisciplinarity and internationality of the module are expected to broaden the students' views and to provide the kind of versatile skills they will need in their future working life. Nanotechnology is as such an enabling and a horizontal technology and thus by nature also interdisciplinary. Consequently, it also has potential to give rise to wild ideas for new products and services. The business aspect of the study module comprised innovation and product development skills and the study module was designed with the intention of fostering the learning of nanotechnology, innovation, business and product development knowledge simultaneously with personal and interpersonal skills.

CDIO as an educational framework (CDIO) and studies on other pedagogic methods including practical tasks relevant to the real world (Savage et al., 2011) emphasize the improvement of personal and interpersonal skills and product, process, and system building skills, as well as disciplinary knowledge, and importantly, also the increased motivation of engineering students in higher education. However, achieving an increase in motivation while encouraging the students to adopt a mindset in favor of entrepreneurship is more complicated. Although it has been suggested that entrepreneurial skills and mindset develop during the course of entrepreneurship-related project-oriented, practical tasks, it is difficult to increase the motivation of students to accept the risk-taking and uncertainty in business (Beránek, 2015). The most common experiential learning method in entrepreneurship education has been the development of business plans, which has, however, also been criticized because it focuses on the execution of ideas and not so much on the conceptualization and development of good ideas (Wheadon & Duval-Couetil, 2014). Li et al. (2014) have developed a so-called CIE-CDIO cultivation mode by adding a creation, innovation and entrepreneurship (CIE) aspect into CDIO-based education. During the conceive step of CDIO, the students were provided lectures on creation, innovation and entrepreneurship, corresponding to the creation step of CIE. During the design-implement experiences, the students were provided integrated innovative design capacity training, and during the operation step of CDIO, the students created a business plan. It was shown that the students' creative consciousness and innovative ability improved and enthusiasm for entrepreneurship was stimulated. Jansen et al. (2015) have developed a more versatile approach, the Three Stage Student Entrepreneurship Encouragement Model (SEEM), which includes three specific steps: educate, stimulate and incubate. The goal of the education step is to awake potential entrepreneurs (e.g., by highlighting role models and success stories), the stimulation step supports the students in the transition from an idea towards a complete business plan (e.g., by providing tools for idea evaluation and pitching possibilities), and the incubation step nurtures startup operations (e.g., by providing networking opportunities, business plan competitions, incubator services and mentoring). They concluded that by using this kind of model, universities may effectively encourage entrepreneurship among students.

The aim of this study was to determine whether a strongly inter- and multidisciplinary approach manages to broaden the views of the students, develop their interpersonal and communication skills, emphasize the need of versatile skills when developing new products, and steer the students towards an entrepreneurial mindset. Another aim was to study whether the design of envisaged future products and services provides some new aspects for design-implement experiences. The implementation framework of the study module was a product development funnel such as are commonly used in product development (Wheelwright & Clark, 1992). It visualizes the work flow and advancements through the various phases of the product development process. The framework consisted of four steps, idea creation, concept development, product development, and product management. The product development funnel and its relation to conceive-design-implement-operate are illustrated in Figure 1. Instead of lectures, creative problem-solving tools and instructions for information retrieval and reading circles were provided to foster creativity, information sharing and collaboration. The students were encouraged to take risks and constantly iterate ideas and concepts to enable the use of new information in the creation of new combinations and product concepts. The business model canvas (Osterwalder & Pigneur, 2010), instead of business planning, was used for fast prototyping and visualization of different business logics. Communication skills improvement was integrated into the study module using a model (illustrated in Figure 2) developed by Nonaka & Takeuchi (1995), emphasizing active integration of communication.

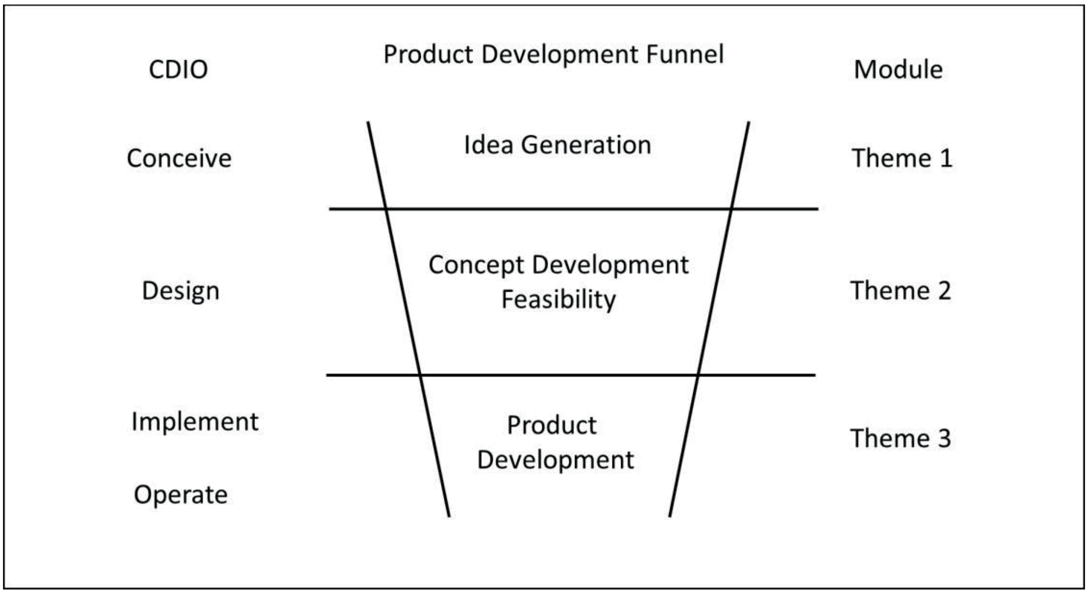

Figure 1. The study module framework.

MODULE STRUCTURE AND IMPLEMENTATION

An inherently horizontal and multidisciplinary field of technology, nanotechnology constitutes an excellent context for striving for the interpersonal learning outcomes specified in CDIO Standard 2. Thus, in the present case, the entire module was conducted in interdisciplinary student groups whereby each one of the 10 groups consisted of 5 to 7 members. The groups were formed based on the students' initially expressed interest in different subject areas such that each group had both information technology and chemical engineering students as members, and one group also had one business student as member. The aim of this composition of the working groups was to emphasize the need of versatile skills and a multidisciplinary approach when developing new products, and the students' teamwork skills were to benefit from working in groups. Background material was provided and some of the week tasks intentionally requested the students to reflect on their group work skills. The working language of the module was English. Not only were all meetings with the instructors conducted in English; 8 out of 10 groups had one or more members whose native language was other than Finnish and consequently, the working language of these groups was English both naturally and out of necessity. The non-Finnish speakers were all students in the English-language degree programme in information technology at TUAS.

The total duration of the module was 9 weeks. The module content was divided into three themes, each processed for three weeks (see Table 1). The weekly timetable was organised in a consistent manner such that each week started with a 2-hour take-off session with the instructors on Monday morning, and on Fridays, the week's work was pulled together with all students and all or, on a few occasions, at least two of the instructors present. On the Monday, a basis was constructed and instructions were provided for the week's work which was then mainly conducted in groups although during some weeks, there were intermediate meetings with the instructors. Background lectures on nanotechnology were provided at the beginning of each theme, including the basics of nanotechnology, applications of nanotechnology, and success stories, i.e., description of SMEs with new and innovative products based on nanotechnology. In particular, halfway through the module, the business teacher met twice with each work group to discuss their specific project, and the English language & communication teacher met each group once over Skype for Business to practise using the program and to check on the group's progress. As a general guideline, the groups were instructed to plan and set a goal for their week's work after the take-off session on Monday, to dedicate Tuesday and Wednesday to information retrieval, reading and week-specific tasks, and to hold a reading circle and compile their group report on Thursday.

The reporting system built into the module comprised both weekly individual reports in the form of a learning diary, and weekly group reports. Some background material was provided by the teachers each week, and students were instructed to find material in line with their specific project topic. In the individual diaries, reflection on given week-specific topics was expected, and in the group reports, the groups were to account for how they had arranged their group work that week, what materials they had shared, and what learning outcomes there were. The use of the RefWorks online research management and writing tool, licensed by TUAS, was expected and encouraged. A special interim report task was scheduled for the groups at the end of each 3-week theme. The first interim task comprised producing a business model canvas and personas for customer analysis (van Dijk et. al, 2010). As the second interim task, the students conducted a Skype for Business meeting (pitching their ideas), inviting the teachers as participants. The final interim task consisted of creating a poster on the group's 2050 nanotech product or service concept and presenting it during a poster exhibition.

All tasks assigned during the module were specifically designed with the intention of fostering the learning of disciplinary knowledge simultaneously with personal and interpersonal skills as well as product, process, and system building skills in the spirit of CDIO Standard 7. Active learning methods (Standard 8) were applied, emphasising the engagement of students in manipulating, applying, analyzing, and evaluating ideas. Such methods included small-group discussions, learning cafés, feedback from students about what they were learning, and simulations of professional engineering practice, for which purpose the Skype for Business tool, among others, was used. In addition, a number of other web-based or social media tools were used to enhance communication and to increase motivation. These included the terminology tool Quizlet and the virtual bulletin board Padlet. The use of various tools, such as the 3-12-3 Brainstorm method and the 4Cs for information-splicing (Gray et al., 2010), mind maps, business model canvases (Osterwalder & Pigneur, 2010) and stakeholder analyses (Mendelow, 1991) was encouraged for creative problem-solving in concept development. The Business Model Canvas is a dynamic development tool to convert business ideas into concepts and products. Unlike a business plan, it offers a way to experiment and prototype different business models in a tangible and structured way with its nine building blogs. Visualization helps the designer to communicate different scenarios and share his/her understanding of a business within the team and to other stakeholders.

Table 1. The structure of the study module.

Theme	Objectives	Tools introduced
1:Wild Ideas	• finding application area of interest • bonding with the like-minded & having wild ideas • understanding horizontal nature of nanotechnology • improving brainstorming & information retrieval skills	• Brainstorming tools • Ideation techniques • Personas • Business Model Canvas • Quizlet for nanotech terms • RefWorks
2: Getting a Grip of Nano	• understanding what nanomaterials are, what nanotechnology is, what services & products are available and how they are based on nanotechnology • understanding the innovation process • being able to communicate this understanding to others and to participate successfully in an innovation process; selling ideas	• NABC method for pitching • 4Cs customer needs tool • Skype for Business • Padlet walls
3: Nano, Inno, Anno 2050	• application of knowledge of nanomaterials and nanotechnology to generate feasible and viable service and product ideas / prototypes • concept development & understanding the next steps • convincing communication skills to ensure fluent progress of the development process	• Stakeholder analysis

The students were instructed to give an elevator pitch, a short and concise sales presentation of a business idea which, when delivered using NABC value proposition and convincing presentation techniques, creates interest and with a neat closing, persuades the interlocutor to ask about the next steps (Carlson & Wilmot, 2006). It answers important questions: who is the customer and the important customer, what the market need is, how the problem is solved, what the benefit per cost for the customer is, and why the solution is superior to the competition.

Theme-based Implementation

Within a CDIO context, it is important to provide students with opportunities to develop their personal and professional skills along with subject knowledge. In engineering education, the teaching and learning of communication and foreign language skills is commonly arranged either by teaching engineering content in the target language, whereby the focus is on the content and not on the language, or by offering the students separate language and communication courses. There is, however, evidence that neither practice is optimal from the language skills learning point of view. According to Ament et al. (2015), for instance, an integrated content and language approach is more effective than a solely content-based English-medium instruction model for university level content courses, if linguistic gains are the desired outcomes of the programme. Yau et al. (2011), on the other hand, describe the twinning of a core chemical engineering module with a teamwork & communication module, taught by separate faculties. While students are reported as having benefitted from the twinning initiative, several issues and challenges related to the general arrangement are mentioned, particularly with regard to timetable and administration. “Nanotechnology - Future Prospects and Business Opportunities” was designed to develop the students’ language and communication skills not only by using English as the medium but by explicitly focusing on said skills parallel with the technological and business content. Ida Klasén (2011) aptly describes this approach with her model of communication aspects in engineering education where the two main principles ‘learning to communicate’ and ‘communicating to learn’ are combined with an integration dimension which ranges from passive to active (see Figure 2).

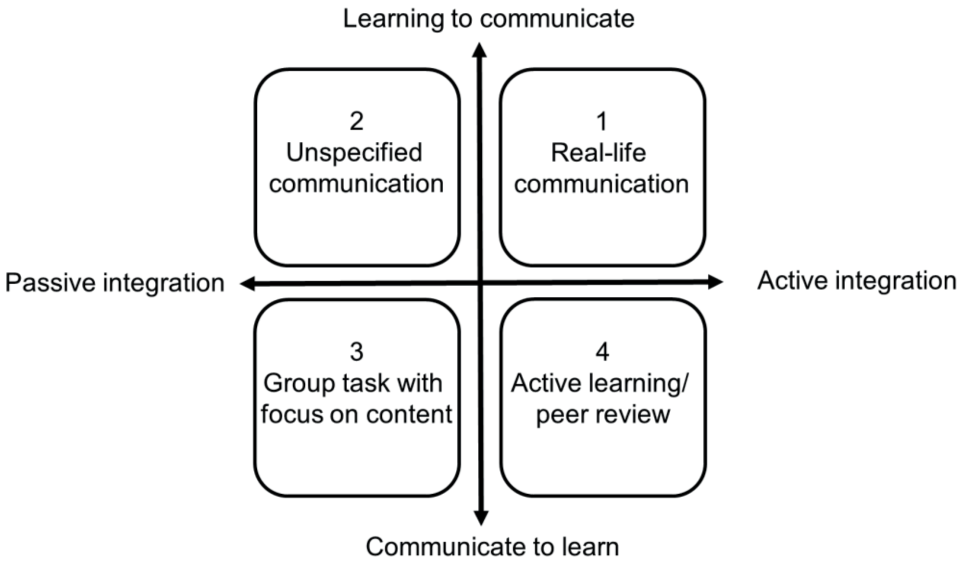

Figure 2. Communication aspects in engineering education (adapted from Klasén, 2011; originally by Nonaka & Takeuchi, 1995).

For the students, one of the three teachers being an English language and communication teacher was presumably as such a reminder that these skills were to be worked on while studying field-related content. Examples of activities designed as described by the four blocks in Figure 2 are provided below.

- Block 1, Learning to communicate with an active integration approach, “Real-life communication”. This approach means that students develop their skills when using subject content in an environment or situation natural for an engineer in his or her occupation. The students were, for instance, asked to conduct an online meeting to pitch their futuristic nanotech-related concept to a financing board.
- Block 2, Learning to communicate with a passive integration approach. An example here would be the weekly tasks where the students were asked to watch a video or read an article and discuss it in their diaries but where no specific form was required of the discussion.

- Block 3, Communicating to learn with a passive integration approach. The idea here is that the students learn to communicate by working on the subject content. Examples include group discussions, brainstorming sessions and reading background material.
- Block 4, Communicating to learn with an active integration approach. An example would be the students writing real-time content questions on Padlet bulleting boards while their peers were giving talks or presentations.

DATA COLLECTION AND METHOD FOR EVALUATION OF LEARNING OUTCOMES

The aims of the study were based on the learning outcomes defined for the module and the fulfilment of the aims was studied by analyzing the module feedback, self-evaluation and peer evaluation forms, follow-up discussions, weekly reports (both oral and written) and poster content and their presentation. In addition, the students separately described the innovation process learning by answering specific questions (typical phases of an innovation process, effect of innovation process on learning, use of innovation tools, visualization of ideas, concepts and solutions, and the clusters and partnerships needed for envisaged products). The poster and its presentation in a separate poster session constituted the final report. The goal was a convincing (both from the viewpoint of technology, business, innovation and communication) poster presentation on a nanotechnology-based product that could be reality in 2050. Thus, a variety of assessment methods was exploited for learning assessment in compliance with CDIO Standard 11. The main source of data for evaluation of learning consisted of the module feedback form (2/3 of the students that participated actively in the module filled the module feedback form) and the posters. The collected feedback data was analyzed by qualitative content analysis. i.e., by identifying and categorizing the core consistencies and meanings.

The learning outcomes of the study module:

- The students are able to describe how nanotechnology will change manufacturing, materials, products and services in the future.
- The students are able to assess business opportunities related to nanotechnology and nanomaterials.
- The students are able to communicate more effectively in different business situations and with actors from different fields.

There were three questions in the study module feedback form:

1. What did you learn? Think of, e.g., nanomaterials, business models, English language and communication skills, social media and innovation tools (e.g., Skype for Business, Quizlet, Padlet; business model canvas, personas).
2. Comment on the way the course is implemented.
3. Any other comments you would like to make?

The self-evaluation form also included a comment window, where several students made comments about the group work, its dynamics and team spirit. Continuous self-reflection in the weekly reports (both in individual learning diaries and group reports) and separate analysis of the innovation process learning provided some additional data about the learning and group work. The poster and presentations in the poster exhibition showed whether the group was able to produce a convincing poster, and to present it in a convincing manner.

RESULTS & DISCUSSION

The group work resulted in visions for 10 future nanomaterial-based products with analyzed customer profiles and business models, presented in a poster exhibition at the end of the study module. Many product visions combined electronics, software and biotechnology or chemistry, and one of the common topics was clean technology, especially clean energy, which shows that the students were interested in environmental and ethical issues related to future products, services and solutions. This may depend on several factors. Environmental issues, cleantech, resource efficiency and circular economy are common topics in today's media, but the students were also provided material where environmental and ethical issues were emphasized in innovations and in the planning of new products (e.g., reverse innovation, i.e., innovations likely to be used first in the developing world) and some of the international students in the groups were from countries of low electrification rate where new solutions are often based on solar energy. Regardless of the reason, in planning, the students took into account social responsibility in accordance with CDIO Standard 7. The content of the posters also showed development in the business ideas during the study module. The brainstorming and the first ideas of the student groups followed the "quality equals quantity" principle, but clear development was seen halfway through the study module (during follow-up discussions and in pitching), and finally, clearly more solid, crystallised and feasible concepts were presented in the posters at the end of the study module. However, determination of customer needs (in 2050) and the use of personas remained difficult throughout the study module. This was expected because most of the students were engineering students, focusing on technology, but some change in mindset was observed towards the end of the study module.

The study module feedback confirmed that most of the aims were achieved and learning outcomes fulfilled. The students emphasized that their communication, English language and collaboration skills improved, but they also reported learning about business, innovation process, nanotechnology, and social media and innovation tools. In their group reports, several groups mentioned having taken the aim of improving their English seriously to the extent that they spoke English even when the non-Finnish speaking group member was not present. The improved collaboration & group work skills were mentioned only in 14 % of the feedback forms, the other skills were all mentioned in at least 55% of the feedback forms. Some students emphasized in their comments that they had difficulties with collaboration within the group, but most groups overcame it fast. Some students requested more guidance (both from the viewpoint of disciplinary background, information retrieval and support for collaboration within the group), which is common in any project-based learning, which requires self-discovery and self-steering. The participants were second year students and the module started already in beginning of the autumn semester and most of the students had experienced earlier only one corresponding shorter course, the introduction to engineering according to CDIO standard 4. In other words, they do not yet have many design-implement experiences and corresponding and many of them still think that the lecture-based teaching is better. Some of the problems in the group work were related to different cultures, but in general the comments reflected the common agony of some students when changing the mindset towards self-steering, and consequently all students in the group did not always do their share in time. However, criticism is also a sign of development, and this was also verified by some of the groups that described difficulties in the beginning and better group work towards the end of the module.

Some of the students criticized the lack of lectures, especially regarding nanotechnology. Four introductory lectures were provided on nanotechnology, two of them during Theme 1 and one at the beginning of Theme 2 and 3, respectively (to support an entrepreneurial mindset, one focused on SMEs with new, promising products based on nanomaterials). In addition, during the lectures, the students wrote questions on Padlet walls, which were then commented on and discussed during a later lecture. To support learning, nanotech-related links and review articles were provided and the groups complemented their nanotechnology knowledge by information retrieval. The results were presented both in written form and orally as part of the weekly reporting, and the students received feedback for their reports. In spite of the provided materials and regular feedback, the nanotech information retrieval and reporting were found difficult, but another reason for criticism was the same as in the case of group work; some students had difficulties with self-steering and consequently in group working, and they did not do their share in information retrieval and reporting in time. To overcome this, the study module implementation could be developed to include several brief “coaching sessions” with the groups to support self-steering, group work and information retrieval.

The implementation of the module contained even other parts affecting the entrepreneurial mindset. The students were faced with uncertain conditions (e.g., in oral reporting on Fridays), where they had to rapidly complement technological and business aspects of their product idea. It has been suggested that the successful future strategist will exhibit an ability to rapidly sense, act, and mobilize, even under uncertain conditions. The ability to master complexity is crucial in the contemporary business environment. According to entrepreneurs such as Schwab and Branson, it is critical to use skills such as thinking in pictures, employing analogies, and synthetizing information relative to the aims (Haynie et al., 2010).

CONCLUSIONS

In conclusion, fruitful ground was provided by the pedagogical approach for an integrated learning experience where the learning of disciplinary knowledge and communication skills were simultaneously fostered (CDIO Standard 7). Most of the aims were achieved.

- The group work resulted in visions for 10 future nanomaterial-based products with analyzed customer profiles and business models. The initial wild ideas had developed into more solid, crystallised and feasible concepts by the end of the study module.
- The students showed interest in social responsibility in the planning of future products and their communication and collaboration skills improved while they also learned about business, nanotechnology, and social media and innovation tools. Thus, a design-implement experience (Standard 5) can also be applied to envisaged products.
- The word “interesting” (and similar) was a common indicator of a change in mindset towards interdisciplinary team work, a prerequisite for an entrepreneurial mindset.

However, to improve the design-implement experience of the study module in the future, more short meetings, “coaching sessions”, will be held with the groups to support the group work and self-steering of the students, i.e., to help students to trust themselves and to better tolerate uncertainty, which also are prerequisites for the entrepreneurial mindset.

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INTEGRATING BUSINESS SKILLS IN ENGINEERING EDUCATION: ENHANCING LEARNING USING A CDIO APPROACH

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ABSTRACT

University degrees, such as engineering, that focus on professional competences are becoming increasingly popular in Sweden. However, there is still a need to not only include but to integrate different interdisciplinary skills in courses and education programs. This paper reports and analyzes a case study of the integration of business skills in two different courses on different study programs and levels. The results show that by shifting the actual foundation of a project course from technology to business development, a high level of engagement are achieved, among the students, to work with technology in a more realistic context. By integrating teaching of different professional skills alongside disciplinary knowledge and by putting disciplinary engineering courses into context, e.g. a business context, the students tend to work more systematically and rigorously both in conceiving, designing and implementing their technical projects. Hence, the situation becomes more similar to a real situation in the industry, where value driven development is a necessity. Additionally, by integrating teaching of such skills into the curriculum of several courses during a engineering program according to the CDIO Approach, a better understanding and a shift in the students' individual choices on project courses towards value driven development can be seen.

KEYWORDS

Integrated learning experience, Interdisciplinary courses, Standards: 1, 2, 3, 5, 7, 8, 9

INTRODUCTION

To study at the university has become an obvious choice for the young population in Sweden and to have a university degree is important regardless of future profession. The degrees awarded in Sweden today can be divided into general degrees (e.g. Bachelor's and Master's degrees) and professional degrees (e.g. medical, engineer and psychologist). Statistics show that, in Sweden, students applying for higher education programs clearly tend to choose study programs that lead to degrees closely connected to certain professions, such as an becoming an engineer (UHR, 2014). In general, students within engineering can either choose to study towards a Bachelor of Science Degree in Engineering (3 years) or a Master of Science Degree in Engineering (5 years), which both are, what in Sweden is denoted as, professional degrees. Since these study programs have such close connection to the profession it is important not only to discuss the knowledge that the students acquire in the field of study, but all skills needed by the students to cope with their future profession. Schwieler (2007) mentions skills such as social competencies, intercultural competencies, entrepreneurial competencies and managing competencies as important for engineers. Furthermore, these multifaceted skills are, in general, desired by the industry (Mechefske, Wyss, Surgenor & Kubrick, 2005).

Hence, the education should not only provide knowledge within the specific field of study but also make the students “prepared to live and work as global citizens, understand how engineers contribute to society. They must develop a basic understanding of business processes” (Vest, 2007, p. xiii). Many engineering programs are founded in the ideas suggested by CDIO (Crawley, Malmqvist, Ostlund & Brodeur, 2007), which is the case of the education programs at Umeå University. CDIO is an organization that has the aim to help bridge the gap that currently exists between engineering education and the business community's view on engineering skills needed by the students. Thus, the students should be able to *Conceive*, *Design*, *Implement* and *Operate* in their role as an engineer, which means that knowledge and skills in all parts of a product's life cycle are of great importance. This involves, for example, identifying needs, planning the development process, develop, production, maintenance and marketing products. Hence, the idea is more explicitly to prepare students for a future career in the industry without changing the academic demands placed on students. The CDIO model provides a broad base for the generic skills that can be expected by both current and future engineers.

Studying and learning are in many ways active processes. Today, project-based learning in a very common way to assimilate some of the skills needed as a professional engineer, and not only disciplinary knowledge. Using this type of learning process is also something that has been deemed appropriate and successful in engineering education (De Graaff & Kolmos, 2003; Mills & Treagust, 2003). Furthermore, basing the teaching on projects also aims to increase the students’ motivation to take responsibility of their own learning process (Turner & Paris, 1995). Therefore it is important for teachers in higher education to move some of the focus from the disciplinary subject area and link the students' projects to a social and business context and relevance (Cardozo et al., 2002). Although different projects on different courses connected to an education program have different objectives, there is often a freedom in some of the choices made by both students and teachers linked to projects in today's engineering education. This paper reports and analyzes a case study (e.g. Stake, 2005; Yin, 1994) of the integration of business skills in engineering courses to put project courses in a more realistic context and further support the design-build test approach.

METHOD AND STUDY DESIGN

This case study analyses process and results from two different courses on different levels and study programs at the Department of Applied Physics and Electronics at Umeå University, in which students' knowledge of business development and business thinking are integrated with a technical development project. These courses illustrated in this article seek to respond to the need to give students skills within the Extended CDIO Syllabus 2.0 regarding integration of business skills in engineering education. Thus, the purpose of this article is to discuss and raise interest in issues related to the role of the engineer as part of the development of society. The courses studied in this paper are *Engineering in a business context* and *Service design and business models in an engineering context* (Table 1).

Table 1. The two interdisciplinary courses included in this case study.

Course	Study program	Level	Study year
Engineering in a business context (15 ECTS, spring, 100%)	Bachelor of Science Program in Electronic and Computer Engineering (3 year education program)	Basic	Third year
Service design and business models in an engineering context (7.5 ECTS, fall, 25%)	Master of Science Program in Interaction Technology and Design (5 year education program)	Advanced	Fifth or fourth year

The courses studied in this research (Table 1) have learning outcomes that relate to both disciplinary and interdisciplinary knowledge. The interdisciplinary learning outcomes are integrated into the curriculums of the courses and focus on e.g. business development and project management. The learning outcomes related to interdisciplinary knowledge are presented in Table 2.

Table 2. Learning outcomes related to interdisciplinary knowledge.

Engineering in a business context	**Service design and business models in an engineering context**
Discuss the concepts of entrepreneurship, business model and business plan.	Apply appropriate techniques for creative product and service development.
Describe the basic laws and regulations relating to start-ups and small businesses.	Specify a product or service and develop a prototype.
Explain basic principles regarding financial reporting.	Establish and follow a project plan for a defined development project.
Evaluate and assess the quality of a finished product on the basis of functionality, technical level and compliance to the specification.	Apply engineering and business knowledge during conceiving and designing a product or a service based on a business idea.
Evaluate, design and present business plans and identify the strengths and weaknesses of these.	Prepare and present a business plan, financing strategy and marketing plan for the project.
Analyze the learning process in terms of creativity, initiative and entrepreneurship.	Formulate a career plan and a plan to build a personal network.
	Evaluate and assess the quality of a finished product.
	Evaluate the project from a personal career perspective.

The data collection for this study (Table 3) has been longitudinal during 2012 to 2016 and was conducted using ordinary anonymous course evaluations (at the end of each course) and anonymous online student surveys (1-2 per course) (Fowler, 2014) spread out during the course as well as group interviews with students (1-2 per course). The group interviews gave qualitative and exploratory insight into the results from the evaluations and surveys. All participation, in any of these data collection sessions, have been voluntarily by the students and to minimize the bias in the surveys, the students were not informed about the use of the data in research beforehand (Aleamoni & Hexner, 1980).

Table 3. List of number of courses included in the data collection used in this case study.

Course	**Course evaluations**	**Student survey**	**Group interviews**
Engineering in a business context	4 (2013-2016)	2 (2015-2016)	1 (2015)
Service design and business models in an engineering context	3 (2013-2015)		4 (2012-2016)

Using case study methodology has limitations in generalization. However, this paper does not aim towards generalization but rather to give insight into the integration of business skills in engineering programs in line with the CDIO principles. Furthermore, Stake (2005, p. 460) states that “the purpose of a case report is not to represent the world, but to represent the case”. The use of a case study, in this case, is suitable since the project is a “unit of human activity embedded in the real world; which can only be studied or understood in context; which exists in the here and now; that emerges in with its context so that precise boundaries are difficult to draw” (Gillham, 2000, p. 1).

RESULTS

Even though a definition of engineering by the American Engineers' Council for Professional Development (ECPD) was stated in 1947 as “the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property”, this definition still have great impact on engineers and engineering in the 21st Century. Hence, to work and have a career in engineering, acquiring a broad range of generic skills is becoming increasingly important for students (Mechefske, Wyss, Surgenor & Kubrick, 2005; Schwieler, 2007). CDIO is an international initiative that provides a framework for providing engineering skills in engineering education. The fundamentals of CDIO is to better prepare students for future work as engineers in the industry by providing necessary skills not only within the area of focus, but everything needed for life-cycle thinking of products and services. According to Crawley, Malmqvist, Ostlund & Brodeur (2007, p. 1), “the CDIO approach builds on stakeholder input to identify the learning needs of the students in a program, and construct a sequence of integrated learning experiences to meet those needs”. Hence, the focus is on the stages - *Conceive*, *Design*, *Implement* and *Operate*. The courses analyzed in this paper aim towards providing results that connect to the CDIO standards regarding Context (Standard 1), Learning outcomes (Standard 2), Integrated curriculum (Standard 3), Design-implement experiences (Standard 5), Integrated Learning experiences (Standard 7), Active learning (Standard 8) and Enhancement of Faculty Competence (Standard 9).

Interdisciplinary courses in engineering education

Due to its ability to support and address both disciplinary skills and generic skills, project-based learning has become increasingly common in engineering education (Mills & Treagust, 2003). Hence, by working with projects, students’ inner motivation, need and will to increase their learning in adjacent areas can increase. Furthermore, great care should be taken into setting up project teams and choosing projects since students tend to have a better learning experience connected to teamwork from good experiences than from bad ones (Bacon, Stewart & Silver, 1999). Since the project ideas on the courses in this paper are self-chosen by the students, it has proven to be more successful to have self-selected project teams due to the need of different competences in the group. These teams also provide a better real-world experience and increase the value of the teamwork (Chapman, Meuter, Toy & Wright, 2006) and, thus, build collaborative learning (cf. Elmgren & Henriksson, 2010; Turner & Paris, 1995). Similar projects have been performed in e.g. project management (e.g. Mejtoft & Berglund, 2015). The results of this paper are deeply funded in the principles of CDIO (Crawley, Malmqvist, Ostlund & Brodeur, 2007) and project-based learning.

Traditionally projects on courses within engineering have a linear structure involving creating concept, development (i.e. design and build) and presentation (or launch) of the product (Figure 1). This structure is well founded in the ideas of traditional project management and teaches the students how to work with available recourses within certain time constraints.

Figure 1. Structure of traditional projects on engineering courses.

Even though not always the case, this traditional structure further supports the thoughts of design-build-test as described by e.g. Malmqvist, Young, Hallström & Kuttenkeuler (2004). However, the idea of integration according to the CDIO Syllabus 2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) can be interpreted as to both increase the "need" that the students feel to prototype in their development and furthermore integrate the product development in a business development process (Figure 2). Hence, such approach more clearly supports the design-build-test concept, since the business development process demands a connection to, and, hence, proof for, a customer centric design method. The students comment on the idea of a business focus on their courses as: "It's important to think about how customers will react to our product and also what the actual value of a product is" and "It's basically all about money, so it feels like it is beneficial with insight into a business thinking when starting to work [as an engineer]".

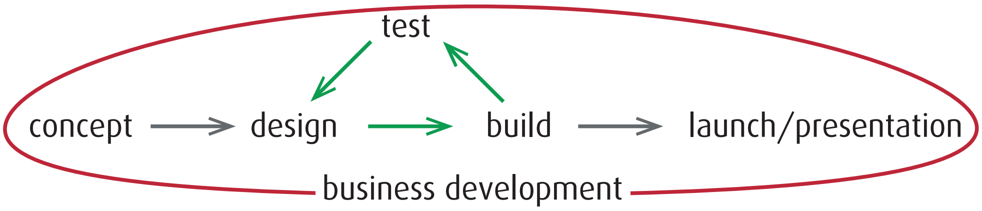

Figure 2. Structure and conceptual idea of projects when integrating business skills in engineering courses.

The results from this research show that introducing interdisciplinary courses that focus on business development in engineering education changes the students' view on the development process from a narrow technical angle to a broad holistic engineering perspective. Hence, by dressing the product (or service) development process in a business costume, a context is clearly created for the students, which gives them the opportunity to focus on "the creation and operation of the goods and services that will deliver value" (Crawley, Malmqvist, Lucas & Brodeur, 2011).

Focusing students' choices by integration

Even though large parts of business development are covered within theoretical parts through lectures and workshops, the students must add to the content in terms of disciplinary knowledge to be able to successfully complete the project work (Ying, Yan & Tong, 2010). This is done both through supervision of the projects and self-studies by the students. By changing the idea of a disciplinary course from a traditional structure (Figure 1) where all attention is on the disciplinary knowledge to a business oriented focus, the students' individual choices for the project get focused on situations, context and, foremost, actual value. Although the two courses studied have their real focus on technology and disciplinary engineering skills, the idea of presenting the courses as business oriented makes the students chose more carefully regarding *how* and *why* certain activities are performed.

There are great differences in which type of input that is needed whether a project in derived from a value driven perspective or a technologically driven perspective (Figure 3). However, the actual disciplinary activities performed are pretty much same or similar based on the input. Hence, it is possible to argue that even though creating a more realistic scenario with interdisciplinary skills integrated into the course, the thoughts on disciplinary knowledge are still intact but set in a context.

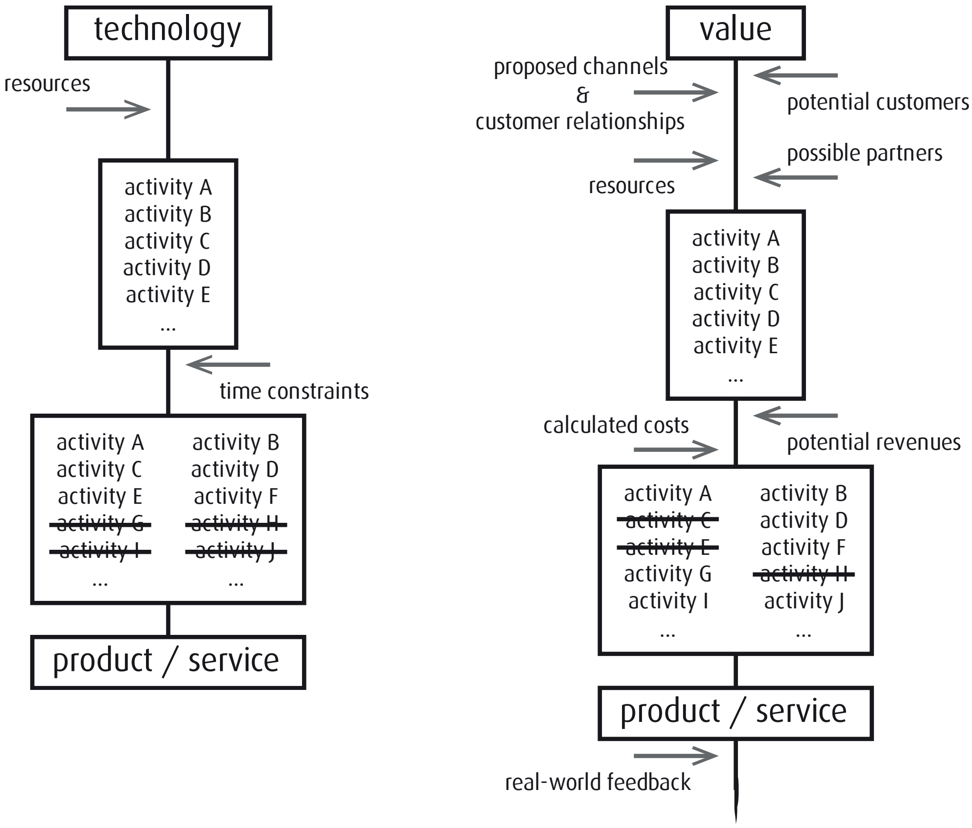

Figure 3. Difference in input and process depending on a technology driven or a value driven focus of the project.

The major difference in achievement by integrating business development in traditional project-based courses is that activities performed in the technical project will have to be structured and ranked depending on when in time they can be performed (based on when e.g. input from users can be collected) and all activities that are set at the beginning of the project will probably not be performed due to the actual need and what the users are potentially willing to pay for (Figure 3). Students express this as the course “gives a clearer picture of how the technology is supposed to be applied and other aspects such as usability, cost, design etc. must be taken into account, not just to merely make the technology work” and “it is important to think about how other people experience products and how important the perceived value of a product is”. Furthermore there are both positive aspects on these courses as well as problematic areas to deal with. The greatest benefits concern the gradually change in thinking that students gain through *a user-centric focus on development*: “I have become better to understand how others think, to create the best value proposition you have to put yourself in another person’s mind”, *a development in business thinking*: “I have become better to connect what I do to profitability, that what we develop should be economically viable”, as well as the opportunity to *nurture entrepreneurial behavior*: “I got much insight and knowledge of how it would be to start my own business”. The benefits of a broad approach to technology, which more tangibly connects to students’ future professional roles as developers, clearly are stressed by a majority of students in the courses.

Nevertheless, this also connects to the major disadvantage, stressed by the students, with a business development focus on courses. Since not all focus is on technology, changes in original plans have to be made and, sometimes, activities that the students wanted to perform might be discarded during the project, which has been mentioned by one of the students as the projects can be “obstructing in terms of the technological development”.

When discussion the course *Engineering in a business context* and the students at the Bachelor of Science Program in Electronic and Computer Engineering, it is possible to clearly distinguish a gradually increase in the understanding for business skills in engineering education during the 10 week course. Surveys during the first three weeks give indications that the primary reason for choosing this course was not the interdisciplinary approach, but the need for a project-based course to include in their degree (which is mandatory). Comments on why this particular course was chosen include: “Because I needed a project-based course and it sounded interesting with a more business oriented perspective” and “One project-based course is mandatory for graduation and out of the ones available, this was the most interesting one”. Even though spending most of the time working with a technical development project, at the end of the course the students more clearly list interdisciplinary skills both as important and as something they have been able to practice: “I have become better to connect what I do to profitability, that what we develop should be economically viable”, “I’ve been much better to argue for my standpoint” and “I got a better understanding for entrepreneurship and starting my own business”.

Understanding of the students’ professional role

The professional role of an engineer is much broader than just technology and sciences (e.g. Crawley, Malmqvist, Ostlund & Brodeur, 2007; Mechefske, Wyss, Surgenor & Kubrick, 2005). Generally, in education, there is a need to provide students with knowledge that bridge the gap between the knowledge of the different subject areas studied through the engineering program’s technical disciplinary courses. This knowledge is strongly related to the professional role of the engineer and the need to synthesize knowledge into a way of thinking about products and services. This kind of knowledge can be e.g. project management, sustainability and business development. The courses described in this paper focus to meet certain part in the CDIO Syllabus 2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) such as *Analytical reasoning and problem solving*, *Experimentation, investigation and knowledge discovery*, *System thinking*, *Attitudes, thoughts and learning* and *Ethics, equity and other responsibilities* in Personal and professional skills and attributes (CDIO Syllabus 2.0: 2) and *Teamwork* and *Communication* in Interpersonal skills (CDIO Syllabus 2.0: 3).

Touching upon the students’ motivation and to use external motivation to increase the inner motivation, combining academic teaching environments with real-world experiences are of great importance (cf. Mejtoft, 2015). Additionally to the “ordinary” project presentation at the end of the course, the courses described in this paper end with the students delivering a two minute pitch of their idea and project in front of 3-4 persons with high business knowledge in the same set-up as the TV-show “Dragons’ Den”. After the pitch, the student are engaged in a Questions & Answers (Q&A) session of approximately 6-10 minutes with questions from the “dragons” that have arisen during the pitch. During the course *Service design and business models in an engineering context,* this is done in cooperation with the industry and an external consultancy firm and the dragons are highly skilled business and management consultants. During *Engineering in a business context* the final pitch is set up internally at the University, but with people with high knowledge and experience from business development and that are previously unknown to the students. This final examination, that is separated in time and place from the project presentation in class, puts great pressure on the students since they have to strategically plan their learning process to correspond to “complex phenomena of the world, including facts and their interrelations” (Svensson, 1997, p. 60), since they have no idea which type of questions and reactions they will get from the

"Dragons" during the Q&A session. All students that have taken part of the external Dragons' Den feel that this is a positive experience that increases the motivation to present and prepare more thoroughly for the final presentation and examination. The students comment the final pitch as: "Very fun and educational. I'm glad they gave a lot of feedback and really seemed to be interested [in our work]", "Super fun! An educational, good and nervous experience. Being nervous means that it's something new and challenging" and "An exciting task that meant you had to show your muscles a little extra, which is a very good exercise".

Teacher's disciplinary and interdisciplinary knowledge

The external company that provide the expertise in business development during the "Dragon' Den", described above, is very satisfied with the students and rank the students' knowledge in business thinking at the course as high and also emphasis the progression from year to year on the course. The region manager of the external consultancy firm (and one of the "dragons") that take part of the examination of the course stated that the "awareness, among the students, about the importance of a business thinking has increased significantly from year to year, there is no question about that". This is a result of further integration of business model thinking in several courses included in the Master of Science study program in Interaction Technology and Design. Currently business model thinking is included in the courses *Interaction Technology and Design (7.5 ECTS)* on the first year and *Product development in media technology using the design-build-test method (7.5 ECTS)* on the third year. Hence, by integrating small pieces of generic skills during several courses a better understanding for the interdisciplinary skills are achieved. This is, however, not done on the third year Bachelor of Science Program in Electronic and Computer Engineering, in which case comments from the students are more connected to that the overall focus has shifted from technology to business. Even though the same or similar activities are performed.

To be able to support Integrated Learning Experiences (Standard 7), and, thus, an Integrated Curriculum (Standard 3), the lecturers and supervisors knowledge is important. Even though it is possible to integrate business skills, as described in this paper, based on several supervisors and lecturers with different knowledge, this do not truly give a successful integrated learning experience. Hence, to truly integrate generic skills into engineering education increases the demand on lecturers and supervisors to have broader knowledge and understanding for context and interdisciplinary skills than just the disciplinary knowledge.

CONCLUSIONS

To prepare students to act in a dynamic and fast-paced business environment is one of the main goals for an education program. This includes both disciplinary and interdisciplinary knowledge that are needed for students to be able to work as professionals. One of the main problems with integrating interdisciplinary subjects and skills in today's engineering education is a tight and already full curriculum. This paper illustrates how business skills can be integrated into the current curriculum by integration into disciplinary engineering courses. The results achieved during this project illustrate that by shifting the actual foundation of a project course from technology to business development a high level of student engagement to work with technology in a more realistic context can be achieved.

By integrating the teaching of different professional skills and by putting disciplinary engineering courses into context, e.g. a business context, the students work more systematically and rigorously both in conceiving, designing and implementing the results of their technical projects. Hence, the situation becomes more similar to a real situation in the industry. Moreover, by integrating the focus and teaching of such skills into the curriculum of several courses during an engineering program according to the CDIO approach, a better understanding and a shift in the students' individual choices on project courses towards value driven development can be seen. Forming cooperation with external partners to provide input into e.g. the final stage of the students' work, in this case a "Dragons' Den", increases the students' motivation to engage in the project work. However, the results from the study show that setting up a similar examination with internal staff that the students are not familiar with gives similar results.

ACKNOWLEDGEMENT

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BIOGRAPHICAL INFORMATION

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IMPLEMENTING A 15 kW ELECTRIC SOLAR POWER SYSTEM AS A STUDENT PROJECT

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ABSTRACT

Solar PV (photo voltaic) power is the fastest growing energy segment globally. In 2014 40 GW of solar PV power was connected to the grid globally. In ten years the growth has been outstanding: from 3.7 GW in 2004 to 177 GW in 2014. In Finland the installed solar PV power is only about 20 MW , so we could do much better.

In Lahti University of Applied Sciences (LUAS) the students of Energy and Environmental Technology can specialize in Renewable Energy Technologies. They have done a lot of research-based studies and projects, but the real hands-on projects were missing from the curriculum. On the other hand, in the Degree Programme of Mechatronics there was a long tradition of these types of projects starting from the first academic year. In the Niemi Campus the facility owner (Osaamiskiinteistöt Oy) expressed that the energy efficiency of the facilities should be improved. Due to these facts, we launched a project where an electric solar power system was installed in the Niemi Campus.

The main specifications for the system were:

- 10 kW nominal power (+ 5 kW reserve for wind mill)
- Grid inverter included (no batteries)
- Web-based data logging and remote control to customer’s server
- Mounting brackets and accessories for the panels
- Training and start-up (1 day)

The aim of this paper is to report how we managed this project with inexperienced students and share information about project learning in general and especially about this project (the process, learning outcomes and curriculum with CDIO community. The scope of this paper is in the process: to report why, what and how we ran this project. The project was successful: all stakeholders (the students, instructors, supplier and customer) gave us positive feedback. The next project, which we have just launched, was encouraged by this project: the windmill project.

KEYWORDS

project learning, active learning, renewable energy (solar), multidisciplinary projects, standards: 3, 5, 6, 7,

INTRODUCTION AND MOTIVATION

Solar PV (photo voltaic) power is the fastest growing energy segment globally. In 2014 40 GW of solar PV power was connected to the grid globally. In ten years the growth has in addition, been outstanding: from 3.7 GW in 2004 to 177 GW in 2014 (Renewable Energy Policy Network, 2015). In Finland the installed solar PV power is only about 20 MW, which is among the lowest figures in Europe (Motiva, 2015). So we could do much better. The European Union National Action Plans (Ministry of Employment and the Economy, 2009) point out that also Finland should substantially increase the production of renewable energies in general. Unfortunately the action plan target for solar PV power is far from ambitious: only 30 MW until 2020. It seems that Finland will fulfill this target, but the problem is that the original action plan target is far too low. On the other hand, Finnish enterprises are doing well globally. It was just announced that Fortum won a contract of a 70 MW solar PV power plant in India. Also ABB and Nocart have managed well in global markets (Motiva, 2015).

In Lahti University of Applied Sciences (LUAS) the students of Energy and Environmental Technology can specialize in Renewable Energy Technologies. The students have done some research-based projects, but the real hands-on projects were missing from the curriculum. There was also a strong demand from the students and other stakeholders, that real hands-on projects should be available in the curriculum. In the Niemi Campus the facility owner (Osaamiskiinteistöt Oy) expressed that the energy efficiency of the facilities should be improved: a solar power system would also improve the image of Niemi campus as a low energy facility. In the Degree Programme of Mechatronics there was a long tradition of these types of projects starting from the first academic year. Due to these facts, we launched a project where an electric solar power system was installed in the Niemi Campus.

PROJECT-BASED LEARNING AND CDIO

From the CDIO perspective project based learning is based on design thinking: design is the key activity in engineering. Design is also a very complex and extensive process, which embraces almost all subjects in engineering. That makes it extremely difficult to learn and teach (Dym & al., 2005). That is why experienced and skillful design engineers are very well paid.

Hands-on projects also have context-based (hardware), social (teamwork) and end-result driven aspects. Well-designed projects provide design experiences for the students. Margot Brereton studied how engineering students learn and develop engineering intuition by continuously shifting their thinking paradigm from engineering theory to interaction with hardware. She demonstrated that “engineering fundamentals are learned through activities at the border that involve continually translating between hardware and abstract representations. She is also suggesting the application of convergent-divergent thinking in a hands-on project context (Dym & al., 2005) and (Brereton, 1998). Project-based learning, which is implemented through numerous well designed hands-on projects, continuously challenge the students´ thinking: communication between engineering Theory and Praxis.

The theoretical basis of project-based learning also lies on the experiential learning theory by David Kolb (fig. 1): hands-on projects serve design and learning experiences, which excite the reflective thinking and knowledge creation of the students (Kolb, 1984). Engineering knowledge is contextualized: it emphasize the knowledge that is relevant to the engineer’s every-day life.

In the curriculum level the hands-on projects should drive the content of study courses rather than the other way around. In many cases the hands-on projects have a more or less weak link to the content of other study courses. It would be beneficial if hands-on projects direct the content of basic study courses: it emphasizes “real life” relevance and makes the course content more compact (Kaikkonen, Lahtinen, 2011).

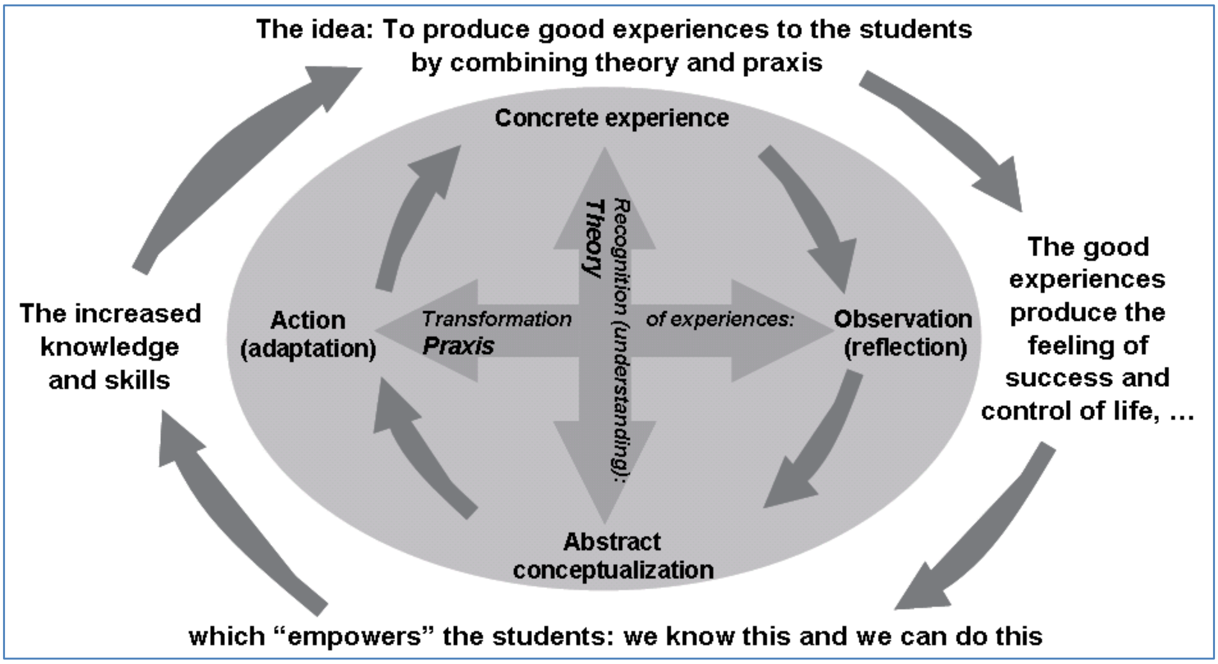

Figure 1: The Experiential Learning (Kolb; modified by Lahtinen)

The experiential learning model by Kolb has four phases: a) experience, b) observation (reflection), c) conceptualization and d) action. This is described in the inner circle of Figure 1. The action-observation pair forms the transformation of the experiences axis, which is very strongly related to the Praxis. On the other hand, the experiences-conceptualization pair forms the recognition (or understanding) axis, which is based on the Theory (Kolb, 1984 and Kaikkonen, Lahtinen, 2011).

Project-based learning can be formulated and defined in many ways, but when implemented trough well-designed hands-on projects, it serves a powerful learning and teaching tool for engineering education. From the CDIO Standards´ point of view it covers the following five standards: 3 (Integrated Curriculum), 5 (Design-implement experiences), 6 (Engineering workspaces), 7 (Integrated learning experiences) and 8 (Active learning) (Crawley & al., 2014). The challenges of project learning are usually related to the change process: the curriculum should be updated, the personnel should be trained as project managers and the workplaces should be equipped with proper hardware. This requires a strong motivation from the personnel and the ability of attitude transition (Kaikkonen, Lahtinen, 2011).

THE PROJECT AND PROCESS

This project is an optional project (6 cr) for the 3rd year students of Energy and Environmental Technology. The students should deepen their knowledge of renewable energy technologies. They should also be able “read” technical documents (wiring plans, mechanical plans etc.). The students should also develop their practical skills related to the implementation process: mechanical and electrical installations.

The project was launched in October 2014 by writing the all required documents for the invitation to tender. After that process Nocart Oy was selected as a provider of the system and they delivered the system in January 2015.The main specifications for the system were:

- 10 kW nominal power (+ 5 kW reserve for wind mill)
- Grid inverter included (no batteries)
- Web-based data logging and remote control to customer’s server
- Mounting brackets and accessories for the panels
- Training and start-up (1 day)

The system consists of 40 pcs of 250W solar panels, control cabinet (inverter, DC-DC converter, EMC filter, PLC and GSM unit). The panel frames were constructed from 40x40 mm aluminum profiles. 20 kg concrete bricks were used as counterweights.

In January also the project team was formed: 3 instructors, 7 students of environmental technology and 2 exchange students (electrical engineering) from UPC Barcelona Spain. Also ICT students of LUAS Faculty of Technology were involved in this project. The data logging server, which was connected both to the Solar Power System and the advanced weather station (big data) were their main tasks.

An experienced project manager (Mechatronics), who is also a licensed contractor of electrical installations, took the main role in project management. He was assisted by a project engineer and a lecturer from the department of Environmental Technology.

The project team had 4 hours/week of lectures in January and February. During the lectures following topics were discussed:

- The basics of electrical engineering related to the solar panels
- The basics of wiring
- Mechanical plans of panel frames and counterweights (together with an expert from Nocart Oy)
- Panel frame construction training (together with the expert from Nocart Oy)
- Safety issues: ground rules and regulations
- Safety issues: safety tool training (harnesses and ropes)
- The basics of DC-DC Converter and Inverter; EMC (exchange students)

In late January a team of four students was benchmarking a 10 kW solar power system in LEMKEM Oy. The system was documented and presented to the rest of the team as a reference. In February the components of the solar panel system were studied (panels, DC-DC Converter, Inverter and filters). The exchange students created study material (MultiSim simulation models) and presented it to the other students in English.

In March the installations started with counterweights and panel frames. In counterweights the bottom plates and through bolts were installed and panel frame aluminum profiles were cut and assembled as wishbones. This was the most time consuming part of the project. The panel frames, panels and wiring were installed in May. The wiring was finalized in August and final inspections were done in November. The system is connected in the grid and the production data will be collected later on.

Besides the lectures the students investigated the rules and regulations related to this scale of solar power plant. They also contacted the authorities and Lahti Energia Oy (power company) during the visit in March. Here is the list of required documents:

- planning permission (City of Lahti and facility owner)
- The connection of the micro power plant to the grid (Energiateollisuus ry; guidebook)
- A Technical appendix for the connection of micro power plant to the grid
- The basic data of the micro power plant (Lahti Energia; power company)
- The preconditions of electric power production and services (Energiateollisuus; TLE 2014 and TVPE11)
- Wiring layout
- Wiring diagrams of the facility control cabinet
- Wiring diagrams of the Inverter control cabinet
- Guide leaflet for safe power cut-off of the system

THE PARTIES INVOLVED IN THIS PROJECT

Nocart Ltd (the provider of power plant) was established in 2010. In 2015 the company is the leading provider of power generation solutions for small power plants in the renewable energy segment. Maximizing the advantages of renewable energy Nocart offers solutions for small power plants. The Nocart Power Generation Unit can be connected with multiple different types of power units, such as wind turbines and solar panels. The system is an economical and reliable choice for any conditions in the field of renewable energy. Installations can be found in farms, industrial estates and even in village communities of developing countries.

The main products of Lahti Energia (power company and grid holder) are electricity produced from combined power plant (Kymijärvi) and district heating. Lahti Energia sells electricity in Finland nationwide. The grid services are provided by the subsidiary LE Oy. The length of the power lines is 4580 km. Lahti Energia is also a provider of natural gas (167 kilometers of natural gas pipelines).

Osaamiskiinteistöt (customer) is focusing on facility services: renting and operating its own or leased real estates and maintenance services.

THE END RESULTS AND FEEDBACK

The end result was approved and all stakeholders (students, provider, customer and power company gave positive feedback for us. In the future the students have an excellent learning platform for the next projects, the provider use the system as one of their references, the customer is more than satisfied and also the power company have listed system as one of their references (fig. 2 and 3).

After the project a short questionnaire for the students was implemented to collect feedback and ideas for the next projects. The questionnaire had 5 questions or statements and open answers (table 1). In scale 1 (totally agree) to 5 (totally disagree) we got 1.4 as a total average. In open answers there were following comments and feedback.

Hits: “The best course/project ever”, “The project was very good and unique. Absolutely more like this”, “The project idea was great and interesting. It was very nice that the students could make the panel installations. More like this!”

Misses: “The schedule did not work too well”, “There were problems in communication between the lecturers and the students”, “The workload was not even between the students”, “It could be better if all students could join all phases of the project (wiring)”, “All students were not present every time”

Table 1. Questionnaire Results

Questions							**AVE**
Scale: 1=totally agree, 5=totally disagree	**a**	**b**	**c**	**d**	**e**	**f**	**Students**
Hands-on projects are useful.	1	1	2	1	1	1	**1,2**
There should be more hands-on projects in Energy and Environmental Technology Programme.	2	1	2	1	1	1	**1,3**
In Energy and Environmental Technology Programme there should be more training of various technical tools.	2	2	1	1	2	2	**1,7**
The training was sufficient before and during the installations.	1	1	2	2	1	1	**1,3**
The safety issues were taking care of during the installations.	2	1	3	1	1	1	**1,5**
Total average							**1,4**

Figure 2: The first panel string installed

Figure 3: The “bird’s eye” view of the location

CONCLUSIONS

According to the experience and feedback collected in this hands-on project, it seem obvious that when the students interact with hardware in well planned projects, transition of knowledge really happens: balancing between Theory and Praxis. Real life experiences strengthen the learning: the students can form a strong link between theoretical and practical knowledge and skills. The motivation aspect is also vital: by learning new practical skills the students will be “empowered”. By proper project management the students can achieve incredible performance even though they might have a weak level of prior knowledge.

From the implementation point of view the safety issues had the outmost importance when working with inexperienced students. The safety training and supervision should be in order. The policies and processes should follow the industrial standards as well as possible (simulation of the real life projects). For example the tools should be “state-of-the-art”-quality to avoid extra cuts and scratches and to make the assembly work more effective.

The trigger for this project was a feedback from the students: “we want hands-on projects”. By analyzing the feedback, it seems that we did quite well. The project is already a solid part of the curriculum. With the next projects especially the timetable and communication should be improved. The timetable issue is already partly organized: the project is now two period course instead of one. It has been a privilege to work with the students, who are so motivated and willing to learn.

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DESIGNING A COMPREHENSIVE METHODOLOGY TO INTEGRATE SUSTAINABILITY ISSUES IN CDIO PROJECTS

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ABSTRACT

We present in this study the first steps in the design and implementation of a new methodology that aims to consider systematically the different dimensions of sustainability, including ethical and strategic aspects, attempting to balance all them. The pilot methodology was implemented in the course 2014-15 in the "INGENIA" course, a 12 ECTS compulsory subject taught in the first year of the master in industrial engineering of the Technical University of Madrid. As this is an on-going process, we also introduce some practical guidelines we are currently addressing to the students by means of taking into account various approaches in particular socio-economic contexts or to differentiate specificities by industrial sectors or activity fields. Ultimately, we aim at enabling our INGENIA-CDIO students to raise reflections and assessments about the related impacts of their engineering projects.

KEYWORDS

Sustainability, Social Responsibility, Professional Responsibility, Ethics, Project-based courses. Standards 2, 3, 6, 7, 9, 11

INTRODUCTION

The global agenda of sustainability is increasingly demanding the acquisition of technical skills and the development of specific personal competences of future professionals. Many of the coming new graduates at our Engineering Schools will have to deal to some extent with the recently approved Sustainable Development Goals (United Nations, 2016), which are crucial to transform our world by means of end poverty, protect the planet, and ensure prosperity for all. Everyone has to contribute to reach these goals: governments, the private sector, civil society and, of course, universities.

In this way, the Escuela Técnica Superior de Ingenieros Industriales of the Universidad Politécnica de Madrid (School of Industrial Engineering, Technical University of Madrid. ETSII-UPM hereafter), launched in 2014-15 the new Master's Degree in Industrial

Engineering in which the above outcomes were outlined as one of the main priorities of the overall curricula. Its program includes a new innovative set of project-based courses denominated “INGENIA”, whose name comes from “ingeniar” (to provide ingenious solutions) and “ingeniero” (engineer). All INGENIA courses have an analogous structure; primarily aiming at the acquisition of professional outcomes not only related to sustainability but also with the ability to design, implement and operate engineering systems, as well as creativity, teamwork and communication skills. Every subject is directly linked in essence to the different ETSII-UPM majors.

The teaching-learning strategy adopted fits to CDIO standards, such as the intensive use of supporting software, prototyping technologies and testing facilities at different labs, enabling the instructors to fulfil adequately all the CDIO steps, from the conception and design, to the implementation and operation.

Sustainability is a key aspect that INGENIA students have to carefully take into account throughout the four CDIO steps. In this sense the initiative requires a comprehensive methodology to be systematically used in all the projects, but flexible enough to be adapted and oriented to the specific social, environmental, economic, strategic and ethical aspects of each of them. A literature review shows that these aspects have rarely been integrated in engineering curricula in a holistic and balanced approach. Additionally, the definition of social value and the measurement of social impacts are issues not yet sufficiently clear both in the academic and practical fields.

We therefore present in this study the design and implementation of a new methodology that aims to consider systematically the different dimensions of sustainability, including ethical and strategic aspects, and attempting to balance all them. Ultimately, we aim at enabling our INGENIA-CDIO students to raise reflections and assessments about the related impacts of their engineering projects.

LITERATURE REVIEW

General background

Engineering programs are increasingly recognizing the ability to formulate sustainable solutions as an important goal to ensure in graduate students’ profile. The concept of sustainable development is grounded on the ethical commitment to the wellbeing and enhanced opportunities of contemporary and the future generations (Chua & Cheah, 2013). Therefore, the application of sustainability framework in engineering education requires a better understanding of the ethical concepts and a responsibility approach would ask questions about the “whys” as well as the “hows” (Brodeur, 2013; Chua & Cheah, 2013).

Several authors have discussed the integration of sustainability and ethics in the context of CDIO engineering education (Augusto et al., 2012; Hussmann et al., 2010; Palm & Törnqvist, 2015; Silja et al., 2011; Wedel et al., 2008), and the CDIO Syllabus 2.0 already includes ethical and social responsibility aspects and sustainability criteria for each one of the lifecycle stages (CDIO, 2011). Nevertheless, while many engineering programs state objectives and learning outcomes in these areas, few have developed effective teaching and learning strategies that holistically and systemically address them (Brodeur, 2013).

The most common strategy used is based on the integration of specific sustainable development/ethics (SD/E hereafter) topics in courses whenever it is consider appropriate, or set up separate courses to guarantee that general aspects of SD/E are included (Enelund et al., 2012). However, in order to make the most of the learning of SD/E topics, the context of engineering practices in which the students have to work frequently with open problems in interdisciplinary projects must be prioritized (Chua & Cheah, 2013; Hussmannn et al., 2010; Wedel et al., 2008). In this line, Malheiro et al. (2015) explain an interesting CDIO design-implement experience which includes sustainability and ethical concerns as mandatory topics to be integrated in the project.

This practical approach enables to consider SD/E issues by a systematic exploration of all lifecycle phases. It provides a holistic view needed to avoid environmental bias and to deal with complexity (Cheah, 2014). It also enhances the training of students in other essential skills such as teamwork, communication, creativity and cultural understanding as integral parts of the education (Crawley et al., 2008). Furthermore, several authors point out the fact that integrating ethical assessment, emphatic design, and social and environmental criteria strengthen the final product (Palm & Törnqvist, 2015, Crawley et al., 2008).

Methodologies for integrating SD/E into projects-based courses

The Life Cycle Assessment (LCA) has been found a useful approach to integrate sustainability into CDIO-based engineering courses since it can help to assess environmental issues under a broader scope and substantially minimize environmental impacts (Jeswiet et al., 2005).

LCA is a “cradle-to-grave” approach for assessing industrial systems. “Cradle-to-grave” begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. The life cycle assessment methodology has been vastly used for the design and environmental evaluation of industrial process and products during the last two decades (Curran, 1996) and it is supported by well established procedures and thoroughly documented guidelines such as the standards ISO14040 or ISO14044.

Enelund et al. (2012) present a successful CDIO experience of using LCA in a Sustainable Product Development course. It begins with general treatment of the environment and sustainable development focusing on global issues. Analytical tools such as LCA and multi criterion analysis are introduced to help determine the effect that products and processes have on the environment. In other project courses the students have to consider also social impacts, such as safety concerns, and to apply models that stress the value of all potential customers for the whole lifecycle of the product (Wedel, 2008; Enelund et al., 2012).

The primary focus of LCA methodology was limited to assess the impacts that a product or process will have on the environment. However, since 2006 and after 30 years of development of those methods, the endeavors strove towards expanding the scope of life cycle thinking to become a comprehensive assessment tool for sustainability, which involved incorporating the three dimensions of sustainable development (planet, people, profit), also known as the triple bottom line (Elkington, 1997). Hence, together with the already well-established methods of E-LCA (environmental life cycle assessment) and LCC (life cycle costing), the need emerged for a new commonly accepted methodology for evaluating a product or process from the “people” perspective, using social indicators. The bases for this complementary methodology to E-LCA, the so-called Social Life Cycle Analysis (S-LCA), were recently launched by Benoît & Mazijn (2009) and later on complemented by Benoît-Norris et al. (2013).

In S-LCA, the social impacts of a good, service or process are assessed using a life cycle perspective and in relation to different groups of stakeholders. For each stakeholder category there is a number of associated impact categories intended to identify social "hotspots" in the life cycle of the product, service or process.

S-LCA is not the only methodology for evaluating the social dimension of sustainability. Other methods and approaches have been developed in last few years for this purpose. Most of them include standards and certifications such as SA8000, OSHAS18001 or AA1000 series, or reporting guidelines like the Global Reporting Initiative (GRI) guidelines, which also adopt a stakeholder perspective for evaluating social impacts. Nonetheless, among the wide variety of tools for assessing the social footprint of a product or process, S-LCA is perhaps the methodology that better grasps a systemic life-cycle perspective in the evaluation.

However, it should be noted that the maturity of S-LCA and other social impact assessment tools is still in its infancy when compared with the well-established procedures and thoroughly documented guidelines of E-LCA. There is a long roadmap to be covered for reaching a common ground on the accounting for the social dimension of sustainability.

Finally, some other structured methodologies to incorporate ethics into projects should be mentioned, like the Value-Sensitive Design (Cummings, 2006) or diverse proposals from the ethical assessment of technology (Brey, 2012; Palm & Hansson, 2006; Wright, 2011; Palm & Törnqvist, 2015). All of them provide practical tools to be used in project courses by means of checklists to identify ethical issues, and sets of questions that must be answered when assessing the ethical aspects of the real cases.

We have found in summary a need to develop a holistic, well-established methodology that enables our INGENIA students to properly integrate the environmental, social, economic, strategic and ethical aspects of sustainability into their engineering projects.

DESIGN OF THE EXPERIENCE

INGENIA courses and non-technical skills

INGENIA students experience the complete development and implementation process of a complex product or system (Lumbreras et al., 2015). They choose among different kinds of subjects (and projects), that cover most of the engineering majors at ETSII – UPM, as shown in Table 1.

These subjects are 12 European Credit Transfer System (ECTS) equivalent, which correspond to a student workload between 300 to 360 hours, distributed along two semesters with the following structure: 120 hours of class work plus 180-240 hours of personal student work usually organized in teamwork. Class work of the subjects is structured in three modules:

- Module A (Technical): 30 hours dedicated to adapt basic theoretical knowledge derived from other subjects to those directly related with the project, and a second set of 60 hours is devoted to practical work in the lab, with professor supervised sessions.
- Module B (Transversal skills): 15 hours for workshops on teamwork, communication and creativity skills and techniques.
- Module C (Sustainability): 15h for lectures and workshops about social responsibility issues such as environmental and social impact, ethics and professional responsibility, health & safety, intellectual property, etc.

These lectures, practical sessions, seminars and workshops, are distributed along the 28 weeks of the two semesters of the first year, resulting in 5 hours per week of lectures or practical sessions in the regular schedule of students. The relation of each module with the CDIO Syllabus can be seen in Figure 1.

Table 1. INGENIA subjects' description

Different INGENIA Subjects	**Product / system developed & objective**
Formula Student	Students take part in the complete development project of a competition car, from the conceptual design, to the final competition.
Machine development projects	Students live the whole process of creating an innovative machine, from the conceptual design stage, to the final trials with real prototypes, searching for design improvements.
Everyday life products / household goods	Students live the whole process of designing innovative products, from the concept step, to final simulations and trials with prototypes.
Smart systems engineering	Students experience the process of designing a smart system, using state-of-the-art engineering resources and taking account of the whole life-cycle. (A set of co-operative drones in current year).
Electronic devices	Students live the whole process of creating a new electronic product, oriented to improving everyday life in our ETSII-UPM, from the concept, to the prototyping stage and trials.
Industrial Construction projects	Students experiment with information management and project planning resources applied to a real industrial construction project (A beer-factory in current academic year).
Electricity supply networks	Students live the development project of an electricity supply network, from an initial renewable energy source to population.
Biomedical engineering design	Students experience the process of creating an innovative medical device, from the conceptual stage, to the final trials with prototypes.

The module C of INGENIA courses focuses on the ABET's learning outcomes (f) - an understanding of professional and ethical responsibility - , (h) - the broad education necessary to understand the impact of engineering solutions in a global, economic, societal and environmental context -, and (c) - an ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability -. They are strongly correlated with several items of the CDIO Syllabus, as the Figure 1 shows.

	INGENIA learning outcomes		
CDIO Syllabus 2.0	Module A (Technical) ABET (b) (c)	Module B (Skills) ABET (d) (g) + Creativity	Module C (Sustainability) ABET(c) (f) (h)
2.2 Experimentation, Investigation and Knowledge Discovery			
2.3 System Thinking			
2.4.3 Creative Thinking			
2.5 Ethics, Equity and Other Responsibilities			
3.1 Teamwork			
3.2 Communications			
4.1 External, Societal and Environmental Context			
4.2 Enterprise and Business Context			
4.3 Conceiving, Systems Engineering and Management			
Environmental needs. Ethical, social, environmental, legal and regulatory influences. Risks and alternatives			
4.4 Designing			
4.4.6 Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives			
4.5 Implementing			
4.5.1 Designing a Sustainable Implementation Process.			
4.6 Operating			
4.6.1 Designing and Optimizing Sustainable and Safe Operations			

	Strong correlation, according to CDIO-ABET correlation (CDIO, 2011)
	Good correlation, according to CDIO-ABET correlation (CDIO, 2011)
	Strong correlation (own criterion)

Figure 1. INGENIA learning outcomes correlated with CDIO Syllabus 2.0.

Conceptual model

In the designing process of our methodology adapted, we have consider first the three classical dimensions of sustainability (economic, environmental and social), emphasizing the essential fact that these dimensions have to be deeply grounded on the ethical and professional responsibility issues that may be relevant to each specific project (Figure 2).

After this, we added in our conceptual model a strategic dimension that must always be considered in every phase of the project, by means of identifying its basic “why”, their main differentiation characteristics or how the long-term shared-value creation will be created in its development. These aspects cannot be studied separately, that’s why our framework also includes the relationships with the different stakeholders that may be affected by the technology/service/artefact developed in the project. These are in essence the foundations of our methodology, characterised in the next Figure 2.

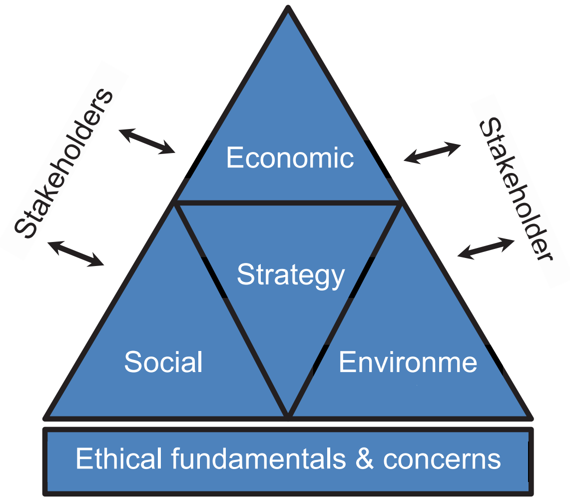

Figure 2. Framework for integrating sustainability and ethics in the INGENIA subjects.

Practical implementation

At the beginning of the course, an opening lecture was given to all the INGENIA courses' students together. We introduced for the first time our conceptual framework (Figure 2), revised the concept of sustainability and the principles of engineering ethics, and presented briefly some categories of both social and environmental impacts. Throughout the two semesters, different workshops and tutorials (12 hours) for each INGENIA course were scheduled. Two faculty members worked closely with the students with the specific objective of integrating all the sustainability aspects into their project.

Key guidelines for dealing with this holistic integration were developed. Inspired by the Value-Sensitive Design method and other experiences mentioned in the literature review, we established four phases to carry out the works: identification of possible impacts, analysis and selection of the relevant issues, the technical phase, and a final reflection.

In the first phase, all the possible ethical, social and environmental issues or impacts related to the project should be identified. Previously, the description of the technological sector in which the project is framed in and its organizational specificities have to be outlined. After this, the students are required to scrutinize the intended and potential unintended social and environmental consequences of the project, and the possible ethical concerns. They have to consider the whole lifecycle and all the stakeholders that could be affected. For supporting impacts' identification, a checklist methodology is proposed and the students are provided with several lists for different dimensions. They have been adapted from several resources from the ethical (Brey, 2012; Wright, 2011), social (GRI; ISO26000; UNEP, 2009) and environmental fields (ISO14000 and LCA). The goal of this first phase is not to make an exhaustive list but to make sure that major impacts will not go unnoticed.

In the second phase, students have to select the most relevant issues to their project from the ones identified in the previous step, and analyze them in depth. Different methodologies are proposed for environmental and social analysis.

For the environmental analysis the general LCA methodology is proposed. However, given the complexity of the projects and the variety of targeted outcomes, the LCA methodology has been simplified and adapted to each specific technical skills on product or system to support a better design building on previous knowledge and specific environmental assessment provided by other subjects within the curricula (Borge et al., 2011). Although the environmental assessment made by the students if far from exhaustive, the setting of system boundaries and reflection on the relevant inputs and outputs supports a systemic and comprehensive analysis of the product, process or service at hand.

In the case of social impact, we proposed a selection of impacts to be analyzed taking into account the consequences of its impact, ease of further analysis or the capacity to influence them. The students are asked to accomplish the following tasks: making a detailed description of the impacts selected; identifying stakeholders and how they are affected; identifying regulations, laws, ethical codes related to them; and pondering on the possibilities of an assessment or quantitative evaluation of the impact.

The third phase is aimed at quantifying and measuring the impacts selected in the previous phase. When possible, the students will test the product, studying the interactions with potential users or affected groups, so as to contrast the expected impacts or to identify new ones. Since this phase depends so much on the nature of the project, and bearing in mind the constraints of the INGENIA courses' academic context, we let this phase as optional.

The last phase is a final reflection. The teams have to produce as deliverable a report which structure is provided beforehand. This report must include the identification, description and analysis of the most significant social, environmental and ethical issues of the project carried out. Two different sections are asked for social impact and environmental impact. Moreover, it has to show how the project has been influenced by this analysis. It should highlight how the risks and negative impacts have been minimized or avoided, how the positive ones have been enhanced, as well as the overall coherence of the project with professional responsibility. This report is evaluated by the instructors and it represents 12,5% of the final score of the INGENIA course.

RESULTS

The experience developed during the course 2014-15 has been analyzed from two perspectives: the overall teaching methodology and the progress of the students in sustainability skills. Qualitative information and quantitative data was gathered not only from the final report described in the last phase of the methodology, but from pre and post questionnaires and specific open questions provided to them.

When asked for the most positive aspects of the experience, students highlighted that they have become more aware about sustainability as an important and key part of the engineering work, expanding their global vision of their future profession. Besides, they emphasized the usefulness of the learning acquired in this module. The questionnaires also showed that the bias towards environmental awareness observed in the initial evaluation had diminished. The greatest improvements were in the knowledge of social impact - particularly negative social impact-, in the self-perceived ability to analyze social impact and the capacity to enhance the positive impacts of an engineering project.

The best valued aspects by the students were the attention given by the C module's teachers and the teaching methodology. However, they also collected interesting suggestions for improvement. As teachers, more support and feedback are requested, as well as more coordination with the technical A module' faculty. The students ask for more clear guidelines and methodologies that allow them to focus on the particular sustainability issues of their project.

Regarding the negative aspects, students considered that the opening lecture is too theoretical and not very useful for the course. The asked also for improving the supporting documentation –providing examples of sustainability analysis of engineering projects – and for reconsidering the workload. All these suggestions have been very helpful to improve the experience during the current 2015-16 academic course.

DISCUSSION, CONCLUSSION AND FURTHER RESEARCH

The conceptual framework we present comes from the need to jointly work with the multi-dimensional, relevant aspects of sustainability. In the learning process it is crucial for example, to remark what is social value and social impact, its dependency on the environmental and socio-economic context and the identification of which are the relevant issues in different domains or activity fields. Alongside, students need support from the instructors in order to strengthen their strategic vision, classify stakeholders' needs or quantify impacts. These tasks are particularly challenging in projects where these aspects don't appear to be very evident (for example software projects, development of domotic gadgets,..).

The analysis of social impacts needs an adaptation of the social footprint methodologies to the CDIO context, as well as designing evaluation criteria and rubrics. We need in this sense a clear but flexible enough framework to integrate this diversity. It is important therefore to minimize the number of key ideas to be transmitted to the students.

In regard with the analysis of environmental impacts, further work is needed to define a more general framework to apply the main principles to any device or system with a similar detail, making it easier to guarantee that environmental issues are intimately integrated in the process and reflected in the prototype design.

After two years of experience in the design of this particular methodology, we can conclude from this on-going process that our conceptual/practical approach is well suited to the teaching and learning requirements that the sustainability agenda demands from the future engineers, obtaining satisfactory results from various perspectives.

Nevertheless, we have some key challenges to address, i.e. to get a common vision of sustainability in the faculty members who teach the subject, and to involve the rest of INGENIA professors by sharing this approach.

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APPROACHING WORK INTEGRATED LEARNING THROUGH LEARNING OUTCOMES AND EVALUATIONS

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ABSTRACT

The core of CDIO addresses criticism from engineering industry according engineering education having too much focus on theoretical training. Here, practice, and especially integrating theory and practice, has had a peripheral role implying students not being well enough prepared for the complexity of industry's real world problems and solutions. CDIO aims to meet that criticism through especially illuminating on project based educational forms, where sections of the, so called, CDIO Syllabus point out desired knowledge and skills that are needed to fulfil complex enough projects in engineering education. That approach not only prepares students in appropriate ways for the benefits of industry, but also increases their value of being employable. CDIO does not explicitly point out industry close work placement in education, neither in the CDIO syllabus, nor in the CDIO Standards. Still, many universities strive after work integrated learning, in purposes of, e.g., employability, and real world preparation. Experiences show problems in work integrated learning due to several reasons, such as, establishing sustainable academy–industry contacts, strategies for project ownership and IPR (Intellectual Property Rights), and guarantees according fulfillment of academic requirements on learning outcomes.

The concept of Demola relates to a platform for collaborations between academy and industry with focus on multi-disciplinary student projects. Especially, focus is on innovation, where industry may experiment with new ideas at low cost. Demola has proved itself to be a successful approach, with developed templates for student-industry contracts, and process models. Still, to be an attractive choice for work integrated learning, the Demola approach also has to be clear with respect to academic contexts of courses' learning outcomes, and course evaluations.

The aim of this contribution is to point out a set of learning outcomes in a purpose of clarifying on such set being an inherent part of Demola. That set, which is based on CDIO Syllabus, shall map towards a tool for evaluations, where the two-dimensional multi-valued tool ZEFsurvey, is chosen. Overviews, case studies, and discussions will be provided, where one purpose is to point out the adaptability of Demola in an international context.

KEYWORDS

University-Industry cooperation, project based work, work integrated learning, CDIO learning outcomes, course evaluation, Standards: 1, 2, 7, 8.

INTRODUCTION

By work integrated learning (WIL) we often mean educational forms, especially projects, where industrial participants are more or less involved in the students' work. Typically, the industrial participants stand for problem statements, guidance and feedback, and being receivers of project results. WIL relates well to Integrated Learning Experiences (CDIO Standard 7), and Active Learning (Standard 8), to students' employability, and to the core of CDIO concerning industry-oriented training. Obviously, academia is gained by including WIL in educational programs. Still, experiences show resistance towards that, probably due to several reasons, including difficulties in establishing sustainable structures for industry contacts, uncertainties according ownership of project work, and lack of academic control of required learning outcomes (LO) and course evaluations.

Demola is a collaborative open innovation platform for students, universities and companies, and has been elected the best cross-border and cross-sector innovator in the Baltic Sea Region (Vinnova, 2012). Here, agreements between universities, students, and companies are based on well-established contracts where aspects, such as project ownership, are handled. Concepts of Demola include structures for process models, and interactions between students and companies. Amongst the responsibilities of the local Demola organization lies establishing sustainable structures for regional companies and universities to cooperate, where multi-disciplinary student teams develop innovative industry-oriented prototypes.

It seems that Demola clarifies several points of uncertainties related to WIL, and thus may work well as a platform for this. Further unclear aspects relate to universities' demands on obligations concerning LO and course evaluations. Therefore, the Demola concept needs to be extended in appropriate ways to live up to such demands. In order to be flexible, and work well in different national contexts, Demola should be gained by being correlated to a worldwide meta-level educational framework, rather than more restricted national frameworks. Here, CDIO, with its Syllabus, may serve as a fundament for that meta-level framework. Still, while being independent of national obligations, CDIO has been proven to correspond well to several national frameworks (Crawley et. al., 2013), that strengthens the choice of CDIO as a supportive model to Demola even more. Moreover, ZEFsurvey (ZEF, 2016) is an advanced tool for making two dimensional, multi-valued surveys, where activities are ongoing in order to use ZEFsurvey as an inherent part of Demola course evaluations. To further serve as a valuable foundation for WIL, a well-defined set of the CDIO Syllabus LO should be chosen, where those should be appropriately matched by the ZEFsurvey. 2D multi-valued surveys implies that the survey answers shall be reflected and given in a matrix where the x- and y-axes correspond to two different scales, i.e.: importance (from less important to more important) and acknowledgement (from disagree to agree) etc. As opposed to 1D surveys, where the participants shall answer by choosing one value on a scale, i.e. between 0 and 10, or 1 and 7 etc., the answers in 2D surveys focuses on the relation between the two scales when placing an answer on the matrix. Moreover, as the 2D ZEFsurveys focus on the relation between two scales, the absolute values of the survey are normalized using z-scoring (briefly described later) algorithm (Selkälä, et al., 2011). Figure 1 below shows an example of a ZEFsurvey result on 2D multi-valued matrix.

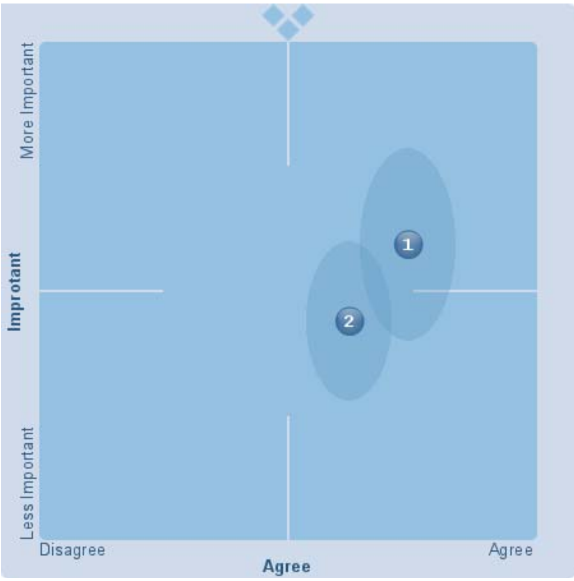


Figure 1. Example of ZEFsurvey result on 2D multi-valued matrix with two statements

Currently, activities are ongoing to integrate ZEFsurvey as an inherent part of Demola. So far the use of ZEFsurvey in contexts of Demola has shown promising results.

We have earlier experienced Demola projects and their reflected LO (Einarson, Wendin, & Saplacan, 2015). The aim of this contribution is to propose a set of LO from CDIO Syllabus to be integrated as an inherent part of Demola, and map that set to the ZEFsurvey-tool. Discussions will furthermore be provided to show that the choice of CDIO Syllabus as a reference framework, will increase the adaptability of Demola in national, as well as, international contexts.

APPROACH

In this paper, two main parameters that stand at the basis of our suggested LO for Demola projects have been chosen: CDIO Syllabus, and LO reflected by Demola. Each of those are briefly described below. The reflected LO are later considered as a result of a case study. The motivation of this contribution lies in the fact that university educational programs are dependent on national regulation systems, here exemplified through the Swedish Higher Education Ordinance, where LO, as well as course evaluations should be considered.

On Swedish Higher Education Ordinance

The Swedish educational system is regulated by law through the Swedish Higher Education Ordinance, where the Swedish Higher Education Authority has the main responsibility of supervising the Swedish higher education institutions (UKÄ). Among other things the Ordinance regulates the intended learning outcomes for a certain educational program, as shown in (UHR, Annex 2) and enforces requirements on course evaluations, as pointed out at (UHR, Annex 2). In contexts of WIL, experiences show conflicts between industry close practical training and scientific ambitions of academia. Here, Kristianstad University (home university of two of the authors) introduces the concept of *research based work placement* to especially emphasize that practical training should be clearly based on academic principles.

With this in mind, the need for academic influences on LO and evaluations, as well as supervision and examination is obvious.

On CDIO Syllabus

According (UHR, Chapter 1) *Higher education institutions shall enable students who are participating in or have completed a course to express their experiences of and views on the course through a course evaluation to be organised by the higher education institution*. This may typically be implemented through course surveys, where state of course is investigated, as well as how well course LO are met. Hence, WIL projects of Swedish educational programs, e.g., Demola projects, also have those obligations. However, due to the concept of Demola being an international approach, this should be gained by having an international approach to LO. Here CDIO with its developed Syllabus may be an appropriate choice, especially since it has been shown that the CDIO Syllabus corresponds well to several national educational frameworks for LO (Crawley et. al., 2013). From (Crawley et. al., 2013) comparisons between CDIO Syllabus Level 2, and ABET of USA, and CEAB of Canada are made, and corresponding comparison with engineering education of Sweden is outlined. Moreover, (Crawley et. al., 2013) states that version 2.0 of CDIO Syllabus has been modified to meet national accreditation boards. This even more motivates CDIO as a meta-level reference system for educational frameworks at an international level, which in turn points out the potentials in using CDIO as a reference system also in contexts of Demola.

Still, as previously has been stated, earlier attempts to use CDIO Syllabus LO in contexts of Demola projects, have shown the need for a more focused approach on this. First, a clearer LO subset needs to be pointed out. Then, experiences show difficulties in students' understanding of CDIO Syllabus based LO, pointing out the need of challenging the students with a process of developing an awareness of a meaning behind such LO. A conclusion is therefore that the approach should include:

1. A focused subset of CDIO Syllabus-based LO
2. A plan to develop a deeper understanding of that subset for the students
3. Matching that subset against an evaluation tool, in this case the ZEFsurvey

According point 1 and point 2, a subset is first chosen at the CDIO Syllabus Levels 1-2. Rather than performing course surveys at the end of a course, it will be initiated quite early. During the course there will all in all be two course surveys, preferably three. At the second appointment the survey will be based on CDIO Syllabus Levels 3-4.

On reflected LO from previous Demola project

The reflected LO from the previous experiment are listed below according to the observations from (Einarson, Wendin, & Saplacan, 2015):

- CDIO Syllabus Section 2: 2.1.1 Problem Formulation and Identification, 2.1.2 Modelling, 2.3.1 Thinking Holistically, 2.4 Attitudes, Thoughts and Learning
- CDIO Syllabus Section 3: 3.1.1 Forming Effective Teams, 3.1.2 Team Operation, 3.1.3 Team Growth and Evolution, 3.1.5 Technical and Multidisciplinary Teaming
- CDIO Syllabus Section 4: 4.3 Conceiving, 4.3.1 Understanding Needs and Setting Goals, 4.3.2 Defining Function, Concept and Architecture, 4.4 Designing, 4.5 Implementing

Case Study

Presentation of the Context

To isolate the experiment an introductory level non-Demola course has been chosen, still with close enough process and project structures. The project assignment was chosen by the course instructors: to build a small robot and an algorithm that shall make the robot follow a pre-defined path in a minimum amount of time. However, it would not be known in advance in which way the robot shall follow the path: how many times to stop or turn. The students were divided into teams, each of three students. The students were required to form groups by themselves, without the intervention of course instructors.

In the next section we explain how we designed the evaluation of the experiment.

Experiment Design

The students have been given a very brief introduction of what CDIO is during their first lecture of the Introductory Course with Engineering Methodology. The experiment was divided into two parts: a pre-study evaluation and a final evaluation. Each of them are described next.

1. <u>A Pre-Study Evaluation:</u>

The set of questions was divided into three main categories:

- Intro-questions:
    - ➢ Have you heard about CDIO? (Yes/No question)
    - ➢ What do you know about CDIO? (open question)
    - ➢ What does it mean for you Conceive-Design-Implement-Operate (CDIO)? (open question)
- CDIO-related questions: (open questions)
    - ➢ Problem solving as such, is a typical core activity of system development. In what ways do you expect the course project to further develop your problem solving skills? **(2.1 Analytic reasoning and problem solving)**
    - ➢ Working in projects often mean that you are exposed to situations requiring new knowledge and experiences.
      What are you prepared to do, to meet the required knowledge that you still don't have, to fulfill your part of the project? **(2.2 Experimentation, investigation and knowledge discovery)**
    - ➢ Successfully working in software projects do not only require technical skills, but also reasonable ways in how you regard the working process. What are your thoughts according attitudes needed amongst project group members to fulfill a project? **(2.4 Attitudes, thought and learning)**
    - ➢ The more complex the project is, the significant is the teamwork. Elaborate on your view on teamwork. What should be especially regarded? **(3.1 Teamwork)**
    - ➢ The more complex the project is, the significant is the communication amongst the project group members. What are your thoughts on communicating matters of projects? **(3.2 Communications)**
- Expectations and goals (Mostly positive/Mostly negative scale question)
    - ➢ How is your attitude towards the project?
    - ➢ How do you feel about working in a team of 3 people?
    - ➢ Do you think this course will be relevant for your future courses in your education program?

The table below shows how some of the CDIO syllabus were mapped to the course intended LO.

Table 1. CDIO standard syllabus mapped to course LO

CDIO Syllabus	Course intended LO (CLO)
2.1 Analytic reasoning and problem solving	• be able to search and locate desired information by using computerized and Internet-based search system.
2.2 Experimentation, investigation and knowledge discovery	• be able to search and locate desired information by using computerized and Internet-based search system.
2.4 Attitudes, thought and learning	• be able to make a clear and structured presentation of own work and discuss other students' work • be able to write a report that is correct regarding the form and content
3.1 Teamwork	• be able to work in a small development group in a structured manner
3.2 Communications	• be able to make a clear and structured presentation of own work and discuss other students' work • be able to write a report that is correct regarding the form and content

2. <u>A Final Evaluation:</u>

As earlier specified, the questions on the pre-study were mainly open-questions. Thereby, the answers on the pre-study were given in the form of plain text, rather than using the built-in matrix with 2D multivalued forms. The reason of designing the questions in this way was to get input on the aspects that were most relevant for students, in order to eventually form a 2D multi-valued final survey.

On one hand, we have looked at the answers given by the participants on the *Intro-questions* and *Expectations and goals* from the pre-study and formulated follow-up questions for the final evaluation. The correspondence between the questions asked in the pre-study and the follow-up questions from the final evaluation is shown in the table 2 below.

Table 2. Intro-questions and Expectations and Goals: Pre-study and Final evaluation

Pre-Study Evaluation	Answers of the Pre-study Evaluation	Final evaluation
Intro-questions		
Have you heard about CDIO?	Majority answered they did not hear about CDIO, although a short introduction was provided during the first lecture.	I feel I understand now more about what a CDIO project implies (scale: important/agree)
What do you know about CDIO?	Many answers included words such as: “nothing”, “not much”, “almost nothing”, “nothing yet” Some answers included a short description showing that they knew that it is an international educational framework, and it is meant to bring industry and academia together	
What does it mean for you Conceive-Design-Implement-Operate	Among the named aspects were: raising quality of education, technical and reasoning ability, carrying out work/project, personal and professional skills, ethics, interpersonal skills, teamwork and communication, business, society, design, implementation, operation, from idea to “product”, group work, cross-disciplinary project-based work, and algorithm. Also some acknowledged that they do not know what it means	What does CDIO mean to you? (choose 3 options): framework raising quality of education; technical skills; critical thinking; carrying out project work; personal and professional skills; ethical aspects; interpersonal skills; business; society; prototype or product; group work; cross-disciplinary project based work; algorithm
Expectations and goals		
How is your attitude towards the project How do you feel about working in a team of 3 people? Do you think this course will be relevant for your future courses in your education programme?		I feel I have learned a lot during this project. (scale: important/agree) Did the project meet your expectations and goals? (scale: important/agree) If you would like something to add:

On the other hand, we have formulated follow-up questions regarding the CDIO-syllabus set of questions.

The process of formulating questions for the final evaluation was the following:

1) **Compression**: compressing the answers from the pre-study for each question, either by synthesizing the general idea illustrated in the answers, the ideas that were in contrast to each other, or by citing the students’ answers as originary stated.
2) **Matching**: in the next stage we have matched the compressed answers with the CDIO syllabus. However, here we chose to match the answers to the questions to CDIO syllabus levels 3 and 4, in contrast to levels 1 and 2 that were used to formulate the pre-study evaluation questions.
3) **Designing** the questions and/or statements: finally, after stage 2), it could be noticed that among participants’ answers, some of the answers matched to level 3 and 4 were repeated. Based on the repeated pattern, we have made a selection of 7 questions. The selection implied the following exclusion criteria, such as: if many of the answers covered some specific parts of the syllabus on level 2, then we chose to specifically exclude questions in the final evaluation on that topic, and rather to select parts of syllabus that had the least amount of mentions. Examples on such exclusions are: CDIO syllabus 2.2, 3.3, 4.2, 4.8.

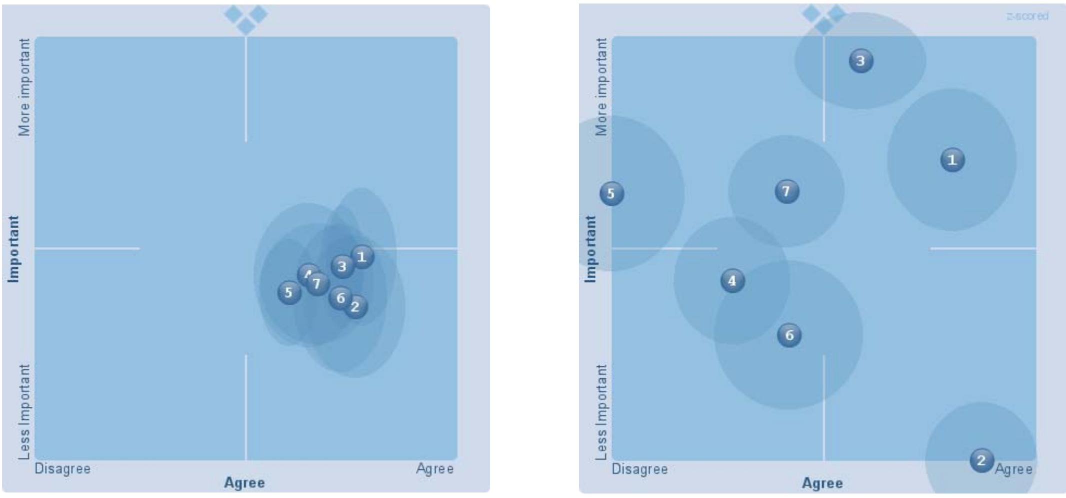
The reason of excluding those was to address also other aspects that were not mentioned by students, but also to increase their awareness concerning those.

Finally, we designed the following set of the CDIO based statements, as a part of the final evaluation:

1. I feel that I have practiced initiative and willingness, to make decisions in face of uncertainty. **(2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty)**
2. I feel that the matter of forming effective teams has been regarded during the project. **(3.1.1 Forming Effective Teams)**
3. I feel that the project has given us opportunities to aspects of communication, such as, inquiry, listening and dialog. **(3.2.7 Inquiry, Listening, Dialog)**
4. I feel that the project has opened up views for me on the impact of engineers on society and the environment. **(4.1.3 Society's Regulation of Engineering)**
5. I feel that I took the group leader role and tried to make use of each of the members' skills and competences in order to achieve the best possible result. **(4.7.5 Building and Leading an Organization and Extended Organization – see its under-levels)**
6. I feel that I made use of time and resources in an efficient way. **(2.4.7 Time and Resource Management)**
7. I feel I discussed with my group mates ethical aspects, integrity principles, and social responsibility when conflict arose in our group work. **(2.5.1 Ethics, Integrity and Social Responsibility)**

RESULTS

Using ZEFsurvey for the Final Survey of our experiment provided us with the insights on the relation between the questions we have asked. Figure 2, shows the values of the answers to the CDIO set of questions from the Final Survey. We can observe here from Figure 2 a, that the overall project experience could be improved with regard to the importance scale, i.e. the majority of the answers to the 7 CDIO questions tending to be viewed as "less important" (right most bottom square). However, these absolute values, and the average of those, do not say too much about the lacks or drawbacks of the project experience, and does not explicitly indicate what shall firstly be improved. ZEFsurvey applies the z-scoring algorithm, such that the values are normalized and *opinion distortion* is removed (Selkälä, et al., 2011). In this way, we can observe that the aspect that was viewed as *least important* for students was 2 *(I feel that the matter of forming effective teams has been regarded during the project. (3.1.1 Forming Effective Teams))*, whereas the aspect which is seen as most important among all is 3 *(I feel that the project has given us opportunities to aspects of communication, such as, inquiry, listening and dialog. (3.2.7 Inquiry, Listening, Dialog))*. 5 *(I feel that I took the group leader role and tried to make use of each of the members' skills and competences in order to achieve the best possible result. (4.7.5 Building and Leading an Organization and Extended Organization – see its under-levels))* seems to be the least regarded aspect, although it is seen as quite important. 1 (*I feel that I have practiced initiative and willingness, to make decisions in face of uncertainty. (2.4.1 Initiative and Willingness to Make Decisions in the Face of Uncertainty)* is the aspect that the majority succeeded mostly with. 4, 6 and 7 can be regarded in the same way.



a. Absolute values b. Normalized values

Figure 2. Absolute and normalized values of the CDIO set of questions from the Final Survey

The chosen set of LO has been based on finding appropriate matches between the CDIO Syllabus, LO from the Swedish Higher Education Ordinance, the reflected LO of the previous Demola project (Einarson, Wendin, & Saplacan, 2015), and the reflected LO of the current experiment.

Proposed Demola LO or project courses LO based on CDIO

1) demonstrate knowledge and understanding in the main field of study **(based on CDIO 1.1)**
2) understand methodologies applicable in the main field of study and demonstrate insights on current research issues, with regard to relevant disciplinary, social and ethical aspects **(based on CDIO 1.2, CDIO 1.3)**
3) demonstrate analytical skills, critical thinking in problem solving, and the ability to work independent **(based on CDIO 2.1)**
4) demonstrate the ability to critically investigate, identify, and formulate a problem, as well as finding solutions to it after gathering information and evaluating it **(based on CDIO 2.2.)**
5) demonstrate the ability to work autonomously in the main field of study within a given time frame, and considering disciplinary, societal, and ethical aspects **(based on CDIO 2.4, CDIO 2.5)**
6) demonstrate the ability to take responsibility and communicate well within- and outside of a team, as well as contributing to the teamwork **(based on CDIO 3.1, CDIO 3.2)**
7) demonstrate the ability to conceive, design, implement and operate a concept or prototype, considering the external, societal and environmental context and the main field of study **(based on CDIO 4.1)**
8) demonstrate project management skills, knowledge about processes, and the ability to identify needs, to formulate and model concepts, and utilize multi-disciplinary knowledge in design, considering sustainability factors **(based on CDIO 4.3, CDIO 4.4 and CDIO 4.5 and reflected LO from both experiments)**

SUMMARY

The main purpose of this contribution has been to propose a set of learning outcomes for the Demola approach to work integrated learning, and map those towards a course evaluation tool. Here, ZEFsurvey has been chosen as an evaluation tool, based on its potential of performing multi-valued analysis. The CDIO Syllabus has here been chosen as a starting point to the set of learning outcomes because of its worldwide meta-level approach, and thus keeping Demola independent of national obligations. Still, to be adaptable into national contexts, a correspondence with the Swedish Higher Education Ordinance has been pointed out. Incentives for choices have been provided, as well as case studies, and results from those. Future work will include further studies of the choice of the set of learning outcomes. Moreover, students' attitudes and insights as further results of evaluations will be investigated.

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BIOGRAPHICAL INFORMATION

Daniel Einarson has a PhD in Computer Science and has several years of experience in teaching Computer Science and Software Engineering. Furthermore, he has been experimenting with several different forms for project based learning. Moreover, with inspiration from the CDIO initiative he will strive after developing the educational forms for Software Engineering even further. He has also been a key contact person between Kristianstad University and the Demola South Sweden team.

Diana Saplacan has an MSc in Embedded Systems and a BSc in Computer Software Development. She has also been involved in participatory (action) research, and teaching experience in Software Engineering courses. Finally, working as a facilitator at Demola has made her gaining experience on innovation processes, project management and student coaching.

Pekka Silven has MSc in Education. He is currently the Head of Demola at Oulu University of Applied Sciences. He has over 15 years of experience in IT-education as a lecturer and international course director. He is a leading Zef expert in evaluation, quality and feedback processes and been an expert member in several international projects and program committees.

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CULTIVATION OF INNOVATIVE ABILITY IN MULTI-LEVEL CDIO WORKSHOPS

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ABSTRACT

As education of student's innovative ability becomes increasingly importance recently, CUIT takes it as one of the significant parts into syllabus design. Currently, the students actually are not strong in promoting their innovative ability. Due to this situation, CUIT has adopted CDIO concept since 2012 by which exerts function of enhancing innovative ability for undergraduate students. Through CDIO workshops, students take part in some projects design and express their own ideas during the process, in which students could experience the process of conceiving, designing, implementing and operating.

There are three levels in CDIO workshops. The first level is basic innovation workshop, which aims at cultivation of creative consciousness for 1st year students. The second level is normal innovation workshop, which aims at training of basic innovation ability for 2nd year students without using specialized knowledge. The third level is specialty innovation workshop, which aims at cultivation of specialty technology ability for 3rd year students, and the works in workshop are closely related to students' majors. In these multi-level workshops, we only provide basic tools, materials and components for students. Students need to design their projects by themselves. There is no limit to the forms of innovation projects, but the projects designed by students must manifest their new ideas or innovative work. The levels of projects are from easy to difficult. In this way, students' creation consciousness and ability are improved step by step. Up to now, there are about 60-70 student teams, about 200 students of photoelectron major have worked in these workshops. The feedback from students is positive.

The motivation of the paper is to describe the practice process, project achievements and effect of innovation ability in CDIO workshop, and to discuss the improvement of future work in CDIO workshop.

KEYWORDS

Innovation ability, CDIO workshop, CDIO practice

INTRODUCTION

CDIO represents Conceive, Design, Implement and Operate. CDIO is one of engineering education models, which offers an alternative educational framework for project-based learning [1, 2]. This education model aims to emphasis engineering fundamentals based on the life cycle of a product. During the life cycle of some products, the students will learn how to solve practical problems and complete projects following the stage of Conceive, Design, Implement and Operate. The CDIO syllabus divides the students' ability into four levels. Those are engineering foundation knowledge, personal ability, team ability and engineering system, respectively [3, 4]. In all these skills and abilities, the innovation consciousness and ability are very important to an engineering student.

However, there is less effort on promoting the innovation ability under present education system. Based on CDIO concept, a series of CDIO workshops are gradually built in Chengdu University of Information Technology (CUIT) since 2012, which aim at training innovation ability of undergraduates. In these CDIO workshops, students do some projects. Through CDIO workshops, students take part in some projects design and express their own ideas during the process, in which students could experience the process of conceiving, designing, implementing and operating.

The motivation of the paper is to describe the practice process, project achievements and effect of innovation ability in CDIO workshop.

MULTI-LEVEL CDIO WORKSHOPS

Innovative practice education is the important guarantee for innovative ability formulation. The innovative practice education is one of the effective ways to build up students' innovation ability. On the other hand, the cultivation of innovation ability becomes increasingly important in now days. To improve the practice ability of students, we built multi-level creative CDIO workshops in our campus since 2012.

These multi-level creative CDIO workshops are designed in three levels. The first level is basic innovation workshop, which aims at cultivation of creation consciousness for 1st year students. In this workshop, students begin to carry out some simple physics or engineering practices, where these practices may be unrelated to their majors. The students analyze and solve engineering problems by using their knowledge of Physics. In this workshop, we mainly concentrate on the originality or improvement in the students' work rather than technical complexity. By this way, the creation consciousness may be strengthened.

The second level is normal innovation workshop, which aims at training of basic innovation ability for 2nd year students without using specialized knowledge. We mainly focus on the thought of "My idea, I do". In this workshop, we only provide basic tools, materials and components for students. Students need to design their projects by themselves. The projects are not restricted to their major. If it is can train the abilities of Conceive, Design, Implement and Operate of students, the project is permitted to be carried out. In the normal innovation workshop, students often experience the whole C-D-I-O process, thus the innovation consciousness and abilities are further trained. There is no limit to the form of innovation project, but the project designed by students must show their own distinctive features.

The third level is specialty innovation workshop, which aims at cultivation of specialty technology ability for 3rd year students. This third level is different from other two, where the work is closely related to students' major. So far, this workshop mainly focuses on photo-electron fields such as photoelectricsensorand control, machine vision and 3D printing. This workshop is equipped with sensors and control module, laser components, machine vision detecting element and 3D printers and other equipment.

The schematic diagram of multi-level CDIO workshops is shown in Figure 1. From first-year of college, the above three workshops are introduced to students at the same time. Students may choose one and more of the three workshops to participate according to their own interests. Actually, the students are strongly encouraged to go through all three workshops. If some students directly involved in the later levels by ignoring the first or second level, they will be asked to participate a test and the teachers will evaluate the performance and skills. They can join directly the higher-level workshop only when the teachers are satisfied with them. For some students, especially those experiencing all three phases, the innovation abilities of students have been greatly improved.

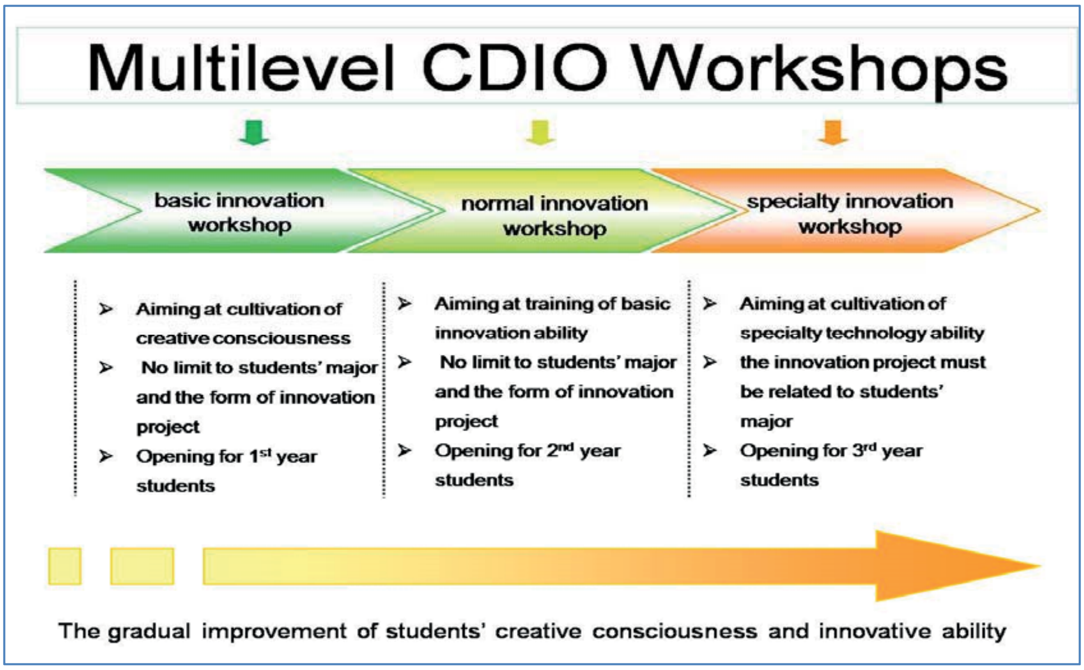

Figure 1.The schematic diagram of multi-level CDIO workshops

IMPLEMENT AND ACHIEVEMENTS IN MULTI-LEVEL CDIO WORKSHOPS

The three-level workshops are open for the students in optoelectron major. In general, one work team includes two or three students and a teacher. At the beginning of their project, the teacher and students will discuss the title, the content, the novelty and the feasibility of the project in details. Then the student needs to submit the application form for their project. During the project, the teacher provides a good direction to the implementation. After the project, the students show the finished work, and write a report of summary and achievements. Each project is limited within five weeks. According to the outcomes of the project and the performance students, the teacher evaluates their works and innovation ability, and gives 2 credits for eligible students.

Figure 2 presents the working scene of students in the basic innovation workshop. We can see that the students carry out circuit tests in the workshop. Figure 3 shows the working scene of students in the normal innovation workshop and the production of one team, which is a wind mill model. Figure 4 gives the working scene of students in the specialty innovation workshop and the students' production named collision-avoiding model. From above three workshops, we can see that the students are glad to participate in these kinds of practice, and their performances are also excellent. They think these practices are helpful to the improvement of their operating, cooperation and innovation ability.

Figure 5 shows the student's works in three different workshops. It can clearly be seen that the student's innovation ability is gradually improved from level one to three. For example, the simple system of sewage disposal was made in basic innovation workshop of figure 5(a) when the student is in the 1st year. After one year, a model of steering engine was produced in normal innovation workshop, shown as figure 5(b). When the student is in the 3rd year, an airplane model is produced by using photoelectric sensor and 3D printing in specialty innovation workshop, shown as figure 5(c). From figures 5(a)-(c), it is obvious that the productions of the student are become more and more complicated. So the students' abilities are trained more effectively when they do different jobs gradually.

Up to now, there are about 60-70 student teams, about 200 students in optoelectron major to work in the workshops. The students like the jobs in workshops. The feedbacks from students are positive.

Figure 2. The working scene of students in basic innovation workshop

Figure 3. The working scene of students in normal innovation workshop and the production of students.

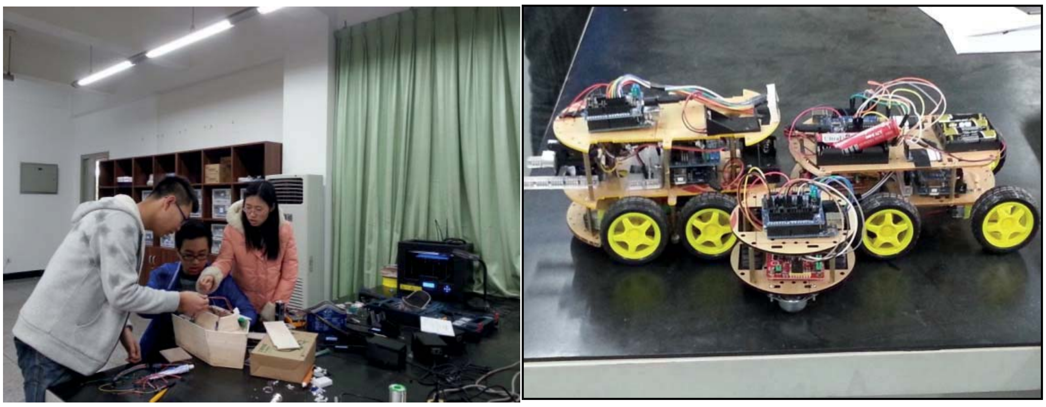

Figure 4. The working scene of students in specialty innovation workshop and the production of students.

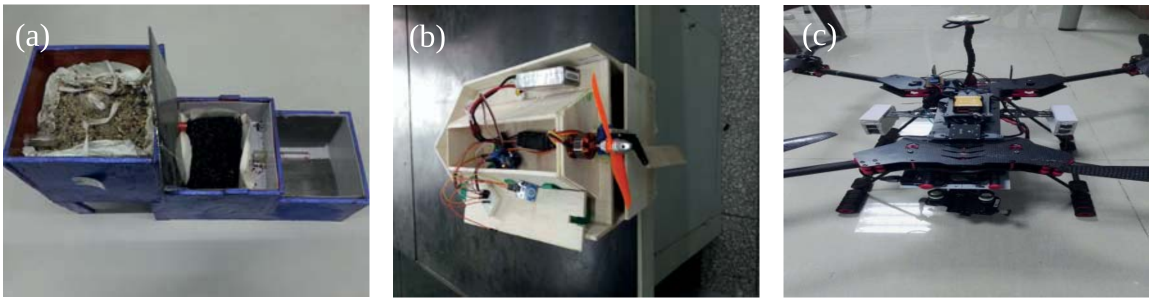

Figure 5.The student’s works from the first level to the third level. (a) A model of a system of sewage disposal; (b) A model of steering engine; (c) An airplane model.

SUMMARY

Multi-level CDIO workshops based on the CDIO conception has been built to improve the students’ operating, cooperation and innovation ability in Chengdu University of Information Technology (CUIT) in the past few years. The CDIO workshops are designed in three levels. They are basic innovation workshop, normal innovation workshop and specialty innovation workshop. In these multi-level workshops, we only provide basic tools, materials and components for students. Students need to design their projects by themselves. There is no constraint to the form of student' project, but the project designed by students must show their new ideas or innovative work. It is believed that multi-level creative CDIO workshop is an effective way to achieve CDIO initiative and standards.

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BIOGRAPHICAL INFORMATION

Min Chen is a Professor in Material Science and a teacher in the Department of Optoelectronic Technology at Chengdu University of Information Technology. She works on topics related to engineering education reform in the department, and focuses on the curriculum design and the improvement of teaching in recent years. She is also the education administrant of Chengdu University of Information Technology. Her current research focuses on implementing of CDIO engineering education model in the University.

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ENHANCING STUDENTS SELF-DIRECTED LEARNING AND MOTIVATION

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ABSTRACT

While mastery of knowledge and technical skills are essential, students must also be motivated and self-directed in order for purposeful engineering applications and innovation to take place. This paper describes an initiative adopted at Singapore Polytechnic (SP) to enhance the motivation of engineering students to be self-directed learners. Using a framework based on the principles of Self Determination Theory (Deci, 1995; Ryan and Deci, 2000) and Tony Wagner's (2012) Creating Innovators, innovative curriculum changes were implemented to enhance the intrinsic motivation and self-determination of learners in the Diploma in Mechatronics and Robotics. .

The curriculum changes, adopted since 2012, were aimed at enhancing the students' intrinsic motivation through meeting their psychological needs of mastery, autonomy, purpose and relatedness (Ryan and Deci, 2000). Implemented into all 3 years of study, the changes focussed on play in the first year, passion in second year and purpose in the third year.

The paper will also share a study conducted to ascertain the impact of the changes in the programme on students' motivation. While qualitative results showed improved students' motivation and engagement in learning, more needs to be done to develop the students' skills for self-directedness and self-determination. The paper will also reflect on the strategies used and suggest improvements for future implementation.

KEYWORDS

Intrinsic Motivation, Self-Determination, Competence, Autonomy

INTRODUCTION

Singapore Polytechnic (SP) recognises that we have a diverse student population with a wide range of interests and abilities. Given this backdrop, SP has developed and put in place a range of initiatives to meet the different learning needs of our students. The Intrinsic Motivation initiative was adopted in 2012 to ***level up less motivated learners*** and to prepare our students better for the Innovation economy.

The definition of *less motivated learners* varies from programme to programme. For example, in some programmes, *less motivated learners* refer to those who lack interest and drive as they do not feel competent in the subjects they are learning. For other programmes, students felt that they were in an unglamorous, sunset industry and hence lacked the motivation to study and underachieved.

To tackle this challenge, SP adapted and piloted an Intrinsic Motivation (IM) framework, based on the works of Edward Deci and Richard Ryan (1995, 2000) and Tony Wagner (2012). The key focus of the framework is to incorporate curriculum activities that encourage competence, relatedness, autonomy, purpose, and the cultivation of a growth mindset (Dweck, 2006).

As learner motivation comes in various shapes and sizes ie not all motivation is the same, lecturers must understand and take into account the nature of student motivation, and not simply the magnitude of motivation, to design effective and engaging learning experiences (Reeve, 1996). Lecturers, hence, must consider the ways in which motivation interacts with and is affected by a wide range of classroom characteristics, such as pedagogical approach, physical environment, teaming and collaboration, and student autonomy.

Together with CDIO and Design Thinking, the Intrinsic Motivation initiative aim to develop the Creative Confidence in students where they have the spirit to *Dare to Do* and *Dare to Think* to be innovative and try new ideas and challenges.

LITERATURE REVIEW

Developing Self-Directed Learners

The main idea in self-determination theory is that of goal internalization, a process whereby individuals actively integrate extrinsic, or externally motivated goals and behavior into intrinsic, or internally motivated goals and behavior. Levels of internalization are described on a continuum with different motivational orientations.

- amotivation, a condition that occurs when learners feel no competence or autonomy, find no value in the learning activity, and expect no desired outcomes.
- intrinsic motivation, a state described by interest, enjoyment, inherent satisfaction, and internalized goals.
- extrinsic motivation, which is initiative and regulation of action that may be prompted by a range of inputs, from external rewards and punishments to an identification of value in the learning activity.

According to the theory, individuals will fully engage in learning when three basic needs are satisfied:

- autonomy, which is the feeling of choice and control;
- relatedness, or the building of social connections; and
- competence, which is the development of a sense of mastery or self-efficacy

Besides, meeting the learners' psychological needs, it is also important that students understand and apply positive beliefs in how they go about their learning.

Students' motivation and learning can also be encouraged through curricula designed to provide learning contexts in which students:

1. can make choices during learning activities and experiment in a playful and less formal context;
2. learn how to master key skills, feel a sense of mastery and develop a passion for the subject;
3. find a sense of personal purpose in their future learning.

As the students journey through the different learning contexts, they recognise that creativity is not the domain of only a chosen few but that with confidence and effort, they too can be creative (Wagner, 2012).

Key to meeting students' psychological needs are the interactions between lecturers and students (Reeve and Jang, 2006). Teacher-student interactions can provide the necessary support system to nurture students' interests, develop important skills and social responsibilities.

IMPLEMENTATION OF THE INTRINSIC MOTIVATION FRAMEWORK IN THE DIPLOMA OF MECHATRONICS AND ROBOTICS

The Diploma of Mechatronics and Robotics (DMRO) adopted the Intrinsic Motivation initiative in 2013. The course chair re-designed the curriculum to include engaging learning activities and interactions that promote the sense of satisfaction, achievement and connectedness, and through which students develop passion and purpose for their discipline.

The Intrinsic Motivation Framework is infused in the curriculum as follows:

- ***i*nspire through Purposeful Play in Year 1**: *i*nspire aims to instil the desire to Be and to Learn in students. Students are given autonomy to learn through play. *Goldilocks tasks* that are neither too easy nor too hard are employed. Activities include experimenting with engineering objects (e.g., building the catapult machine), designing their own products and entering local robotic competitions. The emphasis was on students having both a choice in what they do and experiencing fun in the learning process.

- **Autonomy and Mastery in Year 2**: Students build and develop key skill sets through capstone projects, such as building an autonomous guided vehicle and compete among each other.

- **Possibility and Meaning in Year 3**: Students build upon their foundational knowledge and skills to choose a project of their own interest that has special meaning for them. A learning space is provided within which there are learning spaces for co-creation, facility, play, knowledge and sharing. Relatedness among students, and between staff and students is further strengthened when they work on the final year capstone project.

Feedback from students has been very positive. The students produced very good learning outcomes in the form of several Final Year Projects (FYP) that were selected for public display during the annual SP Engineering Show.

STUDY OF THE INTRINSIC MOTIVATION INITIATIVE IN THE DIPLOMA IN MECHATRONICS AND ROBOTICS

A study of the implementation of the DMRO was embarked in 2015. The aim was to gain a better understanding of the success elements of its implementation and areas that required improvements.

Interview Methodology

We interviewed 16 instructors and students from DMRO. We sought to understand qualitatively what the shared learning experience in DMRO is like for staff and students, and what makes it special. The responses of the interviewees are put together to form a detailed contextual narrative against which the other research results can be interpreted.

Table 1: Details of lecturers and students interviewed.

DMRO Instructors	DMRO Students
• Course chair • Final year (Year 3) level head • Year 2 level head • Lab technician	• 7 Final year students • 3 Year 2 students • 2 Alumni

Going in we knew that DMRO was different from other Engineering courses because of their focus on project work, especially the capstone final year project. The instructors interviewed were selected based on their involvement in the student projects and their high degree of interaction with the students. Likewise, we interviewed mostly final year (Year 3 students) who were going through or had completed their final year projects. They were also in a good position to look back over the past 3 years and comment on the overall experience in DMRO. The students were chosen for a wide range of academic abilities and interest levels in Engineering.

We adopted an ethnographic method to the interviews. The key tool is the use of open-ended prompts to elicit from the participants stories of their prior experiences, which they personally find interesting. This approach is effective at getting respondents to become more receptive to the interview, leading to a richer and more authentic account of what happened than by asking direct, yes or no questions.

We prepared a list of interview questions (Table 2). These acted more as a guide to ensure coverage of issues and would be adjusted in the flow of the conversation.

Table 2: List of interview questions

Questions for staff	Questions for students
• Could you describe the students' journey of growth through your eyes? • How would you describe the students in DMRO? • What was the students' inspiration? • What teaching methods were attempted and how did those work out? • What is important to you as an instructor? • How is it like to teach in DMRO? • What changes do you envisage for the DMRO curriculum in the future?	• What was your life like before SP? • How did you end up in SP, in your course? • Tell us about your experience in your course. • Tell us about the projects that you've done. • Was there something fun or memorable? • What has made you who you are today? • If you could go back in time, what advice would you give yourself?

All participants were assured that their responses would only be used for research purposes and would not be personally identifiable. The interviews ranged from 30 minutes to over 2 hours, and were audio recorded and transcribed.

Each interview transcript was reviewed and cross-referenced against other transcripts. We analysed responses for insights and identified broad themes and issues by clustering related quotes. Three themes, which characterise the success of DMRO, emerged: the quality and nature of relationships between the staff and students, the experiences of the final year project; and the learning environment and culture in the lab.

Along these three themes, the shared learning experience in DMRO is described below through a series of mutually supporting quotes with different voices that builds up to a complete picture. The quotes have been edited for clarity and grammar.

THE SHARED LEARNING EXPERIENCE IN DMRO

Nurturing Caring and Trusting Relationships

From the top down, the course chair and his level heads take the lead to engage the students about their well-being.

> *(The course chair) also really comes down and talks to the student, he finds out what is their problem or whatever, and helps them solve it or whatever … In the evening, after his lesson or what, he will come down and then he will check (on) the students. I think that is important, (to have) care for the students.*
>
> *If you help (the students and) they feel that you are sincere in helping them, then they feel that they also can do their project better.*

The level heads make the effort to be present as often as they can and especially at critical times when the students most desire external guidance.

> *Be prepared to go the extra mile. Definitely much. And one day if (the students) ask you for something and then you say, yeah, I'm going on leave. I'm not contactable. That's it. You lose them.*
>
> *So in the first four weeks (of the semester-long final year project) we try to catch them. That … is normally the time when they are most dependent. You know, they are lost and don't know what to do. We show them the way. Then from there, we start to bond. Yeah. At the moment that they are dependent, if they don't get help, after four weeks, you'll have lost them already.*

And they foster a spirit of easy conversation with the students.

> *I can dare to say that (the Year 2 and Year 3 level heads) are my friends, I treat them as a friend more than a teacher… That means sometimes I need to treat them as a teacher, I need to respect them. But, you know, sometimes when they are free and they start walking around, then we'll start joking around, yeah ... He'll walk around and tease us and make laughter … So it's quite fun also in the process. – Varian*

As a result, the students feel comfortable approaching the course chair and the level heads with their troubles and their needs.

I think the chair, the heads, the teachers, so far have been very good. They guide us … I'm not saying the lecturers, more the heads, the ones that take care of us … So if we got any need, any trouble, we can feedback to them. Then they'll help us … I think (the course chair) took quite good care of everybody over here. That's one of the biggest things.

This builds a trusting relationship between the instructors and the students, and also sets the foundation for DMRO as a safe and desirable place to learn. Without a degree of interpersonal trust, it will be hard to get through to the students to take on even basic responsibilities.

Master and Apprentice Relationship

To open the students up to learning, the project supervisors seek to first establish their credibility and authority. The project supervisors impress on the students that they have useful skills to be imparted. This sets up a relationship similar to that of a master and apprentice.

I'll be there, (guiding them during) fabrication. but we have to show them what can be done. I have to get their trust … If you just talk, you don't show, (the students will say,) "We have to do, but I never see you do right?" (I respond), "Yeah, I can do and I prove that by doing this."

Lead by example. So before you ask (the students) to do it, you must know how to do it. For us, we can and we will.

With credibility in hand, the project supervisors begin by closely directing what the students do.

Nurturing Mastery

The supervisors match the difficulty level of the project to the team's level of ability, to balance the amount of learning by the student with the risk of not completing the project.

We manage their projects. We call it Goldilocks tasks. So for the weaker ones, we advise them to take something simpler. And I think most of them will accept. And the better ones we tell them to pick something more challenging. So (the students) start asking questions, "If I do a challenging project, then is it harder to get A?" So I'll respond to them in this way, "Okay, if you take a simple project, no doubt, you'll get an A. How much do you learn?"… You know, we always ask them to try the more difficult (projects).

Some students are keen to push themselves beyond what the supervisors expect they can reasonably complete. The supervisors have to rein in this enthusiasm while still supporting the students' sense of autonomy.

So this (project) is done by the … very high GPA students. This group actually wanted a more challenging (project) … They want (it to move in the) air, they want land, they want water. So I ask them, "Are you sure?" Because we know what it takes to get there, and we know it cannot be done in 15 weeks. So I said take out the water first, so you do the land … If you finish this, I let you try the water. So they go and try, after 12 weeks they realized cannot be done.

It's important to DMRO that all students finish the projects, to ensure that they gain a sense of accomplishment. To set the projects up for success, the supervisor repeatedly engages each group at the start of the project to level everyone up.

Some of them ask me which group to help. I say, "Whichever group needs the most help." … If this group is struggling, then I will spend more time here. Then after this round, I will see which group is the lowest … In (the case of) project *(work), it's always like that. Some have progressed more, some not. So we always identify the lowest one first. After this one goes up, then the next one becomes lowest.*

We put it very clearly: we don't show favoritism. We don't want to spend all our time on the good ones. The objective is for everyone to finish together

The supervisors ensure that what the students learn during a project is relevant to its success. Students will appreciate the usefulness and purpose of what they're doing.

So all these things are given on a need basis. (The students) need the skill. It's not like during lessons: I'm going to teach you this complex theory and in the future five years down the road, you are going to apply this. But what (the students) see is immediate, that means they need to get these parts, or they need to do this design; immediately, we show. So whatever they learn, they can see the outcome straightaway. So it's like just-in-time training.

Nurturing Independence and Confidence

The supervisors begin to wean the students off their dependence on direct instruction, by not simply giving them the answers each time they ask.

(If) you come to me with a question, I'll give you something back. But don't come to me empty-handed. That means don't come (saying), "how to do this, I don't know how to do this." … That means (the students) must try first. Don't expect people to feed you.

When we need advice for something that we don't really know, we'll ask the lecturer for more knowledge. He'll usually help us to think of the idea, then the rest we'll have to figure it out ourselves to solve the problem.

By giving timely praise in response to good work done, no matter how small, one can increase the students' perception of their competence.

Of course, some encouragement given. Don't undermine this little encouragement, it helps. It helps them a great deal. (No matter) how small the success is. The moment you encourage them, they feel "Oh, actually I can take this up" … You must really mean it and they really have done it. So when they do it, you feel it, you give it to them. It strengthens their (sense of) assurance.

It's common for students to feel uncertain and unsure of themselves and their course of action, when faced with the inherent openness of project work. The students will benefit from continued reassurance.

I say (to the students), "If I don't come and disturb you, or if I don't ask then generally it's okay. Just have more confidence, that's all."

I feel that it cannot work, as in the project won't be out in time. When we first came in, there's only the empty shell there. But (my supervisor) told me, "You don't worry, you take it a step at a time." Then slowly – do, do, do –the whole thing came out. So we must thank him.

Eventually, the students should be able to attain a level of independence as the project work comes to a conclusion.

I (as a project supervisor) really learned how to detach (myself) … We will not touch, only at certain unique situations we'll touch. But in most cases we will let them (try to figure things out), even to a point we have to wait for them to come.

(In the) final year project, you have to be more independent. You have to ask. And then most of the time the teacher will say it's your call, your decision, should you make this longer or shorter.

Building a Culture of Cooperation and Mutual Support

The supervisors don't put all of the responsibility of teaching on themselves; they get help from the students to disseminate knowledge and skills throughout the cohort.

We also use a lot of peer influence, because I cannot handle 40 students at once. So we have this method called cascading influence to a few selected ones. We know that these people can do it more …You won't see it. It's invisible. We are doing it along the way. There won't be meetings …It's like when your parents give you the key, you know, that kind of thing. It can happen anytime.

There's a lot of cross-interaction. So I got this student … when he first started he said he couldn't do something. So he asked, "Hey Ben, come help me do this." … After it finished, now he knows how. He says, "Hey teacher, I need to help this other guy." So it ends up, he is helping another person. This is the way it cascades.

The experience of teaching others raises the students' confidence and begins to build a culture of cooperation and mutual support amongst them.

(The students) are not calculative; (they don't think), "Why must I help them?" They will help each other because they know I will help them. And it's right for them to help others. That's the culture. A lot of the time (they receive help), not from (students) within their group, but from (students from) other groups.

DMRO has a common lab where all students work on their third-year projects. The staff encourage the students – across all three levels – to spend time in the lab, by giving them greater ownership over the space.

So we can leave our stuff here, it's quite convenient. We can leave our bags, like our laptops. We have lockers. So, yeah, it's very convenient, it's very nice. Then it's more homely in a sense when we do our final year projects 'cause we get to see the two classes together in the same course. So we actually see each other, then we can have lunch together.

But let's say maybe (the staff) are not around, we'll ask the students if one of them can stay and check on the lock, to make sure there must be somebody in the lab. It cannot be empty, because there are so many things inside here … So I think making the students responsible also, it feels that they are taking charge of something.

Once students spend a lot of time working alongside each other, the culture of collaboration and sharing spreads easily. The common space creates many opportunities for students to interact with each other and fosters a spirit of progress and momentum for all projects.

Because of this lab, I think almost everyone knows who is who. Then we learn to share, learn to help each other in this whole lab. That's why I say the biggest *part is the lab. It was the lab that brought together all of the three classes in the DMRO, in this lab.*

Let's say those who are new to me, when I first met them, I think we started talking when we are doing fabricating, when we are trying to make stuff… Even though we don't know each other. "Hey, you are doing this a bit wrongly, let me help you with this" or "You should use that, not this." We then start to get to know each other.

CONCLUSION

The Diploma of Mechatronics and Robotics (DMRO) embarked on the Intrinsic Motivation initiation and piloted it for 2 years. It involved curriculum reforms to include design build activities and teacher and student interactions that encouraged play to excite and inspire students; built confidence and autonomy; and provided a sense of purpose and connectedness. The initiative was adopted as students joining the programme generally lacked interest as they did not feel competent in the subjects they were learning.

The interview methodology employed in the study has provided a range of insights into aspects of staff and student relationships relating to the implementation of the intrinsic motivation initiative. For example, the interview data clearly highlights the importance of a caring and trusting relationship between lecturers and students. The experiences of the lecturer-student relationship in turn formed the basis of a master and apprenticeship relationship that helped build the students' mastery and confidence in the subject.
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The importance of a learning space conducive for allowing co-operation and mutual support among students was also highlighted. The DMRO integrated project space provided students with a sense of confidence and belonging as they worked alongside their peers, assisted their less able peers and were inspired by their seniors.

Moving forward, a major consideration in the success of the Intrinsic Motivation initiative will be to ensure the necessary competence of the lecturers involved. They must consider not only the level or amount of motivation but also the nature of students' motivation. Faculty need to be aware of the ways in which motivation interacts with and is affected by a wide range of classroom characteristics, such as pedagogical approach, physical environment, student collaboration and autonomy. More opportunities for faculty development, especially in the area of autonomy supporting teacher behaviours and practices (Reeve and Jang, 2006), will help enhance lecturers' competence to facilitate their students' growth from an amotivated to an intrinsically motivated learner.

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LEARNING BY TEACHING: STUDENT DEVELOPED MATERIAL FOR SELF-DIRECTED STUDIES

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ABSTRACT

The objective of the presented paper is to demonstrate how e-learning course material developed by the students can enhance active learning for self-directed studies outside the classroom in a flipped classroom concept. A method which merges different learning activities such as learning by teaching, video based teaching etc. was developed to improve the students' personal and interpersonal engineering skills in relation to CDIO standards. In an effort to assess the students' satisfaction and practical use of the students' created material, a survey was conducted. Statistics, the students' feedback, and observations show an increase in learning motivation, deepened understanding, and expanded communication skills.

KEYWORDS

Flipping Classroom, Active Learning, CDIO Standard 2 and 8

INTRODUCTION

Motivating students for active learning is a challenge, and theory-loaded engineering courses are no exception. To devise and explain technical problems or presenting complex results to an expert or non-expert so that the listeners can follow and understand the presented problem or solution is in turn also a challenging task to many engineers. The CDIO syllabus 2.0 (Crawley et al., 2011) gives clear guiding principles about what kind of communication skills are required for an engineer and where the focus in teaching should lay. The question is how can we train students to communicate so that they reach their audience? A prior condition for communication in a classroom is that students are actively participating during classes, and not only passive note-takers, which also is the essence of CDIO Standard 8.

Many didactic approaches e.g. learning by teaching, flipped classroom or multimedia teaching have been tested and evaluated in the last decade to facilitate active and hence deep learning. However, the application of these approaches to engineering classes can be challenging due to different boundary conditions and practical limitations, e.g. the available time budget, the number of students, or due to inadequate lab space and equipment.

This paper presents an attempt to adopt the above mentioned approaches and CDIO recommendations to a new introductory course for gas turbine engineering, given to students in their final year of different master's programs, at Linköping University, Sweden. The foundation of our approach is based on the assumption that a student-centered focus, with students actively embedded in the teaching process, improves learning and communication.

LITERATURE STUDY

Teaching engineering students is till this day, with exception of some few courses, often characterized by lecture-based instructions including teacher-centered teaching giving the students little or no room for creativity, communication or self-contained learning. The negative impact on the students learning, when applying this type of teaching, is documented in many studies. Bligh (1998) showed that both psychological and physical performances decrease if not varying the students' stimulation during a lecture. Active student participation during a course reduces the risk that students take on a role of a passive knowledge recipient. The majority of the course participants will most likely favor in their learning when varying class activities. Knight & Wood (2005) showed in their study that *"even a partial shift towards a more interactive and collaborative course format can lead to significant increase in students learning gains"*. When Bonwell & Eison (1991) promoted active learning in their report to the Association for the Study of Higher Education (ASHE) in 1991, they claimed that students should actively do things and think about what they are doing by promoting analysis, synthesis and evaluations. Thereby they acted on suggestions postulated by Bloom's taxonomy of learning domains (Bloom, 1969) which ask teachers and instructors to work actively with their students' mental skills (cognitive), their attitudes (affective), and physical skills (psychomotor) in order to promote higher forms of thinking. Grabinger & Dunlap (1995) stated in their work that *"active learning is based on constructivist values and theories"*. The basic idea of constructivist teaching is that learning occurs as learners are actively participating in a process of constructing meaning and knowledge. An educational technique which includes both active learning and the constructivist philosophy is the idea of the "inverted" or more known as flipped classroom. The basic concept was firstly presented in a paper by Lage et al. (2000) which asserts that if subject matter is outsourced out of the classroom, into e.g. online resources and media, there will be more time available for problem based learning activities during a lecture. The flipping classroom method also combines and employs other learning theories like student centered learning (SCL), which is mainly based on the theoretical work by Piaget (1952) and Vygotsky (1978). Instead of a teacher-centered approach, where the lecturer decides what and how the learner should be taught, SCL aims to shift the focus to a student-centered teaching by enhancing students' self-directed learning and supporting group based activities where cooperative learning is encouraged.

Cooperative learning can be accomplished in many different ways like peer editing, Jigsaw, or by peer-led team learning. However, the heart of all these methods can be traced back to a long known finding that: "by teaching, we learn" Lucius (ca 4 BC - 65 AD). Fiorella and Mayer (2013) studied the hypothesis that learning is enhanced through the act of teaching others. In their experiment they tested if preparing to teach or the entire teaching process including explaining content to others show any benefits in learning or if this could influence the students' attitude to learn. The results of their research showed the fact that to let students prepare content without teaching and explaining it actively is not very useful. However, if students are actively involved in the teaching and explaining process, a better understanding of the content and a deeper learning could be observed.

As mentioned before e-learning outside the classroom takes an important position in the flipped classroom concept. Teaching videos are created and provided online by the course instructor so that students can prepare, review and learn course specific content in their own pace. However, Beach (2012) refers to the problem that students are under these conditions once again only passive consumers and not actively involved in the process of creating knowledge like it is demanded by the definition of active learning. For this reason Engin (2014) suggested to turn the student, by using student produced videos, both into producer and customer and thereby promote active learning.

COURSE STRUCTURE AND LEARNING OUTCOMES

The method presented in this paper was implemented and proved in an introductory course for gas turbine engineering (TMMV12) at Linköping University. The course includes 160 hours of total study time including lectures, labs, assignments and self-study, corresponding to 6 ECTS credits.

The aim of the course is to provide fundamental knowledge and understanding about the functionality of industrial gas turbines and jet engines. Furthermore, different components such as compressors, combustors and turbines, common in all types of turbine engines, are introduced, and fundamental thermodynamic, fluid mechanic and aerodynamic design problems are from an analytical and theoretical perspective discussed for all these parts. Another objective of this course is to promote the students interpersonal skills. These include skills in multidisciplinary teamwork, communication, knowledge discovery, engineering reasoning, and system thinking according to (Crawley et al. 2007) which also correlated to the CDIO Standard 2.

Students which attend the class are mostly mechanical, aeronautical or environmental engineering students in their final year. Approximately half of them are European and international (from all over the world) exchange students. The variety of so many different students and their diverse educational backgrounds are a challenge for every course designer when aiming to offer each student an equal chance to reach the same degree of learning outcome as compared to his class-mates. In addition, many students are often used to more traditional teaching styles, letting them struggle with self-determined and active learning teaching methods like regularly used at Linköping University. Furthermore it is well known and documented (Felder & Silverman, 1988, Biggs, 2001) that students in general receive and process information in many different ways. For this reason, the decision was made to aim for the flipped classroom concept because it offers the necessary flexibility for different student advancement, and involves the students actively in the course and content design.

METHOD

To achieve the above mentioned learning outcomes, groups of ten students were formed and given an assignment in which they prepared and taught an essential topic that typically is not covered extensively in the lectures. The assignment consisted of a written report, creating a problem, and giving a lecture. First the students studied relevant literature concerning the topic, and summarized their gained knowledge in a report. After that, they created problems in which the presented theory was applied. Fiorella and Mayer (2013) have shown that active teaching, by the students, is essential to ensure a high learning outcome. Therefore the idea emerged to let the students teach by producing short videos of max 15 min length. The material created by the students is subsequently collected and uploaded in a student platform called LISAM. This is a learning environment used at Linköping University in which students can collaborate, communicate, and exchange digital course material interactively between each other and with the teacher. The content from the reports is copied to LISAM into a simple Wiki application creating a digital reference book for current and future students. The problems are also uploaded and serve currently as supplementary material for exam preparation or just to delve into a specific topic. LISAM also offers the possibility of having a video channel where the produced teaching videos are uploaded and presented. The equipment for the video production and the necessary video editing software are provided by the Information and Communication Technology studio (ICT) at Linköping University. ICT is a recourse supporting students, teachers and scientists in areas related to information and communication technologies**.**

For all three parts of the assignment the students got very few constrains in order to ensure a high level of creativity. However each group was moderated and supported by teachers and experts during the course to ensure relevant content and educational usefulness. By doing so, it was ensured that the material is understandable, technically correct, and that potential problems (technical or interpersonal), occurring during the assignment, could be caught and solved. For the video production extra support in form of small workshops was offered to ease and reduce the workload to burrows into the story telling, technical equipment, animation, and post-processing. To increase the visual and artistic variety of the videos, the students were encouraged to record their videos not only on-campus but also off-campus by visiting workshops or technical museums.

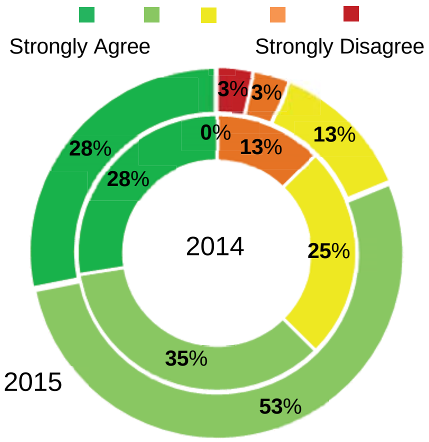
STUDENT PERCEPTIONS AND DISCUSSION

To see how the students reflected about the given assignment and how they worked with the study material produced by their former peers, a survey was given out to each student at the end of the course. In total 70 students completed the survey during the last two years, answering questions using a Likert five point scale or multiple choice answers. In addition, the students had the possibility to write some personal comments to each question.

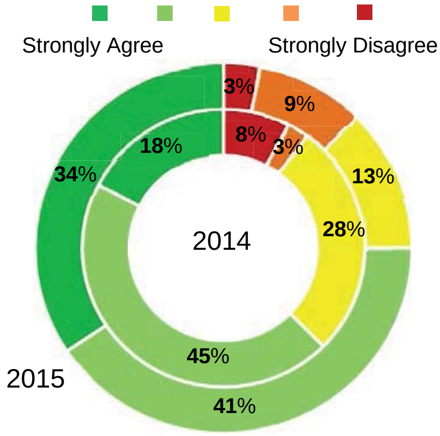
The students' reflections on question 1 indicate that the majority of the students believe that the overall concept of "learning by teaching" favors their learning and understanding of technical content. The diagram also shows that in 2015 the agreement increased, which can be attributed to some changes in the task and group work, based on experiences made in 2014. One of the actions we took in 2015 to improve the learning outcome of this assignment was to introduce the cross-reading of the student developed course material. Because the students only explained a certain component of a gas turbine, they complained that they got experts in only one specific topic. Letting them cross-read the other students' assignments helped them to deepen their knowledge in other gas turbine components, and at the same time reflect about the others' and their own work.

Since motivation is one of the basic requirement for learning (Ngaosuvan, 2004), it was interesting to see if this kind of activity could increase the students' motivation compared to traditional assignments. Most of the students think that learning is promoted by applying the presented method, question 2. The results also show more positive reflections among the students in the subsequent year. The cause for this improvement is most likely the fact that students who attended in 2015 could use and profit from the course material prepared by their former peers for the first time which is an observation from question 7. This probably helped to clarify the basic idea that this teaching method has increased their motivation. Their predecessors in 2014 didn't have access to this supplemental material because they were the first for which this concept was introduced and tested.

When asking the students more in detail what specific parts of the assignment they liked or disliked the results got more differentiated. In general, the students have a positive opinion about the overall setup of the assignment, question 3, however many students took a critical attitude in relation to the video production which they thought was too time demanding. But also writing a technical report, developing a theoretical and practical calculation problem, or to come up with a good pedagogic framework for their teaching seemed to be a challenge for them.



Question 1: The overall concept of teaching a small topic can lead to a better understanding of what you should learn in a technical course like TMMV12.

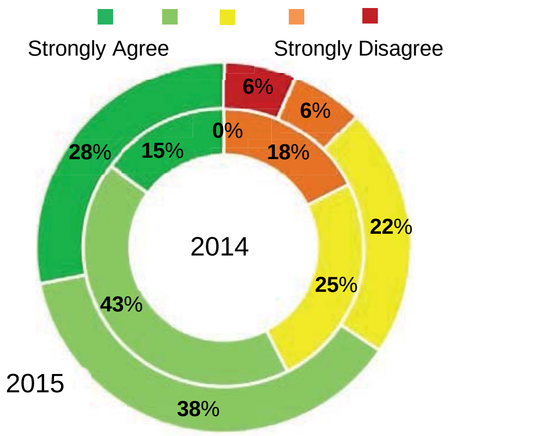


Question 2: This type of assignment motivates me more, compared to ordinary calculation assignments, to go deeper into the course subject.

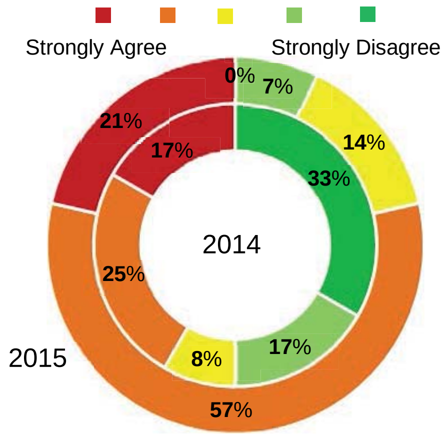
Question 1	Positive	It was easier to understand and memorize the topic because that what you teach you probably don't forget that fast.
	Negative	I prefer traditional classes as I learn more in the lectures. It is possible that you will learn deeper and memorize the content better when doing such assignments, but it’s hard to assess this.
Question 2	Positive	You get to know the content better by doing an assignment like this. With pure calculation assignments you often just use the equations without thinking about them.
	Positive	More fun = more motivation. In order to produce something that get public, you put more effort and drive on it.

When comparing the student’s assessments and comments from 2014, some of the mentioned problems could be segregated and solved in the following year. A major concern of the first students was that each group had clearly defined subgroups (video, problem, report) in which they solved their tasks. However, the problem raised that not all work, needed to solve the assignment, was sheared equally between the group members. The subgroups involved in the video production were not sufficiently embedded in the literature study and the arrangement of the content. For this reason, the students in 2015 were encouraged to share not only the literature survey better between the group members but also to show more flexibility when it comes to "inter-departmental" collaboration. The positive results were clearly noticeable when observing their work in 2015, i.e. less complaints concerning this problem. Furthermore, a higher learning outcome was indicated by 50% more students who “passed with distinction” in the final exam.

Also if the majority in both years agreed that the overall setup of the assignment worked well it was important for us to understand how difficult it was for the students to solve the separate parts of the assignment.



Question 3: The setup of the assignment including creating a report, video, and problem is a good way to learn.

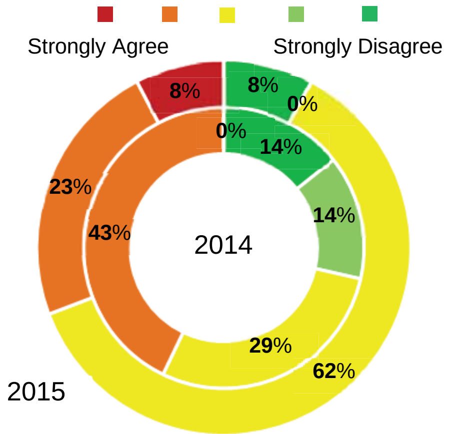


Question 4: It was difficult for your group to create a video.

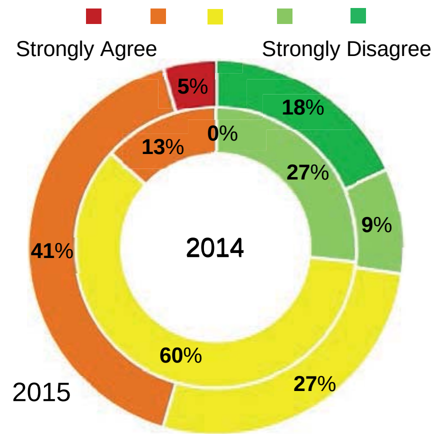
Question 3	Positive	It is a good multidisciplinary approach, great!
	Negative	Creating a video is no help to understand the topic better. I would rather take a book and read it instead of doing this assignment.
Question 4	Positive	Yes, but it was also an interesting experience.
	Negative	The video production and editing took too much of the available time-budget.

Comparing the students’ responses for questions 4-6 highlights that the video generation was the largest challenge for the students. Despite the fact that the students got help in form of small workshops how to prepare and produce a video, they still struggled with that task notably. Comments like: *"time was a major issue", “more equipment was needed”, “or difficult to create good illustrations and animations"* exemplify the problems they faced. However, it seems that not every time this task is equally problematic. The class in 2014 had less problems compared with the following students in 2015. During the course it was observed that more students in the first year of this project had worked with video production earlier and were so probably better prepared.

Compared with the video team the students who worked primarily with the theoretical report and the problem had less difficulties, see questions 5 and 6. However, also here the majority thought that it was not easy to generate good and pedagogical valuable texts or problems. During the team meetings a problem for several groups went to the surface, showing that many of the students seemed to be well trained in solving problems by themselves but to change the perspective and see things from the “learner’s perspective” was quite hard for some of them. However, an important part of teaching is to understand how someone else thinks, approaches a problem, and understands things. Discussing this in small groups or individually helped them to overcome these problems. It was also important to show them the need of the task because many couldn't see a real-world application of the method used in this assignment. Though making them aware of that explaining, introducing, and training people (customers / colleagues) on technical problems or equipment is today a common work task for many engineers too, increased their understanding and motivation. Another observation made during both years was that the students showed difficulties to find necessary literature and material by their own. Some of them googled or used the course book but the available literature in the library for example was hardly used.



Question 5: It was difficult for your group to create a good problem.



Question 6: It was difficult for your group to write a theoretical book chapter.

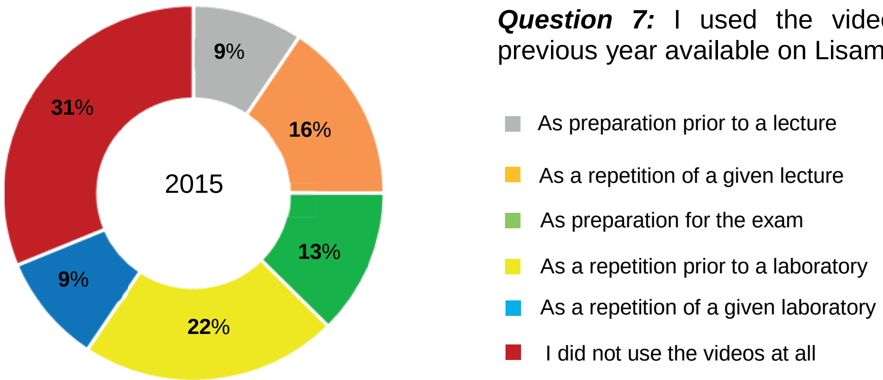
Question 5	Positive	It was difficult but feasible. It was an interesting experience to see how hard it is to create good problems.
	Negative	It is hard especial if you don't have some engine data to create such problems.
Question 6	Positive	I learned that you need a good methodology and focus on the important facts if you want to write a good report.
	Negative	Yes it was, because it was difficult to find good sources.

Another problem they often commented in the assessment was that they often had problems to figure out what information is important for the report. They expected to get clear instruction from the teacher instead of making own decisions what content could be significant for a good understanding, and what could be neglected. A combination of uncertainty to make own decisions and, as previously discussed, the lack of ability to adopt the learner's perspective could be reasons for the large agreement to the question if it was difficult to write the report, question 6.

The above explanations are an attempt to understand why the numbers look like they look. However not all of the student's disagreements can be explained by that. Some of the students mentioned that they would have preferred a more traditional teacher-centered course. Those comments are nothing new in this context, likewise critics and observations were made before when introducing equal or similar teaching methods at other universities and schools Chetcuti et al. (2015) and Triantafyllou et al. (2015). Many students, particularly if they are in final years, are so used to traditional teaching styles, that it is hard for them to adapt to new more active teaching methods. This negative attitude can be faced with clarifications of why this method may be beneficial for their learning.

Another interesting aspect to consider was related to how the students would use their own course material. The students' reflections show that they use their videos mainly as introduction and preparation before upcoming lectures or as repetition of content that was taught earlier in the course, see question 7. About 32% of the students didn't use the videos as supplement material at all. Also the available problems were only used by 50% of the students to some minor extent for their learning. This probably has two reasons: first there wasn't after the first year sufficient content available to create enough interest and second, this

Question 7: I used the videos from the previous year available on Lisam mainly for:



study material was so far only offered as supplementary material. From this year on, the students' generated teaching materials will be integrated more into the course including small examinations about the presented content.

Question 7	Positive	It is a nice way to get introduced to the topic and motivate to go further into it.
	Negative	The videos are interesting but not sufficiently detailed to use them for any kind of preparation.

CONCLUSION

The results of the survey as well as the quality of the student produced content are very encouraging and highlight that the advantages with this method are manifold. The students indicated that these class activities have promoted their creativity and improved their ability in explaining a complex engineering topic in relation to the CDIO Syllabus 2.0. In addition, the presented procedure show that students and teachers are working actively together towards a common aim: to establish deep and wide knowledge by using and creating student developed course material for continuous and individual learning. However, the CDIO Standard 8 asks not only for active learning but also for creating an awareness by the students about what and how they learn. This study shows that when letting students teaching they changed their attitude to learning, increased their motivation and giving their task a meaning: teaching fellow and next generation students.

FUTURE WORK

In the next step of our work the student created material will play an even more central role in the class and laboratory preparation, leaving more space for discussion and other activities during the available class-room time. The produced course-wiki, together with the videos, will deliver interactive and animated theoretical content to the students. To monitor and examine the students learning progress on a regular base during the course, short multiple choice test, using LISAM, will be realized. The questions will be based on the student developed problems generated the years before. With these activities we will take the next step towards the desired goal of a flipped classroom in TMMV12.

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ENHANCING TEACHING SKILLS: A PROFESSIONAL DEVELOPMENT FRAMEWORK FOR LECTURERS

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ABSTRACT

In Singapore, polytechnic lecturers are considered as dual professionals and are expected to be experts of their disciplines as well as possess a deep knowledge of learners and the teaching strategies needed to engage and develop them holistically. Core to a qualified, committed and high quality teaching force is the preparation, induction, and professional development of our lecturers.

Singapore Polytechnic (SP), like most tertiary institutions, offers a range of professional development activities to equip new faculty with essential teaching and learning skills and provide ongoing flexible professional development to further and strengthen necessary pedagogic competencies throughout their career. SP recognizes that lecturers at different points of their teaching careers will have different professional development needs and may require specific re-skilling to respond effectively to new institution and national educational directives.

This paper describes the professional development programmes offered in SP. It also outlines the Lecturer Competency Framework that was jointly developed by 5 Singapore Polytechnics and adopted in SP in 2015. This is comprised of 6 broad competency domains with 11 subsumed competencies, which have been subsequently customized to the institution's context, based on survey data input from a range of SP teaching staff.

KEYWORDS

Professional development, competency framework, Singapore Polytechnic

INTRODUCTION

As professional teachers, our key role is enhancing the learning opportunities and achievement outcomes for the range of learners we teach. Furthermore, as the term professional implies, we must be as current and competent in the most evidence-based knowledge and practices as we can be. Hence, from this basic premise, there can be little argument that professional development must be central to enhancing professional practice, and much is made of the need for lifelong learning in a world of exponential knowledge production and rapidly changing occupational structures.

The core business of educational institutions is ultimately about maximizing student learning opportunities, the student learning experience and student attainment levels. There are many factors that contribute to achieving this, but the quality of teaching (however defined) is the most significant one. For example, Izumi and Evers (2002), from an overview of research on the impact of teachers on student achievement, summarized:

> …nothing is as important to learning as the quality of a student's teacher. The difference between a good teacher and a bad teacher is so great that fifth-grade students who have poor teachers in grades three to five score roughly 50 percentile points below similar groups of students who are fortunate enough to have effective teachers. (ix)

Similarly, at school level, Rowe & Rowe (1993) argued:

> On the basis of our findings to date it could be argued that effective schools are only effective to the extent that they have effective teachers. (p.15)

Petty (2009) fully contextualized the importance of good teachers in real life terms when he wrote:

> Good teachers touch people's lives for ever. If you teach well, some of your students will only succeed because of your excellent teaching. They then might go on to get more advanced qualifications and skills, again just because of your expert teaching. Then they might get a career, indeed a whole life, built on your excellent teaching. No other profession is that consequential and enabling. (v)

In the following sections of this paper, we outline key aspects of the professional development framework in Singapore Polytechnic (SP) and how is has evolved in response to changes in the educational landscape – both in the global and local context. The paper then focuses more specifically on key initiatives targeted towards meeting the diverse competency requirements of the present (and emerging) teaching role (as we frame it) in cost effective evidence-based ways.

FACULTY DEVELOPMENT AT SINGAPORE POLYTECHNIC

SP recognizes that lecturers, at different points of their teaching careers, have different professional development needs and may require specific re-skilling to respond effectively to new institutional and national educational directives. The professional development programmes in SP are, therefore, organized into three broad strands to support:

- the needs of new hires to develop knowledge of their students, how they learn, and what the best pedagogic practices are to support student learning and attainment;
- the on-going deepening of knowledge and skills necessary to implement new school, institutional and/or national initiatives; and
- the development of pedagogic leaders to enhance and innovate best practices in teaching and learning for SP.

Supporting the Needs of New Hires

As a significant number of new academic faculty possess little formal teaching experience, a structured programme for new full time lecturers, the Certificate in Teaching (CT), has been a central feature of professional development at SP. CT participants attend a one-week induction programme, a week-long workshop on integrating ICT in teaching and learning, and various specialised workshops on selected pedagogical topics such as learning design, classroom management and effective assessment practices. At the end of the programme, the participants are required to produce a portfolio of evidence of their work in the course. (see Annex 1 for details of the CT course).

In a recent revision, greater emphasis was placed on developing skills sets that enable our lecturers to:

- Integrate information-communication technologies (ICT) into learning design and teaching
- Develop real work - focused integrated curriculum
- Facilitate active learning
- Use assessment for learning
- Enhance intrinsic motivation in the learning process

Another significant change in our CT programme was a shift from a largely face-to-face workshop delivery mode to a blended one. Content delivery is now mostly online and the face-to-face component focuses on the systematic development of key teaching skills through an Extended Teaching Practicum using a Lesson Study (Stigler & Hiebert (1999) and Supported Experiment Approach (Petty, 2015). This is facilitated by a sustained learning relationship between participants and their supervisors, who provide the necessary mentoring and coaching support when needed.

On-Going Development of Lecturers

After graduating from the CT course, lecturers engage in regular professional development to expand their teaching competencies through a range of specialized workshops. These are standalone programmes in which academic faculty can request and participate in, or workshops specifically tailored to the needs of particular programmes or initiatives. In addition, a range of online workshops are also available on the SP's Learning Management System, BlackBoard (BB).

Teaching and Learning Initiatives

New national and institutional needs and directions often require changes to curricula, teaching and learning strategies and assessment methods. To enable lecturers to adapt and/or innovate existing practices, pilot new approaches and build capabilities, specific training and support of early adopters through small group consultancies are provided. Examples of such initiatives include Design Thinking, CDIO, Holistic Education, Intrinsic Motivation, Facilitation for Learning Express and Flipped Classroom.

Platforms for sharing and learning

Sharing platforms help create a culture of enquiry, evaluation of practices and collaborative learning. Some examples of Communities of Practice (CoP) in SP include the Active Learning Community in the School of Architecture and the Built Environment, the ICT Enabled Learning Community and the Academic Mentors CoP. SP organizes monthly Educational Roundtables and the yearly Excellence in Education and Training Convention (EETC) where lecturers are invited to share best classroom practices and innovative teaching and learning ideas that they are implementing, to the wider SP teaching fraternity.

DEVELOPMENT OF PEDAGOGIC LEADERS

As academic staff progress in their careers, there are a range of specific professional development programmes to prepare them to meet the responsibilities of new roles to which they may be appointed.

Course chairs

Course chairs are responsible for the strategic positioning, management and curriculum design of their courses. Professional development for course chairs takes the form of short workshops and focussed discussions of best practices. The course chair learning community is also a platform for Senior Management to discuss new developments in the education landscape. In addition, course chairs' knowledge and skills in course strategic positioning and curriculum design were enhanced through consultancies with EDU.

Academic Mentor
Academic mentors lead school-based teaching and learning projects and contribute to their school's and SP's wider professional development activities by leading CoPs and cross Polytechnic teaching and learning projects. They are experienced academic faculty who choose the Teaching Career Track. In preparation for this role, they complete a 100-hour blended learning programme aimed at strengthening their abilities to mentor fellow colleagues, and advise them on curriculum design and pedagogy.

Deputy Directors (Programmes)
Deputy Directors provide guidance to course chairs on programme direction and strategy. At the Pedagogy Community meetings, the deputy directors meet once a month to share and appraise innovative teaching and learning practices. This facilitates cross pollination of ideas as well as collaboration on educational initiatives across schools.

TEACHING AND LEARNING COMPETENCY FRAMEWORK FOR POLYTECHNIC LECTURERS

In 2013, a national committee for teaching and learning was set up by the Ministry of Education, Singapore, with the objective of "initiating, developing and nurturing a strong teaching and learning culture across all polytechnics". The first project of the committee was to identify a set of competencies that polytechnic lecturers should develop as they progressed in their careers as educators in the polytechnics. The framework defines what polytechnic lecturers are expected to know and be able to do at each stage of their careers, including key supporting professional values. It also identifies a professional development roadmap that assists lecturers in their journey as polytechnic lecturers. The outcomes of this project echo the call of the European Commission's Report (2012) *Rethinking Education: Investing in skills for better socio-economic outcomes:*

> to revise and strengthen the professional profile of all teaching professionals by reviewing the effectiveness as well as the academic and pedagogical quality of initial teacher education … the professional development of teaching staff based on **clearly defined competences needed at each stage of a teaching career**, and increasing teacher digital competence.

Identification and Validation of Lecturers' Teaching and Learning Competencies
A seventeen member project team from the 5 polytechnics, through an extensive literature review and the polytechnics' own competencies frameworks, identified a preliminary set of 6 competency domains and 16 underpinning competencies. Collectively, the descriptors for these were painstakingly crafted for further validation. This was conducted through a focus group session involving polytechnic lecturers from all five polytechnics, including 20 teaching staff from Singapore Polytechnic (SP). Further feedback was sought from two external reviewers; one from industry and another from academia, who were based in Singapore. The feedback obtained from the focus group and external reviewers were used to streamline the preliminary framework to 11 competencies, within the 6 competency domains.

An e-survey was conducted in 2014 to obtain feedback on the competencies from teaching staff. 184 teaching and management staff from Singapore Polytechnic (SP) participated in the survey. Table 1 and 2 show the age and years of teaching experience of the SP respondents who participated.

Table 1

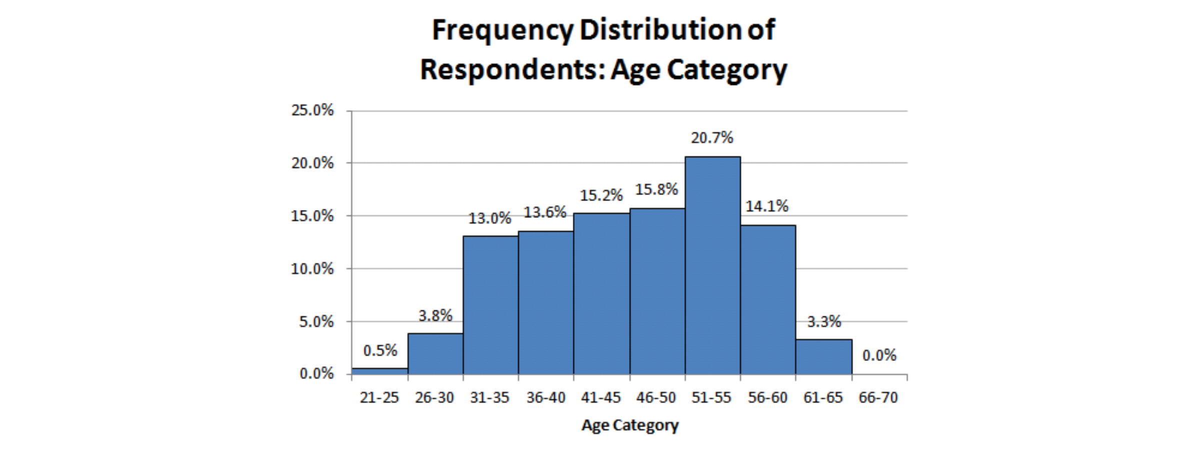
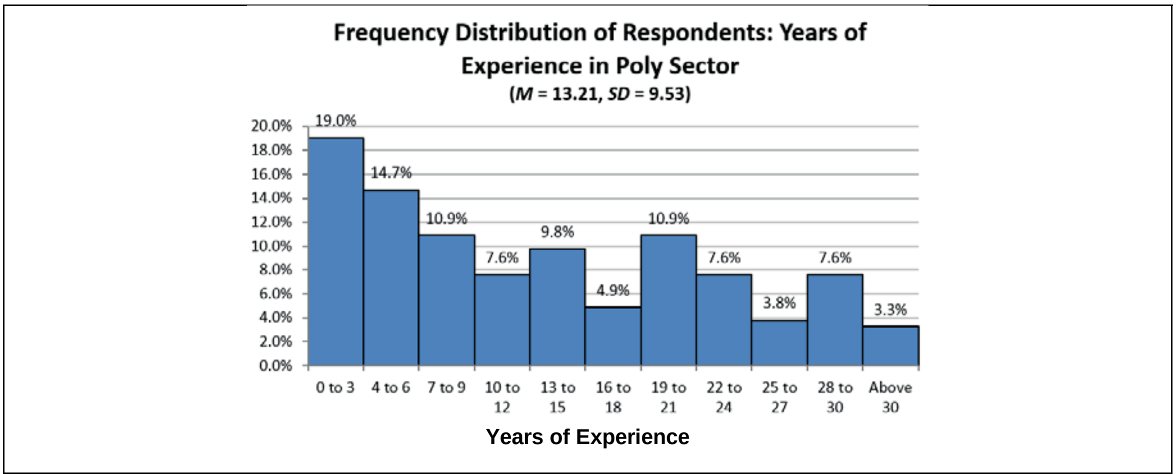


Table 2



Results and discussion

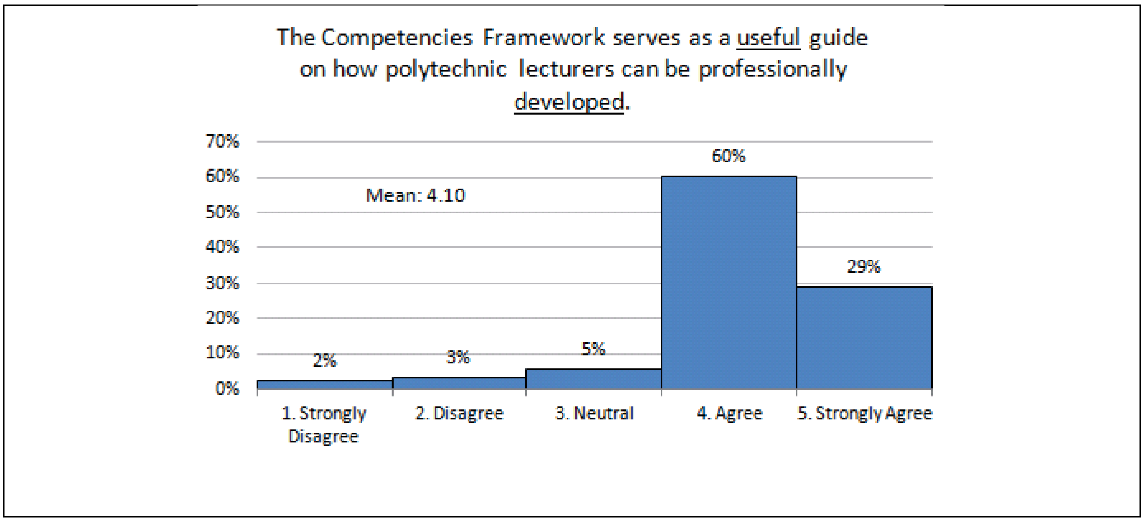
The responses from the e-survey were largely positive and confirmed the work of the project team. 89% of all respondents felt that the proposed framework was useful in guiding them to develop professionally in the competency domains (Table 3).

86% of the respondents also felt that the framework provided a comprehensive coverage of the key teaching and learning competencies (Table 4) but 45% felt that there were “slightly too many” competencies (Table 5) in the framework.

It was notable that the majority of the respondents in SP perceived the competencies proposed as clear, relevant and useful in helping them plan for their professional development needs, regardless of the proficiency levels they are at (Table 6).

Of the proficiencies, 29% and 24% of the respondents felt that they were advanced in facilitating effective learning and curriculum design respectively (Table 7). For dual professionalism, while 18% of the respondents felt that they had advanced competencies in the area, another 45% felt that they had basic competencies. Not surprisingly, the two competencies, Pastoral Care and being a Reflective Practitioner, that were ranked the lowest in importance had the highest percentage of respondents (60%) who felt they had basic level competencies in both.

Table 3



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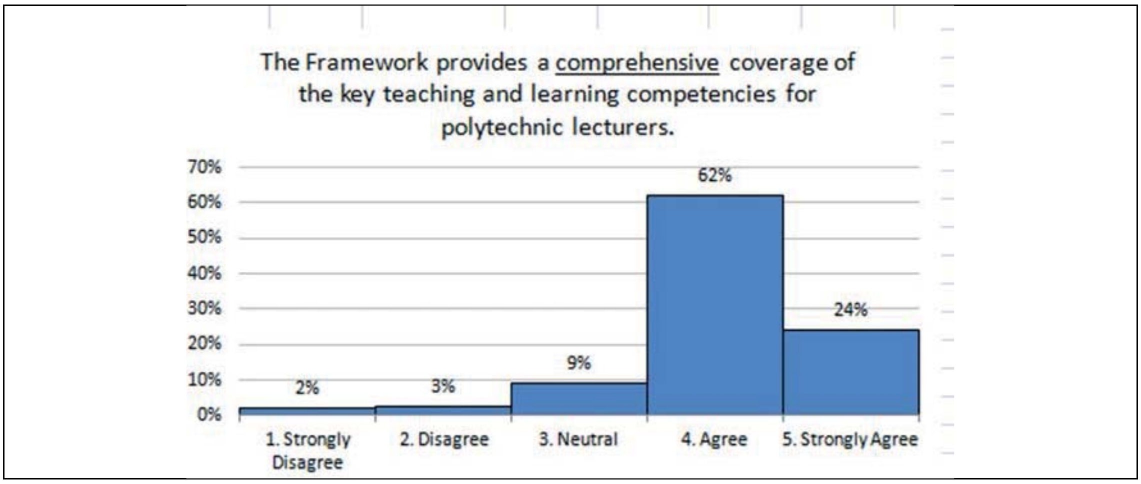

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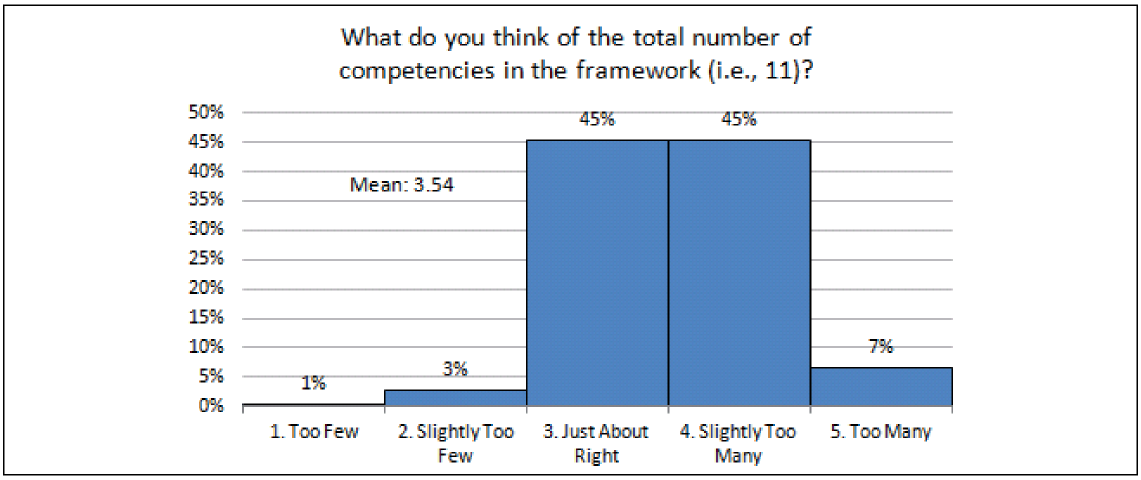

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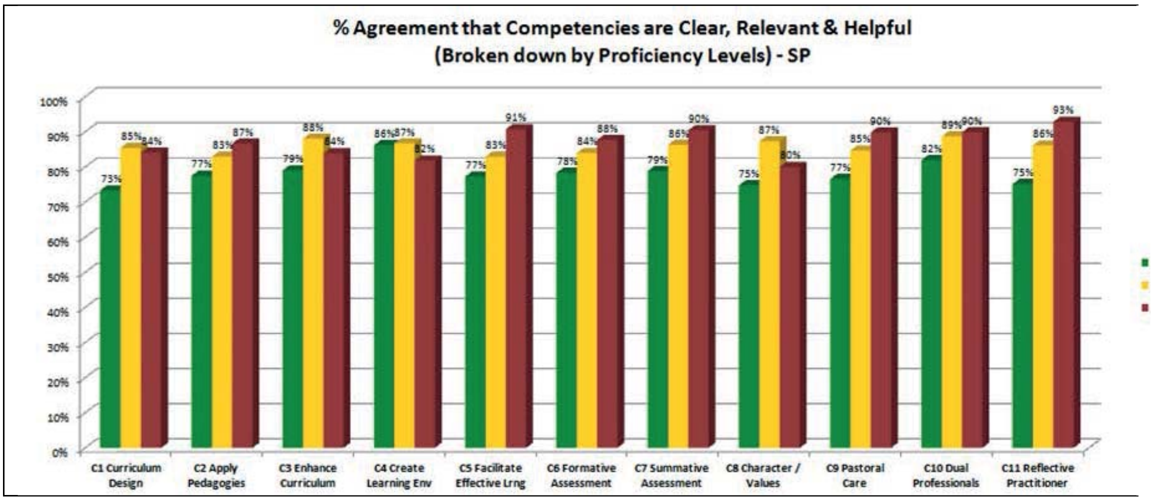
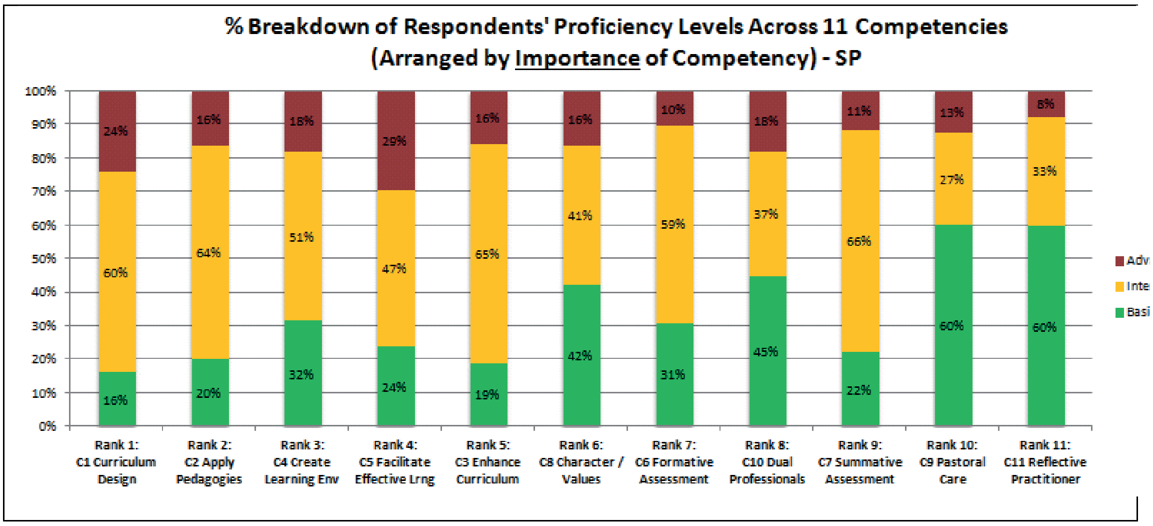


Table 7



On the whole, the majority of respondents positively validated the domain areas, the 11 underpinning competencies and their descriptors.

Customising the Framework for SP's context

The project team agreed that each polytechnic would have flexibility to customise the matrix for its lecturers by using local examples to provide context. SP's customised framework* has taken into consideration its current teaching and learning focus areas, which includes utilizing educational technology in teaching and learning; skill enhancement; development of professional identity, and lifelong learning (Table 8).

Table 8

Competency Domains	Customised Competencies for SP Lecturers
1. Curriculum Design and Development	• Design curriculum and lessons that align with the learning outcomes, students' learning needs and real-world/industry-relevant context • Apply appropriate pedagogies and technologies in planning the curriculum • Enhance curriculum and lesson design through feedback

	• *Design and develop work-place learning curriculum (eg internships and OJT) according to the needs of students and industry*
2. Facilitation of Learning	• Create learning environments that facilitate students' achievement of the learning outcomes • *Facilitate learning experiences with elements of autonomy, mastery, relatedness to enhance the Intrinsic Motivation of students* • *Leverage on Eduutech to design and facilitate a variety of ICT-enabled lessons* • *Create learning experiences that nurtures students' professional identity and formation.*
3. Assessment For and Of Learning	• Design and implement formative and diagnostic assessments to improve student learning and achievement of learning outcomes • Design and implement summative assessment to record student achievement • *Analyse student performance and provide support structures/ mechanisms for feedback in the module/subject by leveraging on Edu Tech tools and learning analytics*
4. Holistic Student Development	• Develop students' character, values, and social and emotional learning capacity • Provide basic pastoral care and career advisement
5. Dual Professionals	• Identify relevant developments in industry, disciplinary content and pedagogy to enhance the curriculum • *Engage industry in developing students' skill sets and professional identity*
6. Reflective Practitioners	• Engage in reflective practice through collaborative action research and professional learning communities

*Work-in-Progress

Conclusion

As teaching quality is the most important single factor in determining student attainment levels, it's essential that we provide training and support to maximize the capability of our teaching faculty. This will involve keeping abreast of new research and knowledge relating to how humans learn and the implications this has for designing and facilitating the student learning experiences.

Certainly, over the past decade or so, much has changed concerning our understanding of what teaching methods work best and the underlying principles involved. As a result, Petty (2009) argued that teaching may finally be ready to:

> …embark on a revolution, and like medicine, abandon both custom and practice, and fashions and fads, to become evidence-based (cover page).

Collectively the research evidence (e.g., Bransford, 1999; Marzano, 2007; Mayer & Alexander, 2010; Hattie & Yates, 2014) is now providing us with a heightened pedagogic understanding of the various facets of highly effective teaching and what strategies tend to work best and why. Hence, we can now start to talk about professional practices in teaching from an evidence-base as is the case in the more established professions. For example, Darling-Hammond & Bransford (2005), from surveying the research findings, concluded that:

> There are systematic and principled aspects of effective teaching, and there is a base of verifiable evidence of knowledge that supports that work in the sense that it is like engineering or medicine. (p.12)

Furthermore, this approach is extended to our professional development model, focusing on in-depth collaborative engagement of faculty in addressing curriculum challenges with strong mentoring and coaching support (Gulamhussein; 2013; Timperley et al., 2008; Joyce and Showers 2002).

The establishment of the Teaching and Learning Competencies Framework provides guidance for polytechnic lecturers' professional development throughout their careers and supports existing major curriculum innovations at SP, such as the CDIO Engineering Education Framework. It is also helping to identify areas of professional development that may need to be further enhanced in future (e.g., dual professionalism, pastoral care and reflective practice).

In summary, SP is committed to the ongoing professional development of Academic Staff throughout their career progression, which is facilitated through the wide range of strategically planned professional development activities outlined in this paper. The overarching goal is the provision of quality learning experiences for our students; maximizing their learning opportunities and preparing them to be Work, Life and World ready.

ACKNOWLEDGEMENTS:
The authors would like to acknowledge the collaborative work and contribution of the members of the Joint Polytechnic Committee for Enhanced Learning and Teaching (JP CELT) in the development of the Polytechnic Lecturers' Teaching and Learning Competencies Framework. We would like to acknowledge, in particular, Dr Moira Lee of Temasek Polytechnic for her leadership and guidance in the project.

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Annex 1

Certificate in Teaching (Higher Education)

The Certificate in Teaching (CT) course has been the main vehicle for providing the key understandings and basic competences in preparing academic faculty for their professional teaching role in Singapore Polytechnic. It is the initial teacher education programme to enable them to approach their teaching from a solid pedagogic base.

For the development of professional competence, the key focus is on the application of the most current and validated knowledge bases relating to human learning and how these can be systematically applied to the design of curriculum, teaching practices and assessment of learner performance.

Key Features

Title	Duration	Remarks
Induction	1 week (Full Time)	The induction programme is designed to help ease new staff into their role as an SP lecturer before they begin actual teaching. In this phase, they learn basic pedagogical knowledge and skills such as: • Lesson Planning • Classroom Management • Designing for Active Learning • Basic Facilitation Skills
Using Technology for Teaching and Learning	1 week (Full Time, conducted during School Vacation)	This week long workshop focuses on the core knowledge and skills needed to integrate the use of technology to improve teaching and learning outcomes. Key areas covered include: • The useful affordance of using technology for teaching and learning • Key trends in using ICT for teaching and learning • Designing an ICT based lesson • Useful tools and apps for teaching and learning
Specialised Workshops	Online	Lecturers participate in online workshops to help them hone and sharpen their pedagogical knowledge and skills. Lecturers attend a variety of workshops such as • Lesson Study Using Supported Experiments • Designing and Assessing Performance Based Assessment • Inquiry Based Learning • Facilitating Online Learning • Motivating Students
Lecturers will also need to submit a teaching portfolio that will showcase the application of knowledge and skills learnt on the CT course		

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INTERDISCIPLINARY FACULTY LEARNING COMMUNITIES IN ENGINEERING PROGRAMS: THE UCSC EXPERIENCE

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ABSTRACT

We're all in a way part of a *learning community*. But what makes a community of teachers a *Faculty learning community*? And how can that learning community generate exceptional results? This paper is an effort to share a systematic approach on how to achieve the above. It's the result of reflection over several experiences, but particularly one with a cross-disciplinary team. The proposal presented in this paper is applicable to any type of faculty learning community. The main experience that inspired this work actually started with the task of improving the Introduction to Civil Engineering course at UCSC. As many students were not acquiring the expected level of communication skills nor satisfactorily achieving other personal and interpersonal learning outcomes, a multidisciplinary team was set up in order to address these issues. This team included civil engineers, a language teacher/actor, a therapist in psychogenealogy and an industrial engineer/organizational coach with expertise in positive psychology. This group was set up and led by a civil engineering professor with experience in engineering education, the CDIO framework, and teaching communities. The result of this work went beyond the task at hand. First, the whole course was redesigned as an integrated learning experience with innovative active learning methodologies. This is now a complex course, embracing CDIO standards nº 1, 4, 5, 7, and 8, and taught by professors from four different disciplines. Secondly, an interdisciplinary faculty learning community was born in the process, as well as a model for interdisciplinary collaboration. The community's working methodology is clear, well-defined, flexible, reflection-based and shared by everyone. Our experiences with this faculty learning community, led by an experienced, engaged leader in a nurturing work environment, can be summarized into a set of best practices to be followed at each stage of the collaboration process.

KEYWORDS

Faculty learning community, personal and interpersonal skills, leadership skills, introduction to engineering course, Standards: 1, 4, 5, 7, 8, 9, 10.

INTRODUCTION

In 2010 the Universidad Católica de la Santísima Concepción (UCSC) created the *Centro de Innovación y Desarrollo Docente* (CIDD), a center to aid the development of teaching practices and boost teaching innovations that follow a student-centered approach. This center fosters the creation of faculty learning communities to promote the exchange of teaching experiences among faculty and the systematization of teaching innovations as well as the continuous improvement of pedagogical practices. Faculty learning communities, as local agents of change, encourage faculty to document their experiences and generate evidence of their results, and to share them with their peers so as to receive feedback and improve their pedagogical practices, either through active participation in internal and external activities such as teaching seminars and workshops, or through the publication of results in conferences, workshops and journals in engineering education.

The first faculty learning community at the School of Engineering was created in January 2012, and included members of the Computer Science, Industrial Engineering and Civil Engineering departments (Cárdenas et al., 2013). Its main goals were to promote active learning and to aid the transfer of successful experiences across sequences of courses in a program and also across engineering programs. Since then, other faculty learning communities with similar goals have been created. Even though these communities have been shown to aid the enhancement of faculty teaching competences (CDIO Standard 9), more effort is needed to facilitate multidisciplinary and interdisciplinary work among students and also among faculty.

Introduction to Civil Engineering Course, short description

In the year 2011, the School of Engineering at UCSC began implementing a CDIO-based curriculum (Loyer et al., 2011). As part of this reform, five engineering programs incorporated an 8 hour/week Introduction to Engineering course (CDIO Standard 4). In the case of Civil Engineering, this course focuses on developing personal and interpersonal skills, as well as on having the students understand the role of Civil Engineers in the world (CDIO Standard 7). Initially, this course was taught by Civil Engineers and by a professor of Spanish, who was in charge of teaching communication skills, such as written reports and oral presentations, tailored to the Civil Engineering context.

Course structure, as shown in figure 1, consisted in 2 hours/week of oral and written communication (OWC) classes and 6 hours/week of lectures and workshops focused on the different roles of a Civil Engineer. During the last quarter, students developed a final project related to one of the traditional Civil Engineering areas.

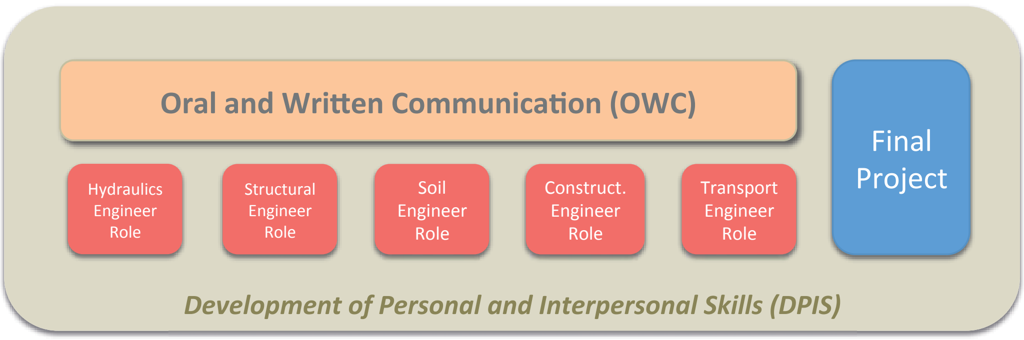

Figure 1: Original Introduction to Civil Engineering Course Structure

The course was mainly based on active learning (CDIO Standard 8), but in spite of the faculty's efforts, periodic evaluations showed that students did not acquire the expected level of communication skills nor satisfactorily achieved other personal and interpersonal learning outcomes, such as engineering reasoning and problem solving, attitudes, ethics, leadership, teamwork, among others. The main reasons were inadequate integration among the multiple activities designed for the course; insufficient communication and coordination between the faculty involved and the lack of a clear-cut responsibility for these other personal and interpersonal learning outcomes. Moreover, the engineers in the team followed their traditional collaboration way, where they relied upon the expertise of the non-engineers in the team instead of getting fully involved in their work: a high degree of involvement was not considered necessary by the engineers. This coincides with the observations about engineers' behavior in cross-disciplinary collaboration presented by Klein (1990) and Borrego and Newswander (2008).

FRAMEWORK

Social Learning Theory states that learning is a cognitive process that takes place in a social context and occurs through observation or direct instruction (Bandura, 1977). As such, the learning process benefits from being part of a diverse community of people sharing common goals. In this context, it is relevant to present the concepts of communities of practice, learning communities and cross-disciplinary collaboration as used in this work.

Communities of practice and learning communities

According to Wenger et al. (2002), communities of practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis". Likewise, according to Baker (1999), a learning community is a relatively small group that may include students, teachers, administrators, and others who have a clear sense of membership, common goals, and opportunity for extensive face-to-face interaction. The relevant literature presents several types of learning communities, such as professional learning communities, faculty learning communities and student learning communities, among others. In particular, Cox (2004) defines a faculty learning community as "a cross-disciplinary faculty and staff group of six to fifteen members (eight to twelve members is the recommended size) who engage in an active, collaborative, yearlong program with a curriculum about enhancing teaching and learning and with frequent seminars and activities that provide learning, development, the scholarship of teaching, and community building".

Cross-disciplinary collaboration

Borrego and Newswander (2008) use "cross-disciplinary" to describe collaborations involving multiple disciplines, and they distinguish between multidisciplinary and truly interdisciplinary approaches to cross-disciplinary collaborations. In the first case, collaborators come together to work on a problem, each one contributing according to his or her own expertise. While the product of this collaboration may well be successful, collaborators might not learn much about the others' discipline. In contrast, in a truly interdisciplinary approach, collaborators work closely together in a more integrated way to solve a problem, combining their knowledge from their own disciplines to work toward a solution. At the end of a truly interdisciplinary collaboration, each collaborator is changed by the experience. Moreover, they, as well as Boix-Mansilla and Gardner (2006), argue that the level of integration for a collaborative project can be a predictor of the quality of the final results.

Truly interdisciplinary collaboration in engineering education requires engineers to work with educators and social scientists. Each disciplinary framework relies upon its own ways of approaching and understanding a particular problem, and requires some effort on the part of all collaborators to understand and appreciate their specific contributions. Each collaborator knows and understands the world according to his or her epistemology, which dictates which research questions, methods and goals he or she considers legitimate. Borrego and Newswander (2008) suggest that how a collaborator understands and appreciates the nature of knowledge will affect his or her collaboration with colleagues in different disciplines, especially if these disciplines are fundamentally different, as is the case between engineering and social sciences. In order to overcome these differences, they say that each collaborator must:

a) be able to identify his or her own epistemological framework and recognize its own inherent strengths and weaknesses,
b) learn enough about other ways of knowing and understanding to be able to respect them, and
c) be able to integrate new epistemologies into the collaboration.

INTERDISCIPLINARY FACULTY LEARNING COMMUNITY

When faced with a cross-disciplinary collaboration, the first question that should arise is whether to follow a multidisciplinary or interdisciplinary approach. However, engineers rarely ask themselves this question, but rather follow the multidisciplinary approach and tend to break up the work and divide the tasks among the experts (Muis & Haerle, 2006). Also, as mentioned in the framework section, one could expect better results from an interdisciplinary collaboration. Finally, if the results of the collaboration are expected to be something new or innovative, we recommend creating an interdisciplinary faculty learning community.

There are several models for faculty learning communities that can be adopted for a multidisciplinary or interdisciplinary faculty learning community. One of the main difficulties in cross-disciplinary collaborative work is the lack of integration of its members, due mainly to their different epistemologies as mentioned previously. Most authors state the importance of this integration, but don’t necessarily give guidelines on how to achieve it. Borrego and Newswander (2008) propose having informal interactions in the collaborator selection stage in order to determine compatibility. While this is important, it may not be enough. So how can you make the collaborators work in an integrated way? We attempt to address this issue in the model presented below, which incorporates a set of activities in the inception phase.

Interdisciplinary Faculty Learning Community Model

Figure 2 presents two models for cross-disciplinary collaboration. On the left it shows the traditional multidisciplinary approach and on the right it presents our interdisciplinary model. Both models have two main phases, the inception phase and the collaboration phase, being their main difference in the inception phase.

The traditional multidisciplinary model includes three stages: identification of the problem or research question to be addressed; setting up the team and roles; and finally a working stage that can follow different working schemes or approaches.

The interdisciplinary model presented identifies four stages, adding another stage in the inception phase that focuses on the team integration or blending. The purpose of this integration is for collaborators to get to know each other and, most importantly, to get to know their ways of knowing and understanding the world. In other words, to familiarize themselves with each others' epistemology and aspects of their disciplinary knowledge that are important for the collaboration to succeed.

Since this new stage demands a learning process from the collaborators themselves, we approach it in the same manner as we do with our students: by using active learning. Collaborators from different disciplines design workshops and other active learning activities which are carried out by the team, thus learning in a more effective way about each others' disciplines and hopefully start the process of understanding each others' different epistemologies, a process that should continue throughout the whole collaboration (CDIO Standard 9). According to (Borrego and Newswander, 2008), *"truly interdisciplinary collaboration requires some effort on the part of the collaborators to understand and appreciate the contributions presented by various disciplinary frameworks"*. And this is where the active learning experiences were particularly effective. Each faculty really got to know well what the others were doing, therefore facilitating future communication.

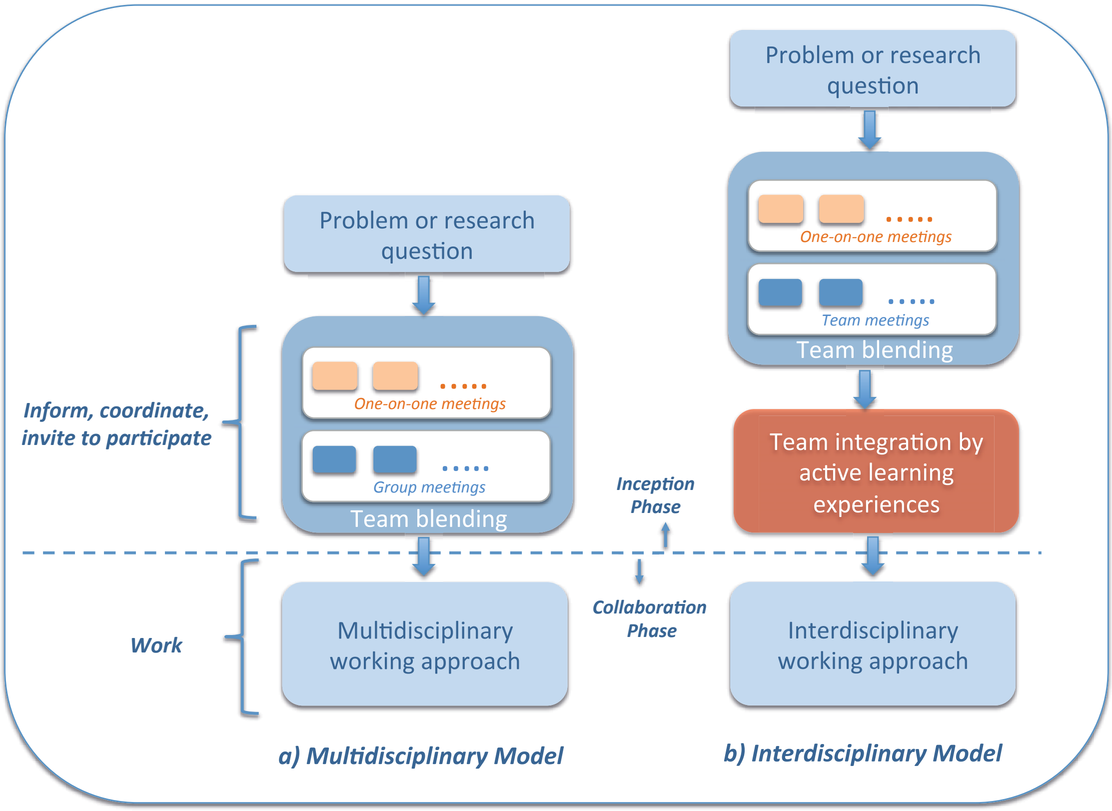

Figure 2. Multidisciplinary versus Interdisciplinary Faculty Learning Community Model

In the collaboration phase, an interdisciplinary working approach is followed. Work is organized through weekly structured meetings, during which:

a) the previous week's work is reviewed, analyzing what went well, what went wrong and how to fix it,
b) the work plan's progress is checked, and
c) the new week's work is organized, assigning tasks, responsibilities and timeframes. The work plan is also updated, if necessary.
d) Meeting notes are recorded and made available through a shared platform

Some key issues in this approach are selecting the team leader and having a good work environment. The team leader must help organize and articulate the work, motivate and engage the team and at the same time create a horizontal organizational structure, where every collaborator feels his or her contribution is visible to, and valued by, each team member as a whole by creating a supportive climate of openness, trust and mutual respect that promotes loyalty and cooperation. He or she must lead the team in forging the vision and goals, and also provide them with regular, clear, accurate and timely feedback.

Collaborative work benefits from meeting in a flexible, well-lighted work space, with food and tea, coffee and soft drink availability, where people feel comfortable and have fun working together. Even though extensive use of electronic collaborative tools such as Dropbox, e-mail, whatsapp, is essential, nothing beats face-to-face interaction to foster innovations and creative ideas.

RESULTS

The faculty learning community that inspired this work was actually born as a spinoff of a multidisciplinary team put together for the above mentioned Introduction to Civil Engineering course. As many students were not acquiring the expected level of communication skills nor satisfactorily achieving other personal and interpersonal learning outcomes, such as engineering reasoning and problem solving, attitudes, ethics, leadership, teamwork, among others, a multidisciplinary team was set up in order to address these issues. This team included civil engineers, a language teacher/actor, a therapist in psychogenealogy and an industrial engineer/organizational coach with expertise in positive psychology. This group was set up and led by a civil engineering professor with experience in engineering education, the CDIO framework, and teaching communities.

The initial task was to redesign the course, keeping the original learning outcomes and also integrating all the disciplines that were considered in the course. After contacting the collaborators, the leader held a series of one-on-one and group meetings with all potential collaborators, in order to inform them about the challenge, but most of all to listen to what they had to say. After the team was set up, a set of workshops and discussion sessions were organized (CDIO Standard 10). The resulting course has an innovative and complex design, which is further explained in the following section.

Introductory Civil Engineering: new course design and results

The main first result of this community was the redesign of the Introduction to Civil Engineering course. The new design is presented in figure 3, and at first glance you can see the integration of the different disciplines that are part of this course.

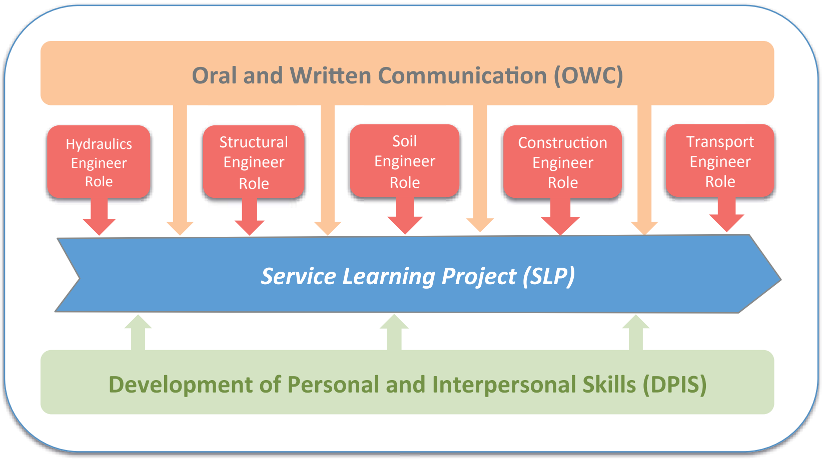

Figure 3. New Introduction to Civil Engineering Course Structure

The backbone of the course is a Service Learning Project (SLP) that is developed throughout the semester (CDIO Standard 5). Due to the nature of this project, it include the basic CDIO stages: Conceive, Design, Implement and, in some cases, Operate (CDIO Standard 1). The 8 class hours were divided into 2 hours of the "Engineering role" (ER), 2 hours of Oral and Written Communication (OWC), 2 hours of Development of Personal and Interpersonal Skills (DPIS) and 2 workshop hours, either for ER or for SLP (depending on the schedule). The main accomplishment of this course is that all course disciplines were integrated by means of the service learning project.

Students' perceptions of their learning outcomes

A survey of students' perception of their proficiency level was answered by 72 of the 120 students (60%) registered in the Introduction to Civil Engineering course during the first semester of 2015. The results presented in Table 1 show that students in general perceive high levels of proficiency in most of the CDIO skills. Although there was not a significant difference in their grades compared to previous years, the results shown in table 1 are consistent with the instructors' opinions of the same students in the following semester, where they noticed that they had higher confidence in their skills and attitudes.

Table 1. Students' perceptions of their learning outcomes

CDIO Skills	1	2	3	4	5
2.1. Analytical reasoning and problem solving	2%	10%	39%	27%	20%
2.4. Personal skills and attitudes	3%	11%	25%	38%	21%
2.5. Proffesional skills and attitudes	0%	10%	28%	38%	25%
3.1. Teamwork	3%	10%	29%	36%	20%
3.2. Communications	3%	15%	35%	30%	15%
4.1. External and societal context	1%	7%	25%	37%	28%
4.3. Conceiving, system engineering and management	1%	7%	25%	37%	28%
4.4. Designing	0%	13%	25%	40%	21%
4.5. Implementing	6%	11%	42%	30%	7%

Note: 1) To have experienced or been exposed to; 2) To be able to participate in and contribute to; 3) To be able to understand and explain; 4) To be skilled in the practice or implementation; 5) To be able to lead or innovate in

Interdisciplinary faculty learning community best practices

There is plenty of literature regarding best practices for interdisciplinary communities, faculty learning communities, professional learning communities, and so on. Our proposal's main difference is that it is organized according to their time of application, as is shown in Figure 4. The "Before" section shows best practices to be followed before the collaboration, the "During" section presents best practices to be followed during the collaboration, and the "After" section shows best practices to be followed after the collaboration has finished. The central section presents best practices to be followed throughout the collaboration process.

Figure 4. Interdisciplinary Faculty Learning Community Best Practices

CONCLUSIONS AND FUTURE WORK

This work presented an interdisciplinary faculty learning community, as well as a model for interdisciplinary collaboration. As a result of this community's work, the Introduction to Engineering course was redesigned as an integrated learning experience with innovative active learning methodologies, embracing CDIO standards nº 1, 4, 5, 7, and 8, and taught by professors from four different disciplines. At the same time, thanks to the interdisciplinary collaboration model, the multidisciplinary group evolved in a natural way from a team to an interdisciplinary faculty learning community. The community's working methodology is clear, well-defined, flexible, reflection-based and shared by everyone. Our experiences with this faculty learning community, led by an experienced, engaged leader in a nurturing work environment, was summarized into a set of best practices to be followed at each stage of the collaboration process. This approach addresses CDIO standards 9 and 10.

Our preliminary results are promising, but many challenges still remain. Among them, we must mention how to give team members more autonomy and less reliant on the team leader, how to make the team more resilient to changes in its membership, and how to transfer their know-how to other cross-disciplinary teams involved in other courses. Special mention must be given to the topic of teaching assistants, as they spend considerable face-to-face time with the students: they were not considered initially in the inception phase, and at the same time, they might change every semester.

Also, the issue of costs must be taken into account: creating and maintaining interdisciplinary teams with collaborators from many different disciplines is expensive in terms of money, time and resources, requiring a long-term commitment from university administration and staff.

Finally, more work is needed to evaluate the impact of this work in the medium- and long-term.

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STEPS FOR ITERATING DESIGN-IMPLEMENT EXPERIENCES INTO A CDIO COURSE

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ABSTRACT

This paper describes how a particular form of iterative design-implement experiences were driven in the fourth-year Advanced Project in Science and Telecommunications Technology of the Degree in Sciences and Telecommunication Technologies taught at the Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona (Telecom BCN), in which students were faced with the incremental development of an innovative mirroring tool for facial paralysis rehabilitation. This work was done in the research framework established by Telecom BCN, Bellvitge University Hospital and Bellvitge Biomedical Research Institute (IDIBELL).

KEYWORDS

Design-Implement Project, Incremental Development, Telecommunication Engineering, Standards: 5, 11

INTRODUCTION

The CDIO approach meets the challenge of increasing the quality of engineering education by providing a learning environment in which students understand how to Conceive-Design-Implement-Operate (CDIO) complex technological products (Crawley et al., 2014). Accordingly, CDIO functions as a lifecycle model of these products where Design-Implement (D-I) remain as their key stages and usually involve an iterative loop to meet certain constraints and criteria in a process of refinement (Cross, 2008).

Iterative procedures wherein enhancements in some parts lead to modifications in others are actually inherent to the very nature of D-I. For building meaningful D-I experiences, implying practical hands-on activities that generate real-world verifiable results (Crawley et al., 2014), a kind of "Reflection-in-Action" (Schön, 1984) should be carry out, in which knowing and doing are inseparable and thus problem understanding and its solution have to be developed side-by-side. In a search for systematization different approaches to iterative, evolutionary and incremental development has been conceptualized and proposed, particularly in fields like software engineering (Larman, 2003).

This work shows how a particular realization of such iterative D-I experiences was introduced in the fourth-year Advanced Project in Science and Telecommunications Technology (12 ECTS credits) of the Degree in Sciences and Telecommunication Technologies taught at Telecom BCN. As the basis for engineering-based active and experiential learning in the context of a design-implement project, students were faced with a process of refining the design and coding a novel and pioneering software tool based on computer vision and machine learning (Prince, 2012) for aiding the neuromuscular re-education of hospital patients with facial paralysis (VanSwearingen, 2008) using a mirror therapy. This work was done in the cooperative research framework recently formed by Telecom BCN and IDIBELL (Domingo, et al., 2015) and looks upon some previously neglected issues such as the product usability tested in the intended target user.

The paper is organized as follows. In the next section, some key concepts on iterative D-I experiences are introduced and several proposals for their practical realization in the context of the Design-Build courses path at Telecom BCN are presented. The course Advanced Project in Science and Telecommunications Technology taught at Telecom BCN in collaboration with IDIBELL is then reviewed. Finally, conclusions are summarized in the light of the previous sections.

ITERATIVE DESIGN-IMPLEMENT EXPERIENCES: CONCEPTS AND PROPOSALS

Design-Implement experiences as central to Telecom-BCN curricula

The term Design-Implement experience is used to denote a whole range of engineering activities central to the process of developing novel products; while *design-* emphasizes plan definition, block diagrams and algorithms that describe the product, *-implement* refers to hardware building, software coding, testing, validation and any other stage involved to obtain an operating product from a design. Accordingly, D-I experiences necessarily include practical hands-on activities for students to design, build, generate, test, and operate a real product as a counterpart to theory for supporting, enhancing and deepening active and experiential learning in which students mimic professional engineering practice (Crawley et al., 2014). In this way, they remain crucial to project-based courses and to programs in general.

The need of iterative and incremental approaches to Design-Implement

Reflection-in-action in engineering design

Engineering design is similar to problem-solving since it involves a solution proposal in the form of an artifact (or a product) based on a conceptualization and understanding of a problem to be faced. As a consequence of this fact, problem and solution have to be evolved side-by-side (Cross, 2008; Koh et al., 2015) and engineering design can be then viewed as a "reflective conversation with the materials of a situation", wherein the designer frames and re-frames the problem yielding new discoveries which call for new reflection-in-action, forming an indissoluble knowing and doing; thus, "the process spirals through stages of appreciation, action, and reappreciation" (Schön, 1984). This reflection-in-action, which implies that knowing and doing are inseparable, involves a reflective practicum in academy, i.e. a learning-by-doing within a reciprocal dialogue between students and teachers (Binder et al., 2011) through practical hands-on activities that produce real-world demonstrable results (Crawley et al., 2014).

Iterative and incremental approaches to D-I

The spiral process of reflection-in-action is, in fact, that of Design-Implement experiences. Iterative procedures, in which enhancements in some parts lead to modifications in others, are very common in the stages of D-I, usually involving an iterative loop to meet certain constraints and criteria in a refinement process (Cross, 2008). Although a solution could be obtained using a waterfall model, i.e. through the execution of a convenient number of sequential stages, as soon as any of its details are not clearly defined, some form of iterative project management life cycle (PMLC) model should be employed instead (Wysocki, 2013).

The basic idea behind iterative PMLC (Figure 1) is to obtain a product through repeated (i.e. iterative) cycles and in smaller portions (i.e. incremental) at a time, allowing engineers to exploit what was learned during earlier stages of the cycle and, more specifically, through previous versions of the product. Enhancement and refinement comes then from both product development and use in a way that changes and new functional abilities are considered at each step. For (software) development projects, the most popular iterative PMLC models are, among others, Evolutionary Development (or, in short, Modified) Waterfall, Scrum and Rational Unified Process (RUP) (Larman, 2003; Wysocki, 2013):

- The modified waterfall model was proposed in the seventies and became a highly influential refinement of the simple stage-wise waterfall model, providing recognition of the feedback loops between stages, and a guideline to confine the feedback loops to successive stages to minimize feedback rework (Boehm, 1988).
- Scrum was originally formulated as a holistic approach with six features that join together in jigsaw puzzle-like fashion: built-in instability, self-organizing project teams, overlapping development phases, "multilearning," subtle control, and organizational transfer of learning (Takeuchi & Nonaka, 1986).
- The RUP (Kroll & Kruchten, 2003) has four project life-cycle phases –inception, elaboration, construction and transition– that are similar in presentation to a 'waterfall'-styled project and interact all of them. RUP uses three building blocks for describing what is to be produced (work products), the skills required (roles) and how development goals are to be achieved (tasks). Within each iteration, the tasks are categorized into six engineering disciplines –business modelling, requirements, analysis and design, implementation, test, Deployment– and three supporting disciplines –Configuration and change management, Project management and Environment–.

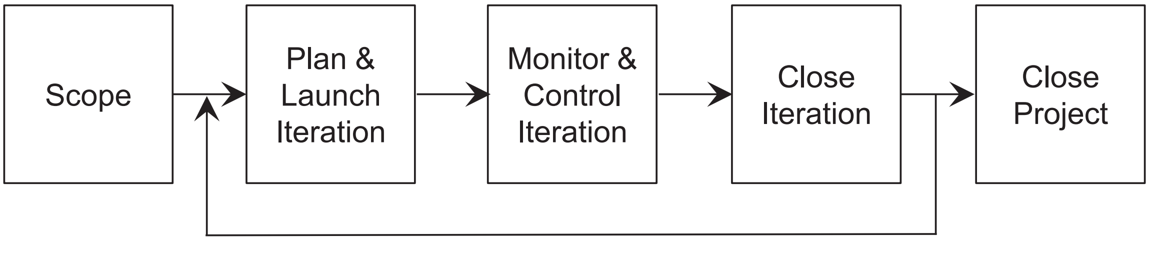


Figure 1. Iterative PMLC cycle (adapted from Wysocki, 2013)

Steps for an iterative proposal to Design-Implement in CDIO courses

A simple iterative model of D-I (Figure 2) is introduced in this section. It is not intended to provide a complete framework for managing highly complex projects but only to suggest tentatively a very preliminary model, loosely constructed upon the PMLC models reviewed above and suitable to be used in Design-Build courses. The basic features of the proposed model can be briefly summarized as follows:

- It is a spiral-based iterative model (Boehm, 1988) divided in three phases or cycles –inception, elaboration and construction–. Each cycle of the spiral starts with planning and requirements definition/modification followed by design and implement –divided in hardware work/software coding, testing and evaluation– and ends with a tollgate, measured objectively through a set of deliverables (see Table 2). The final prototype is deployed at the end of the third cycle.
- It is user/client-driven (Gould & Lewis, 1985) since meetings with clients and potential users are conducted to (re-)define product requirements and test and evaluate early and mid-term prototypes, thus allowing their refinement and enhancement along the process.

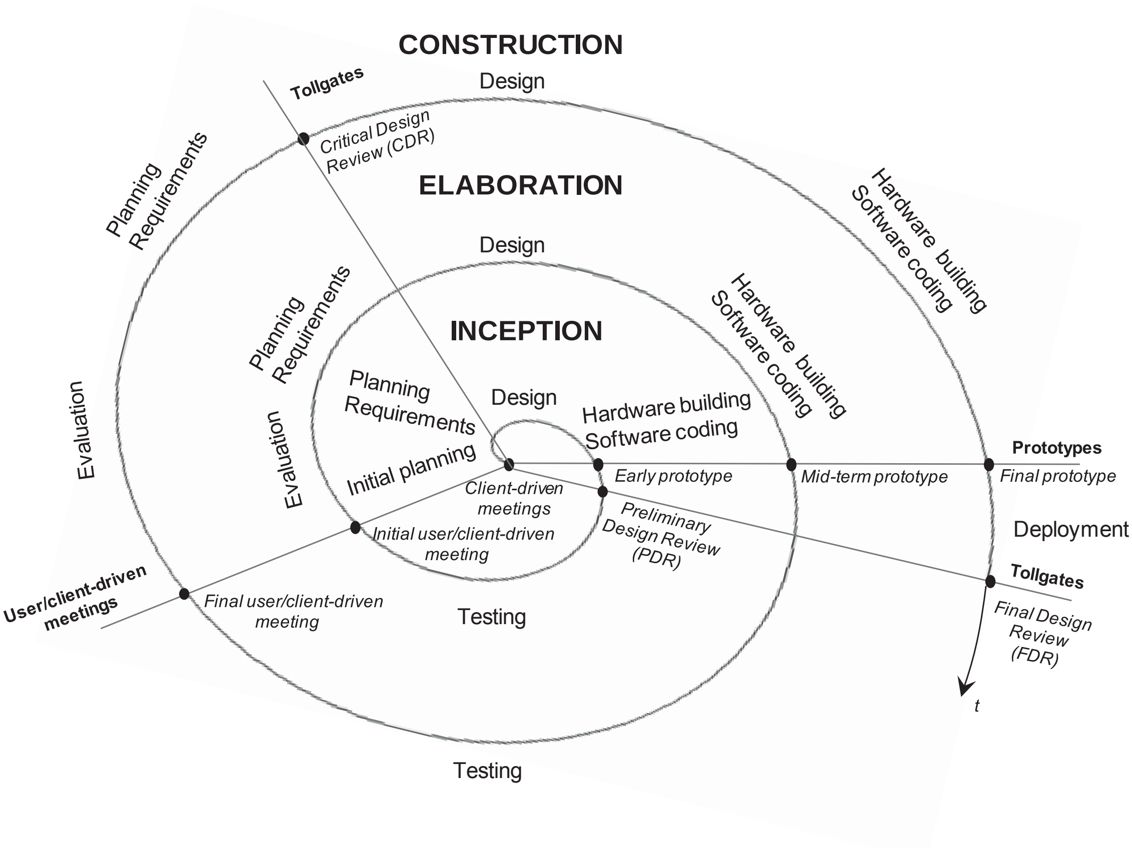


Figure 2. The suggested spiral model for iterative design-implement

Table 1. Tollgates and deliverables

# week	Tollgate	Deliverables
3	Preliminary Design Review (PDR)	- Project Charter (PMBOK Guide; Project Management Institute, 2013) - Project Management Plan
9	Critical Design Review (CDR)	- Reviewed Project - Management Plan
12	Preliminary Final Design Review (FDR)	
13	FDR	- Reviewed Project Plan - Project Report
13+	Project presentation + Demo	- Poster - Final Report - Business Plan - Presentation
weekly	Meeting minutes Lab logbook	

DEVELOPING A MIRRORING TOOL FOR FACIAL PARALYSIS REHABILITATION: A CASE STUDY IN ITERATING DESIGN-IMPLEMENT EXPERIENCES

Course Outline and Aims for 2015 Edition

The course in the academic plan

The fourth-year Advanced Project (AP) in Science and Telecommunications Technology (12 ECTS credits) is intended as a capstone course for students of the Degree in Sciences and Telecommunication Technologies taught at Telecom-BCN (UPC). It aims to provide students with a significant design experience and integration of knowledge from several courses for culminating conception, design and implementation of a complex system, and also a means to practice system thinking, project management, technical writing, and technical presentation skills. AP students were previously enrolled in two other Design-Build courses.

Course aims for the 2015 Edition

AP students were challenged with the design and building of a new and inventive software tool that relies on computer vision and machine learning (Prince, 2012) for aiding, through a mirror therapy, the neuromuscular re-education of hospital patients with facial paralysis (VanSwearingen, 2008). The software shows in real time to the patient a video where the affected half of the face is substituted by a mirroring of the healthy side. Moreover, the software takes measures of characteristic points over the face in order to track the progress of the patient while trying to do some facial movements such as smiling, mimicking a kiss, etc. The course was conducted in cooperation with the Rehabilitation Unit of the Bellvitge University Hospital and IDIBELL that worked as the client in the D-I model. This is one of the nine projects offered this semester.

Results and Discussion

Course preliminaries

Students were first divided in two groups (of 8-9 members each) with a leader and assigned to the same project to be developed in laboratory sessions for a total of 90 hours. Teachers acted essentially as technical consultants in these sessions and also monitored their group dynamics attending to weekly group meetings. Students were provided with a very rough version of the intended software written in C++ that make use of several machine learning and computer vision toolboxes (e.g. OpenCV) and a well-known proprietary integrated development environment.

The key role of user/client-driven meetings

At the beginning of the *inception phase*, two meetings between clients, students and teachers were done in order to define the basic requirements and the general functionality of the application; the first meeting was face to face and the second one by e-mail through a questionnaire. Later, two face meetings of four hours each were conducted in the rehabilitation unit of the Bellvitge Hospital between group leaders, a teacher, two physiotherapists (clients) and several voluntary patients affected by facial paralysis (users) at the end of *inception and elaboration phases*. In these meetings, software prototypes were extensively tested by users giving their detailed impressions about them. Also, clients gave important insights on the clinical framework in which these aiding tools will be incorporated.

Early, middle-term and final prototypes

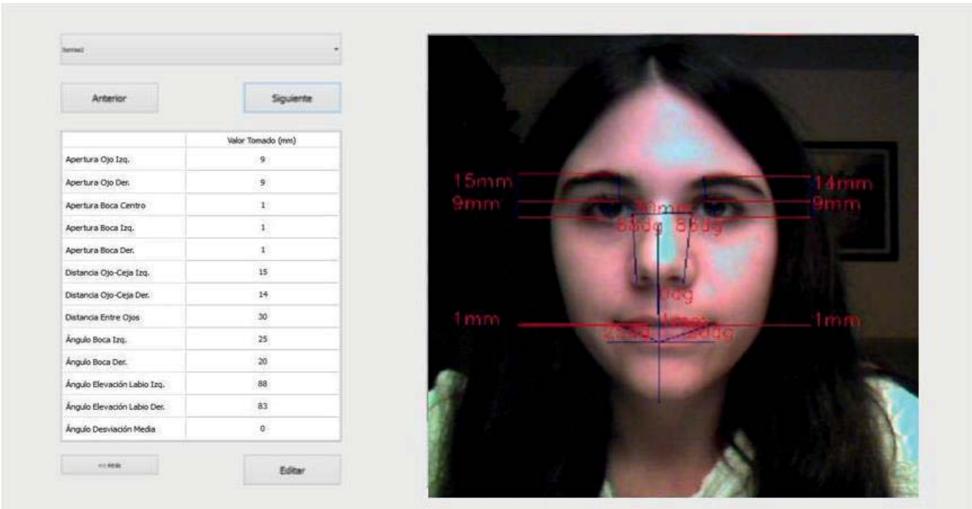
A clear differentiation in depth and sophistication between prototypes was present. Early software prototypes included only a basic version of the real-time mirroring facility that made possible a very fruitful user/client-driven meeting since their test and evaluation reveal relevant bugs to be solved and reveal new requirements. On the other hand, mid-term prototypes included important improvements of the basic mirroring algorithm in terms of speed and effectiveness and also incorporated new functionalities like a real-time automated measurement tool for assessing the user improvement among sessions and several managing tools to maintain a user database. Lastly, final prototypes also included advanced mirroring algorithms for enhancing the user experience and completed the managing and measurement tools for obtaining and maintaining a detailed set of user statistics.

Discussion

The use of an iterative D-I model allowed obtaining the gradual refinement and enhancement of a system that was elaborated through constraints that were introduced incrementally since some of them were only possible to be discovered after testing and evaluating a functional prototype with the help of real users and clients. In this sense, user/client-driven meetings remained vital for early development of operating prototypes and for providing important feedback and insight for further substantial refinement and enhancement. Students obtained not only vital feedback from direct users and clients (i.e. patients and physiotherapists) but a clear picture on the real conditions in which the software will be run that allow refining much better the most relevant technical requirements. For all these reasons, the final prototype (Figure 3) was much more complex and robust than those of prior editions of the AP course, in which basically a waterfall model was employed.

CONCLUSIONS

A preliminary iterative model for design-implement experiences has been proposed and tested in the fourth-year Advanced Project taught at Telecom BCN for students to incrementally develop a mirroring software tool for facial paralysis rehabilitation. The spiral-based model has three cycles –inception, elaboration and construction– for refining and enhancing incrementally previous design-implement efforts and relies on user/client-driven meetings and tollgates with deliverables for subsequent improvement of prototypes until their deployment. The application of such model allowed students to obtain a final prototype technically richer and better suited to the needs of clients and users than those based on an almost linear PMLC model employed in previous editions.



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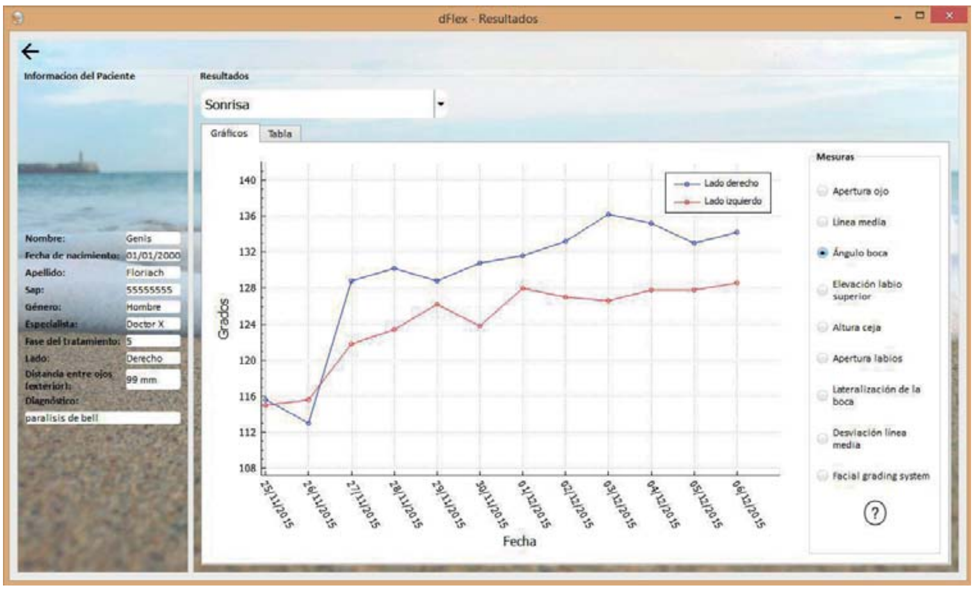

b)

Figure 3. The software aiding tool for facial paralysis rehabilitation: a) the automated measurement window and b) the statistics windows

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ASSESSMENT IN A LEARNING-CENTERED COURSE DESIGN FRAMEWORK

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ABSTRACT

It is important for course designers to establish assessments in accordance to intended learning outcomes and course activities in order to promote deep learning in higher education. In this context a learning-centered course design (LCCD) framework could be utilized to interconnect the assessments towards the high level learning objectives and learning activities. The primary objective of this paper is to highlight the effectiveness of using such a framework with the emphasis on assessment component for developing a new course, Fluid Mechanics, at Linköping University, Sweden. This study indicated an implementation of the LCCD framework, which facilitate establishment of CDIO Standards 8 and 11. This has been achieved by designing an assessment method that involves active learning activities in accordance to the intended learning outcomes. The inherent property of this approach, the integration between different components of teaching, is thus the key feature in achieving the highlighted standards and contributes in enhancing the student's knowledge, skills and attitude within the subject.

KEYWORDS

Student-centered learning, Constructive alignment, Active learning, Developmental assessment, CDIO standards: 8, 11.

INTRODUCTION

According to Black and Williams (1998), assessment includes all classroom activities that students carry out, such as observing the students within class discussions, analyze their classwork and/or homework, tests and etc. These analyses can be used for improving teaching and learning process according to the students' learning needs, i.e. student-centered learning. Snyder (1971) found that what influenced the students was the method of assessment and not the method of teaching. Moreover, Ramsden (1992) discussed that from the students' point of view it is the assessment that forms the curriculum and not the material indicated in the curriculum.

It is therefore important to strive for assessment activities that effectively work towards the intended learning outcomes (ILO) of the curriculum during the design process. This is also reflected in the description of the CDIO Standard 11, stating that the assessment of student learning should reflect on the extent in which individual students achieves specified learning outcomes. This standard highlights assessment of student learning in personal and interpersonal skills as well as in disciplinary knowledge, which in turn can call for developmental assessments (DA) correlated to active learning activities (ALA). While according to Garfield (1993) active learning activities play an important role in disciplinary knowledge, they assist the students in developing other personal and interpersonal skills and attitudes such as teamwork and communication, see Loyer et al. (2011). Establishing teaching methods under the concept of ALA has been well documented, e.g. Meyers and Jones (1993), Shakarian (1995), Silberman (1996). High importance of ALA has been highlighted by CDIO under Standard 8, which calls for direct student engagement in thinking and problem solving activities, rather than listening passively to an instructor. Thus, the instructor will incorporate active learning methods in order to foster active learning.

The importance of integration between ILO, DA and ALA have been highlighted. In order to facilitate course designers for establishing such integrations, a learning-centered course design (LCCD) framework could be used Fink (2003), which interconnects the high level ILO to the DA and also ALA; which also can be viewed as constructive alignment Biggs (1999). This framework has been used to develop a new course, Fluid Mechanics (TMMV18), at the Division of Applied Thermodynamics and Fuid Mechanics. This course is an intermediate course in fluid mechanics, taught entirely in english and open for program students and international exchange students. The objective of the current study is to evaluate the DA method which has been employed when utilizing this framework for designing this course. The contribution of the used method in CDIO standards will be addressed in order to indicate how assessment methods in a LCCD framework can enhance implementation of CDIO programs in course design level.

In the subsequent sections first a brief review on the implementation of the LCCD framework for designing this Fluid Mechanics course is given. Then details of the developmental assessment will be covered. Afterwards, students' perception and CDIO related discussions will be given followed by concluding remarks.

LCCD FRAMEWORK FOR COURSE DESIGN

To productively establish learning processes that facilitate the students learning requires careful considerations in the course design stage, Diamond (1998). Figure 1 indicate the LCCD components, also used by Whetten D. (2007), Fig. 1.

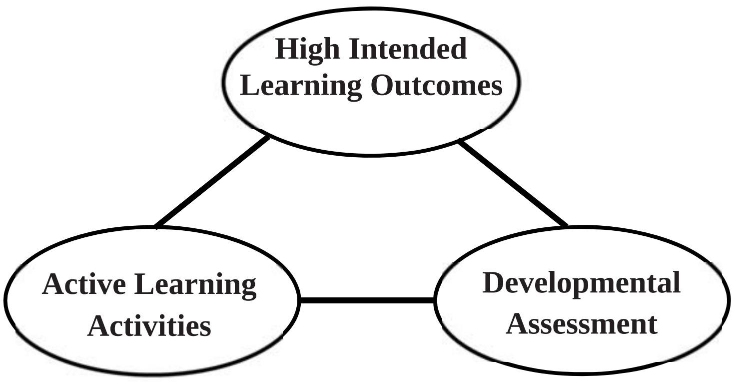

Figure 1: Components of learning-centered course design adapted from Fink (2003) and Whetten D. (2007).

The order in which these LCCD components are defined in this study reflects on the so called ‘’backwards design’’, Wiggins, G. (1998). This design outline has the following steps:

1) Explicit high intended learning outcomes have to de defined. In this regard, the taxonomy of learning objectives (verbs) suggested by Anderson and Krathwohl (2001) have been used for this course. This includes both comprehension (remembering, understanding and applying) and application (analyzing, evaluation and creation).

2) Valid developmental assessment of student learning, i.e. progressive examination and feedback throughout the course, needs to be identified based on ILO. This indeed has to reflect on questions such as how can I assess high level learning outcomes in the best and effective way. The consistent and effective implementation of such assessments has been shown to be the hardest element of LCCD, see Walvoord and Anderson (1998), Wiggins (1998). The DA for the course subjected to this study is designed such that it consists of two parts: i) performing a number of defined tasks during the course period and ii) written examination. Since DA is the core of the study, it will be addressed in detail in the consequent section.

3) Appropriate active learning activities must be created in order to promote engaged learning. The activities for this course include lectures, seminars, computer lab sessions and lesson session. Among these, the seminars will be addressed more elaborately in the following section as they are part of the DA. Figure 2 indicates the distribution of different activities including performing different tasks during the course. This Gantt Chart has been provided to the students to assist them in the planning throughout the course.

This design order highlights the choices of the students learning assessments that should follow the activities designed to enhance the learnings.

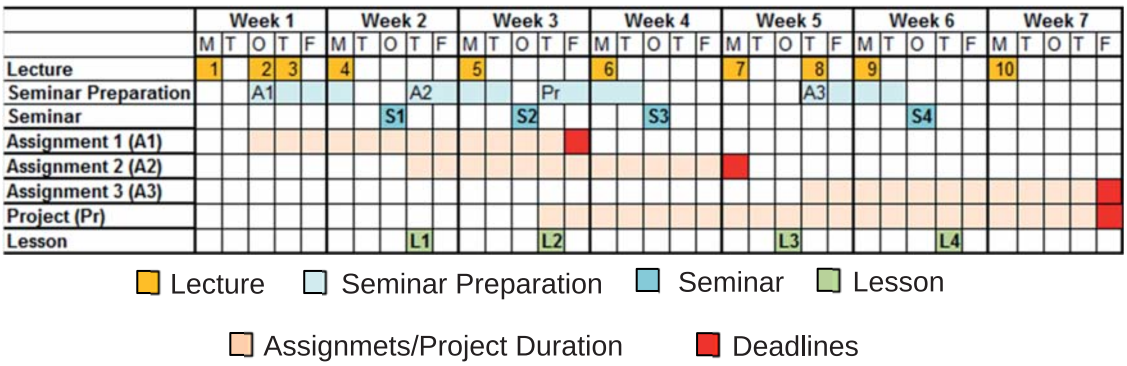

Figure 2: Distribution of different activities shown as Gantt Chart.

DEVELOPMENTAL ASSESSMENT

The developmental assessments for this course has two components, i.e. tasks (named assignments and project) distributed during the course and a final written examination. Table 1 indicates the contribution of these tasks as well as the written examination. It also shows the different activities designated to each task, which they have also impact in the assessment.

The assignments and project structure, which are considered also as part of the active learning activities, are described in the following content. A problem in line with the learning outcomes will be given to the students to be solved. The process in which the problems are solved is considered as jigsaw group project, Clarke (1994), and is divided into three phases (seminar preparation, seminar and final report) according to Tab. 1. It is worth mentioning that the project combines features from the assignments in a more advanced level and also demands slightly higher scientific level when it come to the final report.

Table 1 The contribution of different activities in the final assessment of the course.

Activity	Maximum Points			Total Points	Contribution in the Final Assessment
	SP[A]	S[B]	FR[C]		
Assignment 1	1.5	0.5	2	4	
Assignment 2	1.5	0.5	2	4	
Assignment 3	1.5	0.5	2	4	
Project	1.5	0.5	6	8	
Total points from all assignments				20	20*0.5
Written Exam	20			20	20*0.5
Final Assessment					20[D]

[A]Seminar Preparation, [B]Seminar, [C]Final Report
[D]Grading is: 0 – 9.99p → Fail, 10 – 11.99p → 3, 12 – 15.99p → 4, 16 - 20p → 5.

Seminar Preparation: In this stage students will be given few generic questions, relevant to the problem, and essential to be understood in order to solve the problem in hand. Note that these questions are important part of the problem, but they will not lead to a complete answer. Thus the students will need to utilize their knowledge from these questions to be able to solve the problem in hand.

The students are expected to work in groups of two; in total there are 20 students, to provide their answers as a written document and within a time interval. Since, the questions have not been discussed previously, complete and correct answers are not expected and grading assessed based the level of answer, group summative assessment GSA. Feedbacks will be provided for the students in order to allow them for further improvements both for their final report as well as next seminar preparations.

Seminar: In the seminar, students are initially re-formed into focus-groups (4 to 5), dividing partners from the seminar preparation group, to work on one specific question from the preparation assignment. Since the students have provided preliminary answers, the instructor will decide on the question to be assigned to each group. In this way it can be assured that in each group there is at least one student with good background about that particular question and thereby can guide and lead the others.

> ***Note:*** In the first seminar (corresponding to assignment 1), the entire class was considered as one group and the students were encouraged to participate in the discussion by formulation of questions from the instructor. However, after this seminar the abovementioned formulation has been used throughout the course. The motivation for this will be discussed in the next section.

Thereafter students will conduct discussion between themselves to formulate a final answer to the specific given question. The instructor participates in the group discussions for both encouraging the students to contribute in formulating the answers and also to make sure that the right answer is developed. Active participation in the discussions will reflect on the students' assessment and contribute in the grading, and individual assessment. When the final answer has been achieved, the students will write them on the whiteboard. These seminars are organized in special classrooms where relatively long whiteboards are indicated around the class to give the possibility for each group to write their answers.

After this, from each group one or two representative students should also explain and present the final answer to the entire class, i.e. teaching others through panel discussion. The first objective here is to promote the learning by means of teaching, Springer et al. (1998). This oral activity is also utilized to encourage the student to participate further in the discussion and to improve their presentation skills. The presenter will change from one seminar to the other.

The seminar is considered as one of the ALA and further activities coupled to the assignments/project and seminars include lectures and computer labs. The lectures cover the foundation for performing the assignments and give an introduction to the problem. In the computer labs the students and instructor have the possibility to interact for solving the problem in hand problems.

Final Report: After the seminar, along with completion of the computer labs, the students are able to complete the given task and write a technical report including the answers to the questions together with some further investigations.

To facilitate the students in efficient writing and thus improving their writing communication skills, some guidelines regarding the structure of the report as well as a template have been provided.

The technical reports, written in the group formats as seminar preparation, will be assessed, graded (GSA) and direct reflections will be provided to the students. To engage the students further into critical thinking, each group is also asked to formulate a relevant question to the problem in hand. These questions will be collected and available in a web-based student platform called LISAM, which could be used as preparations for the final exam.

Group working and assessment can not only benefit the students by promoting learning through cooperative and active learning, promote skills etc., but also benefit the higher education institutions by reduced time and material resources required and reduced marking effort, Bacon (2005). However, it is of high importance to have procedures with fair, accurate and repeatable individual marks, e.g. see Thorley and Gregory (1994) and Burdett (2003). According to Lejk et el. (1999) integration of marks from group assessment is associated with some level of uncertainty, unease and reliability debate, in comparison to marks gained in individual assessments. Therefore, the DA for this course has also utilized the final examination to distinguish individual marks from group marks. The written examination covers content related to the lectures, assignments and teaching activities within the seminars, some relevant questions addressed within lesson sessions and also formulated questions by students.

STUDENTS PERCEPTION AND DISCUSSION

The developmental assessments approach for this course has been assessed using two anonymous surveys (A and B with similar questions) conducted during the course and an interview with three students after the final examination. Survey A was conducted after the first seminar and survey B in the end of the course. Since this DA method has been implemented for the first time, survey A was conducted in order to get preliminary measures about student's perception and possible indicators of success or failure related to the seminar preparations and seminars method. Obviously such an early survey may not reflect on the true impact of the method in student's learning. Therefore, survey B was conducted in the end of the course to obtain a more thorough quantitative measures about the influence of the DA in achieving the ILO. The interviews were conducted to obtain more detail information from the students including reflections about the final examination. It should be noted that from the total number of students (18), the number of respondents for survey A and B are 16 and 17, respectively. It is of utmost importance to note that in order to verify the findings of the study, further evaluation of the method is essential.

Considering the seminar preparations, the results from both survey questions (Q1-Q9) show that this activity can facilitate students for better understanding of the contents discussed in the seminar. However, the interview results suggest that the students will benefit the most from the seminar preparation if enough time is designated for it, the questions are formulated clearly and appropriate literature is suggested. Figure 2 reveals relatively tight schedule from introducing the seminar preparation until the seminar, i.e. aligned with students' comments. Therefore, it is wise to allocate appropriate time interval to use the advantages of the approach. The students will also benefit from clear questions and instructions as they can devote their time to actual problem-solving rather than interpretation and surfing for literature.

> **Q1:** The seminar preparations were valuable and helpful in better understanding of the contents discussed in the seminar. Both surveys: 76.4% respond in strongly agree and agree.

As noted earlier, the first seminar considered the entire class as one group for the discussion. Even though, the instructor could involve the students into the discussions to some extent, it was not satisfactory enough. Therefore, instructor decided to investigate the cause for low interest from the students to participate in the discussions through survey A. Interestingly, the results indicated that despite of students' interest in participation in the discussion (Q2) the organization of the seminar seemed to not the reduce the motivation (Q3). Further investigations have revealed that creating informal cooperative groups, which can facilitate active learning is an effective and convenient approach for in-class group discussion according to Giddon and Kurfiss (1990), Johnson and Johnson (1994a). Indeed, this was aligned with students' comments that indicated conducting the discussions in smaller groups can be helpful as it will give them more comfort for expressing their thoughts. Therefore, the organization of the seminars has been changed to the procedure, re-grouping within the seminar, mentioned in developmental assessment section. The responses from survey B (Q3), showed that this adjustment was appreciated among the students. Thus, the results showed the importance of small group learning in promoting students achievements and interest towards course materials aligned with finding of the comprehensive study done by Springer et al. (1998). More detailed comments from the interviews show the students appreciation for oral presentation and constructive feedback from the instructor, learning by teaching, giving directions rather than direct answers, instructor engagement. The students have recommended to prevent very deep discussions, focus towards the group as a whole and prior clarification on the content of the discussion.

> **Q2:** I would like to participate in the discussions as it will assist me for deep learning. *Both surveys:* 81.25% respond in strongly agree and agree.

Q3: The seminar was organized appropriately and could increase my knowledge while assisting me to complete the assignment. *Survey A:* 50% respond in strongly agree and agree. *Survey B:* 76.5% respond in strongly agree and agree.

An important part of the assessment has been designated to the final report. It has been found that providing instructions and templates can assist the students for finalizing a better report (Q4, survey B). The interview results indicate the importance of constructive feedback on the reports.

Q4: The templates and report instructions were convenient and supportive in finalizing a better report. *Survey B:* 70% respond in strongly agree and agree.

The students' interest in formulating questions was found to be relatively low (Q5 survey B). A possible explanation for this can be the fact that this question is addressed before rather than after the exam, hence the students have not practiced their own critical thinking outcome yet and have not seen the real use of their work. In the interviews, the students commented that by creating your own questions for the written exam you are involved in recognition of important contents.

Q5: I think creating questions as part of the assignments/project are helpful. *Survey B:* 50% respond in strongly agree and agree.

One of the important findings was that the students recognize the connection and integration between different parts and their alignment with the course objectives (Q6-Q8, survey B), i.e. constructive alignment The results from the interviews complement that the assignments and projects are clearly connected to the lectures as well as the final exam. The students also appreciate the scientific level of the project and the fact that it demands their knowledge from the earlier assignments. This in turn has facilitated the students for continuous increase of their knowledge and promoting their skills.

Q6: There was a clear connection between different activities (Lectures, Seminars, Lessons, Labs etc) and they matched with the course objectives. *Survey B:* 94.2% respond in strongly agree and agree.

Q7: Overall different parts of the course can enhance my knowledge. *Survey B:* 100% respond in strongly agree and agree.

Q8: Overall different parts of the course can promote my skills. *Survey B:* 94.2% respond in strongly agree and agree.

The results further showed that students have a major concern regarding the course workload (Q9, survey B). Although, this may be interpreted as students' engagement in quality learning, it can also hinder students learning. A comment from the students' interviews was related to low motivation for the final exam due to high workload during the course. The comment, however, also suggest that exam preparation assisted students to obtain deeper knowledge. This suggest that the efficiency of the DA method should be improved in this regard.

Q9: I think the course workload is normal and evenly distributed. *Survey B:* 12.5% respond in agree.

The developed assessment method employed for this course in its current form has a major limitation. This is associated with the possible number of students for the seminar sessions. Thus to maintain desirable interaction between the students and the instructor as well as time management considerations, the number of students should be retained in the limit of 20 per seminar session. In addition, an important aspect of this DA is to provide quality feedbacks on seminar preparation, seminars and final reports, to allow students to improve their performances. This can be a time demanding task for the instructor and may call for adjustments to improve the efficiency of the method.

Developmental Assessment and CDIO

CDIO Standard 8 emphasizes on using teaching activities that engage students directly in the learning process. The DA method developed through this LCCD framework utilizes a number of active learning methods. Performing the assignments/projects follow the jigsaw group project as a whole. The seminar preparation demands small group work on questions. The seminar includes the group and panel discussion for deep learning. The final report includes creating questions, which encourages the students to think deeper about the course material.

The description of CDIO Standard 11 clarifies that the level in which the students achieve specified learning outcomes of their respective courses is the true measure of the assessment of student learning. It is therefore highlighted that an effective assessment uses combination of assessment methods, including written and oral tests, observations of student performance etc. Within the employed method students are assessed based on their pre-study outcomes, participation in discussion and oral presentation, written communication skills and final examination. This DA examines students both with respect to their disciplinary knowledge and personal and interpersonal skills.

CONCLUDING REMARKS

A learning-centred course design framework has been used to develop an engineering course, Fluid Mechanics, at Linköping University. The students’ overall high grades and positive feedbacks, suggest an aligned integration between teaching activities and developmental assessment components of the LCCD to achieve high intended learning outcomes. However, implementation and evaluation of the method in the subsequent years is required for increasing the certainty of the outcomes.

In conclusion, the study highlights the importance of assessment in a LCCD framework in order to enhance the student’s knowledge, skills and attitude within the subject. Successful implementation of the developed method enables is an effective approach to meet CDIO Standards 8 and 11.

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WORKSHOP ON IMPLEMENTING COMMUNICATION ACTIVITIES IN ENGINEERING EDUCATION – INTEGRATING CONTENT AND LANGUAGE

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ABSTRACT

This workshop aims to establish the main aspects of incorporating *CDIO Syllabus 3.2 Communication* in engineering education. Various aspects of communication and writing in the disciplines have been central to the CDIO initiative since the start. However, to institutions new to CDIO, this may not be as well-known. Therefore, this workshop will investigate some of the reasons for having communication education in engineering disciplines. These reasons include *writing as a cognitive tool*, *writing for disciplinary socialisation*, and, of course, *writing to communicate disciplinary knowledge*.

In the workshop, we will look at how communication (writing and speaking) can be implemented and integrated in different types of courses and student projects. We will also look at how such learning activities can be designed to meet assessable learning outcomes while at the same time scaffolding content knowledge-building and professionalization.

Curriculum design and progression of learning sequences are also important aspects of integrating and designing learning activities around writing and speaking in engineering programmes, and this is something that will be addressed in the workshop.

Participants in the workshop will be able to work on existing communication activities in their respective engineering programmes, or on potential learning activities that can be implemented as new components in an engineering programme. Thereby, the workshop is designed to cater for both those who have worked extensively with CDIO-implementation, as well as for those whose institutions are new members in the CDIO initiative.

KEYWORDS

Communication, Writing, Speaking, Integration, Curriculum design, Standards: 1, 2, 3, 7, 8

WORKSHOP INTRODUCTION

Communication skills in various aspects are important engineering attributes that we need to equip our students with. This is also acknowledged and promoted in the CDIO initiative through Syllabus 3: *Interpersonal skills: Teamwork and Communication* which emphasizes communicative aspects that students need to acquire. There are many different educational concepts in higher education in general, and in engineering education in particular, where writing and communication are integral components. In many cases these components are seen as generic graduate attributes and in other cases they are seen as more discipline specific attributes. There are many different approaches and initiatives in higher education that deal with teaching and learning these communicative attributes such as *Writing-Across-the-Curriculum* (WAC) and *Writing-in-the-Disciplines* (WID) where writing is seen as central and something that goes against the misconception that writing (instruction and learning) is separate from content (instruction and learning).

Within these approaches, apart from the concept of *Learning-to-Write*, writing is therefore seen as a cognitive tool (Tynjälä, Mason, & Lonka, 2001) for understanding and contributing to disciplinary knowledge – *Writing-to-Learn*. With this view, it is fair to say that communication is part of several of the CDIO Standards in terms of understanding the context (*Standard 1)*; learning objectives (*Standard 2)*; integrated curriculum (*Standard 3)*; integrated learning experiences (*Standard 7)*; and active learning (*Standard 8)*.

The importance for our engineering students to develop good communication skills (with well-defined learning objectives, clearly designed learning activities, and suitable assessment practices) is recognized by most teachers and programme managers alike. The problem is how to fit it into an already full curriculum without taking away what is already there. One solution to that problem – which is also the theme for this workshop – is to integrate communication and content and not treat it as a separate subject.

This integration can also be seen as a shift from a pure skills model to academic literacy and writing as academic socialization (Lea & Street, 2006) which means that communication activities support students' active participation in the academic and discipline specific discourse. By introducing "apprenticeship genres" (Carter, Ferzli, & Wiebe, 2007) students are given different assignments typical to the specific disciplines that help them understand and reproduce communicative patterns and text types within their field of study.

With the help of the CDIO curriculum, we are going to define learning objectives for written and oral communication in different engineering educational settings. We are also going to explore different ways of integrating communication objectives and activities in existing content courses. In this sense, we are also going to discuss potential "added value" to students' learning by using communication activities for acquiring content knowledge and skills.

Workshop organization

Participants in the workshop will work actively with learning objectives for writing and speaking within existing engineering education. This can be carried out at a curricular level or in a specific course or course component. During the session, we will explore potential communication activities (written and oral genres) that can be used as learning activities in various disciplinary settings, with a focus on STEM education. This can of course also be transferred to other disciplinary contexts outside of STEM for any participants who would want that.

The discussion on "who should teach?" and "who should assess?" is an important part of the workshop, and we will look into different ways of sequencing and integrating learning activities in content courses, and ways of enabling engineering content teachers to teach and assess this with the help of language and communication experts. The concepts of peer response and self-assessment will be explored to further scaffold communication learning activities and assessment.

The development of rubrics and criteria will be introduced to make the connection between learning objectives and assessment practices clear, and participants will create an outline for assessment strategies and assessment goals within their own disciplinary setting.

Overall, the workshop aims to cater for participants from all disciplines and at any stage when it comes to CDIO implementation. Therefore, it is the ambition to provide useful outcomes for faculty new to CDIO and new to integrating communication and content, as well as for faculty who are well familiar with writing and speaking instruction in a CDIO context.

Workshop outcomes

The workshop has a broad scope in order to provide a foundation for integrated language and communication activities in engineering education. This means that it is possible to "tailor" some of the workshop components or activities to suit individual participants' needs. However, the basic outcomes for the workshop are that participants should have the opportunity to explore and develop an understanding for ways of working with language and communication in higher education. This can be summarized in the following list:

- *Identifying different purposes for communication learning activities*
- *Finding appropriate (apprenticeship) genres and communicative contexts in STEM education*
- *Establishing a relationship between content learning and participation in the disciplinary discourse (integrating communication and STEM specific content)*
- *Designing learning outcomes for integrated writing and speaking activities*

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APPLICATION OF CDIO APPROACH TO ENGINEERING BENG, MSC AND PHD PROGRAMS DESIGN AND IMPLEMENTATION

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ABSTRACT

The paper presents the results of analyses and evaluation of the *CDIO Syllabus v2* relevance to the design of undergraduate (BEng), graduate (MSc) and postgraduate (PhD or Aspirantura in Russia) engineering programs. The analysis is based on requirements to the competencies of graduates at various higher education cycles taking into consideration the *Russian Federal State Educational Standards* (FSES) and the accreditation criteria of the *Association for Engineering Education of Russia* (AEER) harmonized with the International Engineering Alliance (*IEA) Graduate Attributes and Professional Competences* and *EUR-ACE Framework Standards and Guidelines.* The results of examination of the structure and content of the *CDIO Syllabus v2* made by the participants of the network training program “Applying the concept of CDIO in Engineering Education” developed and implemented by Tomsk Polytechnic University and the Skolkovo Institute of Science and Technology also used in the paper. It is recommended to adjust the requirements of *CDIO Syllabus v2* to learning outcomes of BEng, MSc and PhD programs graduates considering the peculiarities of complex, innovative and research engineering activity.

KEYWORDS

Undergraduate, graduate and postgraduate engineering programs, graduate learning outcomes, accreditation criteria, Standard 2.

INTRODUCTION

Due to the up-to-date world technological development, the division of labor in the field of engineering is becoming more complicated. It is therefore necessary to develop *tiered system of engineering education* and training of university graduates for different types of professional activity. In accordance with the Bologna process in Europe, including Russia, as well as in a number of other countries, the tiered system of higher engineering education is formed by the implementation of programs at three levels: *undergraduate (*Bachelor’s programs*), graduate (*Master’s programs*)* and *postgraduate (*PhD-programs or Aspirantura-programs in Russia*)*.

Many universities around the world use the *CDIO approach (Conceive, Design, Implement, Operate)* (E. Crawley et al, 2014) to update their Bachelor’s (Beng) programs to prepare graduates to more *complex engineering activities* at all stages of the life cycle of technical objects, processes and systems. This approach is widely used, as it is consistent with the requirements of international standards (*IAE Graduate Attributes and Professional Competences*) to the engineering HEI's graduate learning outcomes and competences of professional engineers (www.ieagreements.org/IEA-Grad-Attr-Prof-Competencies.pdf). The *CDIO* approach allows the design and implementation of BEng programs as a basic engineering education in accordance with the criteria for accreditation of engineering programs in the countries - signatories of the *Washington Accord*, including the accreditation criteria of the Association for Engineering Education of Russia (AEER) (A. Chuchalin, 2012).

Master's (MSc) programs in engineering in accordance with the AEER accreditation criteria, harmonized with *EUR-ACE Framework Standards and Guidelines*, generally orient graduates towards *innovative engineering activities* (www.enaee.eu/eur-ace-system/eur-ace-framework-standards). Russian postgraduate programs (Aspirantura) as required by Federal State Educational Standards (FSES) focus mainly on preparing graduates for *research activities* in the field of engineering sciences. The report of the *«Quality Assurance in Doctoral Education - results of the ARDE project»,* carried out by the European University Association *(EUA),* contains similar recommendations for the *PhD* – programs (*J. Byrne et al.* 2013).

It should be noted that Bachelor's are involved in complex engineering activities at the *Conceiving* and *Designing* stages of technical objects, processes and systems. However, in practice, BEng program graduates are more often involved in the *Implementing* and *Operating* of products and systems. Innovative activities of MSc program graduates are often concerned with the *Design* of new engineering products or systems. Research activities of PhD–program graduates mainly aim at creating a scientific basis for the development of innovative products and systems at the *Conceive* stage. However, Masters and PhD-holders may also participate in the *Operating* and *Implementing* of engineering products and systems.

The Systems approach to the design of engineering education at the Master's and PhD – levels, similar to the CDIO approach to the basic engineering education at the Bachelor's level, is still in its early stages of development. At the same time, it is important for research universities, such as Tomsk Polytechnic University, the Skolkovo Institute of Science and Technology and others to develop guidelines similar to *CDIO Standards* and *CDIO Syllabus* to improve the quality of educational programs in engineering and technology at Master's and PhD levels. The advantage of the *CDIO Syllabus* is that in contrast to the accreditation criteria, the *CDIO Syllabus* requirements are more detailed and are comfortable to use in the curriculum design process. At the Skolkovo Institute of Science and Technology, a special Learning Outcomes Framework has been developed for the design of graduate and postgraduate programs focused on research and innovation (E. Crawley et al. 2013). The Framework is an extension of the CDIO syllabus v2 but does not take into account peculiarities of intended learning outcomes for MSc and PhD-program graduates related to the peculiarities of their future professional activities.

Currently, for the design of undergraduate engineering programs, the *CDIO* approach recommends the learning outcomes presented in the *CDIO Syllabus v2* (Crawley, E.F. et al. 2011). *The* structure, content and implementation technology of educational programs depend on the intended learning outcomes. Thus, the structure and content of the learning outcomes presented in the *CDIO Syllabus* are the system-forming factors in the design of engineering programs.

All learning outcomes presented in the *CDIO Syllabus v2* are relevant to BEng programs focused primarily on the preparation of graduates for complex engineering activities. However, the degree of their relevance is different, which is reflected in the structure and content of engineering programs. The degree of relevance of *CDIO Syllabus v2* sections and items for MSc programs and PhD-programs may differ significantly from the degree of their relevance to BEng programs as they are intended for training of graduates for other types of activities (research and innovation).

The authors of the second edition of the book *«Rethinking Engineering Education, the CDIO Approach» (Springer*, 2014) indicate the fundamental possibility of adapting the *CDIO* approach to the development of Master's and *PhD*-programs (E. Crawley et al, 2014). However, they do not give recommendations on how to adapt the *CDIO Standards* and *CDIO Syllabus* to a tiered system of engineering education taking into account the differences between intended learning outcomes for BEng, MSc and PhD-programs related to the differences between prioritized professional activities of their graduates.

This paper is an attempt to further analyze and evaluate the relevance of the *CDIO Syllabus v2* to design educational programs for undergraduate, graduate and postgraduate studies in engineering and technology. The analysis is based on different requirements to the competencies of graduates at various higher education cycles for complex, innovative and research activities. Integration and systematization of the requirements of the Russian FSES and AEER accreditation criteria harmonized with the *IAE Graduate Attributes and Professional Competences* and *EUR-ACE Framework Standards and Guidelines* define the requirements to the competencies of BEng, MSc and Aspirantura (PhD) program graduates. The results of the examination of the structure and content of *CDIO Syllabus v2* made by the participants of the network training program "Applying the concept of CDIO in Engineering Education" developed and implemented by Tomsk Polytechnic University and the Skolkovo Institute of Science and Technology (A. Chuchalin, 2015) are also used in the paper. Representatives of 15 universities from Russia and the CIS countries took part in the study.

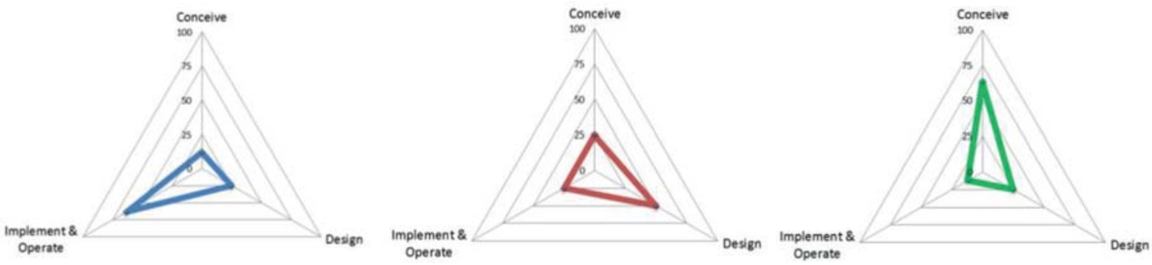
TYPES OF ENGINEERING ACTIVITIES AND COMPETENCIES OF GRADUATES

As mentioned above, the graduates of BEng programs are mainly trained for complex engineering activities: Conceive, Design, Implement and Operate technical objects, systems and processes, solving a wide variety of technical and other issues at all stages of the engineering product life cycle. Solving complex engineering problems requires *basic* knowledge of mathematics, natural sciences, engineering and other sciences, as well as specific technical, economic, administrative and other knowledge, including interdisciplinary knowledge in the area of specialization.

Analysis of Federal State Educational Standard and AEER criteria shows that most core competencies of Bachelor's (>60%) corresponding to AEER accreditation criteria, are related to complex engineering activities at the stages of *Implementation & Operation* of technical objects, processes and systems. About 25% of the intended learning outcomes are focused on *Design*, and a little more than 10% of competencies enable Bachelor's to participate in activities at the *Conceive* stage. This structure of competencies defines the prioritized area of s' professional activities (Figure 1, a).

Masters are prepared mainly for innovative engineering activities aimed at the development and design of new technical products, systems and technologies for human needs to get social and (or) economic impact, and therefore demanded and competitive. Innovative engineering is an interdisciplinary activity. It requires *deep* fundamental and applied knowledge, based on the analysis and synthesis of technical objects, systems and processes with the use of mathematical models of the high level with more emphasis on Interdisciplinary knowledge.

Half of the master's learning outcomes (50%) corresponding to the AEER accreditation criteria are related to *Design*, 25% are focused on *Implement & Operate*, and 25% of competencies enable Masters level graduates to participate in activities at the *Conceive* stage. This structure determines the scope of the Master's graduate main professional activities (Figure 1, b).



a) b) c)

Figure 1. The areas of prioritized engineering activity
of Bachelor's, Masters and PhD-holders

The PhD-program graduates are prepared mainly for *research activity* in the field of *engineering sciences*. It aims to *generate* new knowledge and to transform fundamental knowledge into applied knowledge for its subsequent use in engineering, as well as scientific support of the development of new technical products, systems and technologies based on research results.

In the draft of new Russian Aspirantura FSES for the area "Engineering, technology and technical sciences" the majority (>60%) of expected graduate competencies is connected with the preparation for research activities at the stage of *Conceive*, 25% of learning outcomes focus on activities at the stage of *Design*, and a little more than 10% of competencies refer to *Implement & Operate* stages. This structure of competencies defines the area of prioritized activities of Aspirantura (PhD)-program graduates (Figure 1, c).

APPLICABILITY OF *CDIO SYLLABUS V2* ITEMS FOR BENG, MSC AND PHD-PROGRAMS

A group of experts from leading Russian universities was asked to assess the applicability of *CDIO Syllabus v2* items. Figure 2 shows the results of expert assessment of the grade of applicability of the *CDIO Syllabus v2* items, as factors for planning learning outcomes of Bachelor's, Master's and PhD-programs in engineering and technology. The grade of the *CDIO Syllabus v2* items applicability is evaluated by 4 - point scale: 1 - low, 2 - medium, 3 - high, 4 - very high.

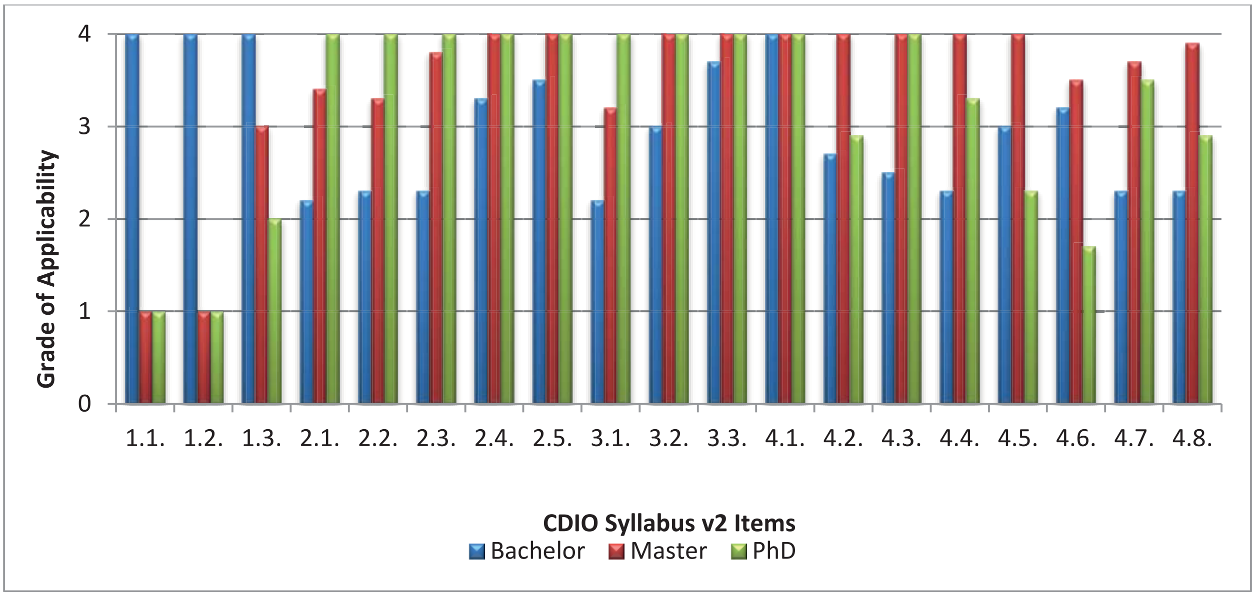


Figure 2. The level of applicability of the *CDIO Syllabus v2* items for planning learning outcomes for Bachelor's, Master's and PhD-program graduates

The explanatory comments to the results of the expert evaluation of topics of the *CDIO Syllabus v2* sections and items for planning learning outcomes for Bachelor's, Master's and PhD-program graduates are as follows.

SECTION 1 OF *CDIO SYLLABUS V2*

"Knowledge of underlying mathematics and sciences" (Item 1.1), "Core engineering fundamental knowledge*"* (Item 1.2), as well as "Advanced engineering fundamental knowledge, *methods and tools"* (Item 1.3) corresponding to the field and specialization of training are necessary for complex engineering activities. This knowledge should be fully acquired within undergraduate educational programs. The AEER accreditation criteria require that at least a quarter of scientific and educational resources of a program (60 out of 240 *ECTS* credits of a 4-year Bachelor's programs) should be provided to the study of mathematics and natural sciences.

The advanced natural science and mathematical training necessary for innovative engineering activities in a relevant field to be carried out at the Master's level (AEER criteria recommend up to 15 of the 120 *ECTS* credits of 2-year Master's programs). The study of advanced methods and tools for engineering activities related to the specialization is also possible. However, far fewer resources are required for this in MSc programs than at the BEng level. Development of the competence to generate new scientific knowledge, the level of which significantly exceeds the level of basic knowledge, is a task of training for PhD-program graduates. Therefore, scientific and educational resources on assimilation of ready-to-use knowledge should be limited in PhD-programs.

Thus, for the design of engineering programs at the MSc and PhD levels, it is necessary to adapt Items 1.1 and 1.2 the *CDIO Syllabus v2* to the requirements of preparing graduates for innovation and research activities. It is felt that some focus must be given to interdisciplinary knowledge to broaden the perspective of graduates and post-graduates. Some specific knowledge in the processes of innovation should also be considered. It is advisable to specify the wording of Item 1.3 of the *CDIO Syllabus v2* for different higher engineering education levels, taking into account the intended learning outcomes.

SECTION 2 OF *CDIO SYLLABUS V2*

"Analytical reasoning and problem solving" (Item 2.1), especially in the "Formulation, analysis and evaluation of the problems in the face of uncertainty", as well as making recommendations to address them, refer to the competencies of graduates of MSc and PhD studies to a greater extent. These competencies are especially important for innovation and research engineering activities. BEng program graduates deal to a lesser extent with pure analytical work. However, in the course of complex engineering activities, they can use the models of technical objects, processes and systems that have been developed by graduates of MSc and PhD-programs. It is necessary to consider this in the design of appropriate educational programs.

"Experimentation, investigation and knowledge discovery" (Item 2.2) is more typical for graduates of MSc and PhD-programs engaged in innovation and research engineering activities. This is especially true for the topic of formulating, testing and defense of hypotheses. It applies to a lesser extent to the search for information using print and electronic media, where BEng program graduates can also be engaged in the process of complex engineering activities.

"System thinking" (Item 2.3) necessary to evaluate and find a balanced solution to various problems in determining the priorities and reaching trade-offs in innovation and research engineering activity is required from MSc program graduates and PhD-holders to a greater extent than from BEng program graduates. System thinking is also necessary for ,s to be able to understand the conditions of occurrence of systems and the ability to organize system interactions in the process of complex engineering activities. However, more attention should be given to the formation in system thinking for graduates in MSc and PhD programs than in BEng programs.

The expert assessment shows that initiative, decision-making, perseverance in achieving goals, creative and critical thinking, time and resources management are almost equally required from Bachelor's, Master's and PhD-programs graduates. Engineering specialists of all categories, each at their own level of engineering activity should be aware of the importance of self-education and lifelong learning, integration of knowledge and formation of *"Personal attitude, thought and learning"*.

Graduates of BEng, MSc and PhD-programs must demonstrate truthfulness, social responsibility and commitment to professional ethics. They should be able to perceive the adversity in modern relationships in the world of engineering and technology with confidence, loyalty and in an impartial manner, have a personal vision and intention in life and professional courtesy. All this defines "*Ethics, equity and responsibility"* (Item 2.5) of each engineering specialist in his/her workplace.

Thus, according to expert assessment, Items 2.1, 2.2 and 2.3 of the *CDIO Syllabus v2* are more relevant for the design of MSc and PhD-programs than for BEng program design. This should be considered in the distribution of scientific and educational resources of corresponding programs. It is advisable to adapt the wording of Items 2.1, 2.2 and 2.3 of the *CDIO Syllabus v2* for various higher engineering education levels. The urgency of the requirements in preparing Bachelor's, Masters and PhD-holders to complex, innovative and research engineering activities in Items 2.4 and 2.5 of the *CDIO Syllabus v2* is almost identical. This should be considered when designing engineering programs at all levels.

SECTION 3 OF *CDIO SYLLABUS V2*

"Expertise in *teamwork"* (Item 3.1) and "*Communications"* (Item 3.2), including "C*ommunication in foreign languages"* (Item 3.3) is important for any kind of engineering activity. According to expert assessment, Bachelor's, Masters and PhD-holders must be almost equally able to develop a communication strategy, possess writing and speaking skills, carry on a dialogue, use graphic and electronic media, establish communication and build up networking. The AEER accreditation criteria recommend 20 - 30 credits of humanities and economic sciences in BEng programs within the 240 *ECTS* credits of 4-year programs. However, such abilities as negotiation, compromise, conflict resolution, formation of effective team, leadership, team management and team development are mostly required from Master's and PhD-program graduates. The particular relevance of Item 3.1 and a number of components of Item 3.2 of the *CDIO Syllabus v2* should be reflected in the structure of the scientific and educational resources of Master's and PhD-programs to prepare graduates for innovation and research in engineering and technology.

SECTION 4 OF *CDIO SYLLABUS V2*

Understanding the "*Social and environmental context"* of engineering activities (Item 4.1) is a requirement to all categories of specialists in the field of engineering. It is important to understand contemporary issues and values of the human civilization, its historic role and the responsibilities of the engineer, the cultural aspects of engineering, the impact of engineering on society and environment and the need for sustainable development and the global perspectives.

As a part of "*Enterprise and business context"* (Item 4.2) graduates of engineering programs at all levels need skills to work in organizations, experience in engineering entrepreneurship, ability to use new technologies for the development and evaluation of professional activities. Work experience in international organizations engaged in innovation and research activities, ability to evaluate the interest of various stakeholders, defining goals and strategy considering economic and financial aspects of engineering design are particularly necessary for graduates of Master's and PhD-programs. This should be taken into account during the formation of scientific and educational resources of corresponding programs.

Experience in "*Conceiving, system engineering and management"* (Item 4.3) and "*Designing"* (Item 4.4) of technical objects, processes and systems is more important for Masters and PhD-holders than for Bachelor's. In the area of '*Implementing"* (Item 4.5), the ability to design sustainable manufacturing processes, the system integration of technology and software products, as well as production management are the most important topics for graduates of MSc programs. According to the expert assessment, the graduates of BEng programs need skills in the production, testing, verification, validation and certification of end products. Production skills are not very relevant to PhD-holders. The difference in training specificity needs to be reflected in the distribution of scientific and educational resources within engineering programs at various levels.

According to the expert assessment, skills and experience in "*Operation"* (Item 4.6) of technical objects, processes and systems are important for BEng and MSc program graduates. The skills in the design and optimization, the sustainability and product safety, the experience in how to operate technical products and their systematic improvement and evolution are most important for Masters graduates. The most relevant skills for Bachelor's who are actively involved in complex engineering activities are the following: supporting the system life cycle, including decommissioning and disposal of products with the determination of the impact on the environment. Preparation for most of the stages of the production operations is not highly relevant to PhD-holders except their possible participation in the process of system improvement and evolution of engineering products. A significant difference in the degree of applicability of competencies of Bachelor's, Masters and PhD-holders in the use of the skills of engineering for product operation should be taken into account in the design of appropriate educational programs.

Competencies in the "*Leading engineering endeavors"* (Item 4.7) are essential for high-level specialists involved in innovation and research activities. The ability to identify a paradox, thinking creatively and visioning of high-level solutions, leadership skills in the organization and beyond, are most important for PhD-holders. The ability of thinking creatively and visioning of high-level of solutions are also important for MSc program graduates. However, preparing for innovation in terms of development and defense of projects, project planning and management, control over their implementation until completion is even more important for Masters rather than for PhD-holders. All of the components of leadership competencies in engineering enterprises are a priority for Master's and PhD-program graduates. According to the expert assessment, they are likely to be less required for BEng program graduates in the course of complex engineering activities. It is advisable to consider these peculiarities during the design of educational programs.

The ability for "*Engineering entrepreneurship"* (Item 4.8) is obviously mostly manifested in innovative engineering. Therefore, adequate scientific and educational resources aimed at developing an entrepreneurial culture should become a significant part of MSc programs. The recommended volume for entrepreneurial and innovation activity is at least 30 credits within the 120 *ECTS* credits for 2-year Master's programs according to AEER accreditation criteria. However, for complex engineering situations, Bachelor's can also participate in entrepreneurial activity, creating enterprises and develop innovative product marketing. They may also require entrepreneurship skills in knowledge-intensive business planning, production and services design using new technologies, development of a new innovation system and new engineering processes, creation of an innovation infrastructure and, in particular, management of the intellectual property. Varying degrees of applicability of Section 4 items of the *CDIO Syllabus v2*, related to social, environmental, entrepreneurial and business context of complex, innovative and research engineering activity should be considered when designing engineering programs of Bachelor's, Master's and PhD-studies through the appropriate distribution of scientific and educational resources. When designing the structure and content, as well as considering the technologies for program implementation at various levels, it is necessary to provide resources adequate for priorities in the formation of certain competencies for the planning, systems engineering and management, as well as the design, implementation and operation of technical objects, processes and systems at different levels.

CONCLUSION

In order to use the *CDIO* approach for the design of tiered engineering programs in order to improve their quality, it is necessary to adjust the content of the *CDIO Syllabus v2* to the learning outcomes of BEng, MSc and PhD-programs, considering the peculiarities of complex, innovative and research engineering activities. It is possible to improve the structure, content and implementation technologies of tiered engineering educational programs based on the CDIO Syllabus, adapted to the training of specialists in the field of engineering and technology for various types of activities. It is important to distribute the scientific and educational resources of BEng, MSc and PhD-programs for the effective achievement of the intended learning outcomes. It is also appropriate to update the *CDIO Standards*, defining the requirements for educational programs at various levels in the context of specific engineering activities, including the requirements of the curriculum, the learning environment, the learning technologies, the professional qualifications of teachers and the methods of evaluation of programs and the particular graduate learning outcomes.

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BIOGRAPHICAL INFORMATION

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DESIGN-BUILD EXPERIENCES – ICU GAME CAPSTONE PROJECT

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ABSTRACT

A capstone innovation project has a central role in the third study year of the curriculum of Degree programme in Information and Communication Technology at Turku University of Applied Sciences (TUAS) in Finland. The Capstone innovation project is one of our implementation examples of CDIO Standard 5 (Design-Implement Experiences). In this paper we focus on describing one of these innovation projects called ICU game. The project assignment came from another faculty of TUAS (Faculty of Health and Wellbeing). Their partners in this project were Intensive Care Unit (ICU) of the Turku University Hospital and Faculty of Nursing Science at Turku University. The intensive care unit employs a large number of nurses. Work in an ICU requires specific expertise. This expertise can be achieved partly through working in an ICU and partly in training sessions. The idea of the ICU game was to develop a tool/a serious game for nursing education to support learning these ICU specific skills and knowledge. The aim of the project was to develop a serious game prototype simulating and teaching intensive care unit operations. The game development project used user-centric methods together with possibilities in simulation and virtual pedagogy. The capstone innovation project used three phases of CDIO – Conceive, Design and Implement. The project team started conceiving the needs, the specific environment of ICU and possible other tools in the market. After the conceive phase a prototype was designed and implemented in a cyclic process.

KEYWORDS

Capstone, Innovation project, Game development, Intensive Care Unit, Education game, CDIO, Standards: 5, 8

INTRODUCTION

The Capstone innovation project implements thinking known as the Lean Startup philosophy, which includes testing the ideas on real customers as early as possible. Through this kind of thinking and activity, the students learn to take the users into account and build working solutions which the customers are also ready to pay for. (Crawley et al 2014.) The capstone innovation project has a central role in the third study year of the curriculum of Degree Programme in Information and Communication Technology at Turku University of Applied

Sciences (TUAS) in Finland. This project is a 15 ECTS module combining students from the Degree Programmes in Electronics, Information and Communication Technology, Business Administration and Library and Information Services in a multidisciplinary way. In addition, Capstone unites working life with studies in a realistic and concrete way, thus benefiting both the students and the customer companies. The Capstone innovation project is one of our implementation examples of CDIO Standard 5 (Design-Implement Experiences). All innovation projects are real projects raising from the needs of the partner organizations. In this paper we focus on describing one of these innovation projects called ICU game. The project assignment came from another faculty of TUAS (Faculty of Health and Wellbeing). Their partners in this project were Intensive Care Unit (ICU) of the Turku University Hospital and Faculty of Nursing Science at Turku University. The intensive care unit employs a large number of nurses. Work in an ICU requires specific expertise. This expertise can be achieved partly through working in an ICU and partly in training sessions. The idea of the ICU game was to develop a tool/a serious game for nursing education to support learning these ICU specific skills and knowledge.

Critical care/intensive care is in interest of large number of nursing students (39%). However, only minority of nursing students (14%) have the possibility during nursing education to practice at intensive care unit (ICU unit) because places for nursing students are too few. Critical care nursing is an own specialty in nursing field and requires specific competence of nurses. At this moment critical care nursing courses' amount of ECTS credits vary between 0 – 5 in Finland. Also there are not any post graduate specialist nursing educations in Finland for this need. The growing need for special education at the basic nursing education level is evident. (Cf. Lakanmaa 2012).

Young new nursing students seek innovative new effective learning methods. Also the need of digitalization and the decreased number of amount of theory and class room teaching play an important role and create pressure for nursing lecturers to seek new approaches for learning. One solution can be serious games. In health care, and more precisely in critical/intensive care there are not any tested validated serious games in markets. Reasons for that can be only guessed but most likely the reason is that the game development process for special educations purposes needs large amount of resources; money and multi-professional collaboration. Well-working validated serious game, as planned ICU game, can give for all nursing students' access to practice and learn basics of critical care safely, for fun, "again and again" and "where ever you want". (Cf. Kaczmarczyk, Davidson, Bryden, Haselden & Vivekananda-Schmidt 2015.) It is also known that critical care nursing competence is transferable and useful also for other fields of nursing (Lakanmaa 2012).

The aim of this innovation project was to develop a serious game prototype simulating and teaching intensive care unit operations. In this paper, the experiences of the Capstone process as well as of the ICU Game development process are reported. The ICU Game development process and CDIO design-implement experiences of Capstone are described, and the key findings based on the ICU Game development results are discussed.

DESIGN-BUILD EXPERIENCES

Capstone innovation project

The ideology behind Capstone is based on the CDIO concept, developed at Massachusetts Institute of Technology (MIT), which strives to develop education to better meet the needs of working life (Crawley et al. 2014). In Turku University of Applied Sciences, the Capstone project is divided in three main phases: Vision, realization and start-up (Figure 1). The Vision phase follows the Lean start-up process from idea generation and rapid prototyping and vision building (Ries 2013). The realization phase focuses on the project implementation, and it is implemented according to the principles and values of agile development using Scrum as the project management method. The realization phase consists of seven two weeks sprints. The final phase of project is start-up that focuses on reflection and evaluates potential spin-off or start-up opportunities. (Kulmala et al 2014). Actions taken with the project follow the typical agile development process plan-do-test-evaluate (see e.g. Sutherland & Schwaber, 2007). The Capstone innovation project simulates the innovation process and the process that a start-up company would go through to launch a new product or service (Armstrong et al. 2005).

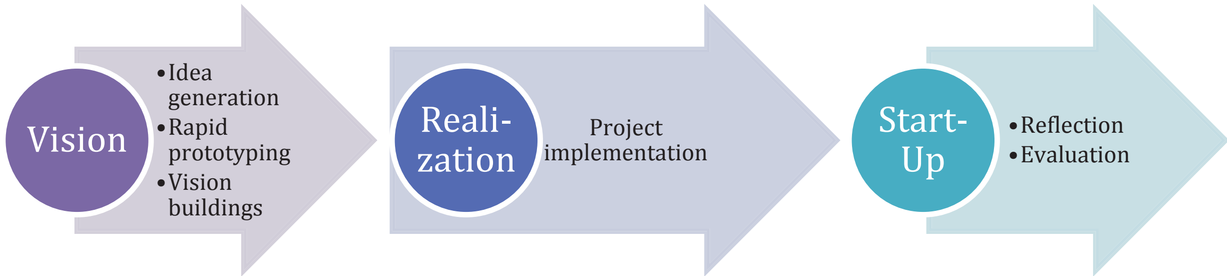

Figure 1. Capstone project´s phases in TUAS

Working with real customers makes the project work concrete as the teams need to negotiate with clients about deadlines, content and the quality of work. This environment also teaches students to work with uncertainty. (Alarcon et al. 2013.) For companies and organizations, Capstone is a risk-free environment for developing and trying out new, even bold solutions (Crawley et al. 2014). The game development project used user-centric methods together with possibilities in simulation and virtual pedagogy. The ICU Game capstone innovation project used three phases of CDIO – Conceive, Design and Implement. The project team started conceiving the needs, the specific environment of ICU and possible other tools in the market. After the conceive phase a prototype was designed and implemented in a cyclic process (Figure 2).

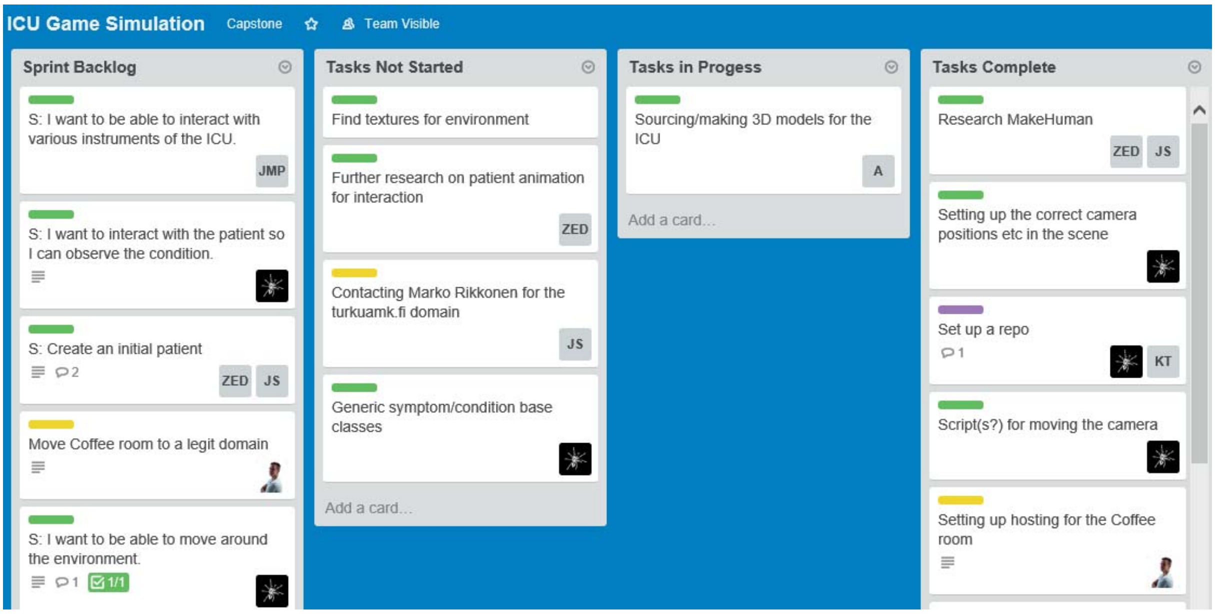

Figure 2. Project working process tool example view

ICU game development process

By playing the ICU game the basic of critical care will be learned lively and grippingly. ICU game consists real patient cases and knowledge packages, tests and ethical dilemmas. The idea is to give feedback for the player immediately and analyzed by calculating competence credits. The main idea is to reward for good performance and guide and give tips in incompetent performance. The structure of the critical care competence and the game idea is based on theoretical framework.

Development of the contents for the game was demanding. The process started in 2013. First the authentic patient cases were gathered and created. The knowledge packages and tests were developed together with nursing students and experts of ICU unit. The first prototype of the ICU game was developed by engineering and library information service students guided by an ICT lecturer. Media lecturer and media students participated in the manuscript writing process of the ICU game. The game idea is based on the selection of action fields and dialog. It can be described that in this prototype phase the game follows adventure simulation game idea (Figure 3).

The very preliminary ICU game prototype test showed how much and what kind of game the students want to play. In autumn 2015 during one critical care nursing course eight paramedic students tested one patient case (Mr. Mäkinen, an acute open heart bypass surgery patient, third day in ICU unit). The outlook of game scored 3.2 and the average score of the questions (9) was 3.5 (1-5 scale, 1= satisfactory 5=excellent). As such they would play the game 5 – 30 minutes sessions and all together 2h - 30 hrs. They suggested to develop the graphics and prefer more happenings to the patient. The five engineering and library information service students evaluated the prototype parallel. Their average score for the prototype of ICU game was 3.3. They think that the game has potential and others than nurses would like to play the game. Most important findings at this stage were to develop graphics, interactivity and doing in the game. A game based on only dialogs was evaluated too boring.

Figure 3. ICU patient Mr. Mäkinen in an ICU room (picture: ICU Game Capstone project team)

DISCUSSION

The aim of the project was to develop a serious game prototype simulating and teaching intensive care unit operations. The project was conducted as a Capstone innovation project (15 credits). As mentioned above, the ideology behind the Capstone project activity emphasizes an entrepreneurial attitude, creative thinking, regional cooperation as well as agile and lightly organized creation and development in cooperation with entrepreneurs in the region. Mere knowledge is not enough, skills are also needed. A close combination of research and practice develops the students' abilities for real working life situations and thus creates even more skilled and realistic workers for the future. Solutions to the problems are searched in cooperation with other professionals and stakeholders.

The skills to network, question and develop existing and new solutions in a user-oriented way and the ability to think flexibly are central competencies for the professionals of the future. One solutions to increase the ICU staff competencies of the future, can be serious game combining with the simulation education. The capstone project was a good example of experimental learning too. The CDIO standard 8 describes active learning experiential when students take on roles that simulate professional engineering practice, for example, design-implement projects, simulations, and case studies. In addition, the result of the project has effects on teaching and learning in the nurse education. The use of the prototype brings an element of active learning in the nurse education too.

The ICU game can be entertaining. The idea is to use the game in theory learning, combined to simulation learning and in clinical practice orientation. Critical care is interesting and full of drama. There are persons among ICU staff - everything can happen to patients and to staff.

There are elements in ICU game for entertainment game when animation and graphics are at the same level as in television hospital series. There should be fun and lively animations in the game manuscript. The game cannot replace the real simulation learning in groups and real practice placements in hospital in nursing education but it can make the preparation for the simulation practice and clinical practice more effective. The game is good extra supplement method for clinical learning. The game gives equality, control, authentic patient cases and effective boost for clinical orientation and lectures. In addition, in the game, the pictures and stories learn vividly.

CONCLUSIONS

The ICU game capstone project was a good example of design-build experiences and it carried out CDIO standards 5 and 8. In addition, this capstone innovation project was also a good example of multiprofessional collaboration between engineering education and nursing education. Furthermore, the capstone project agile development process plan-do-test-evaluate supported the project excellently.

The results of the present Capstone project can be used when planning and implementing serious game in healthcare sector. In addition, there is room for a serious game integrated simulation education for ICU nursing courses. However, the development work of the game is still needed dreadfully. In this paper the phases of development of the first Capstone project were reported.

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USE OF CONCEIVE-DESIGN LEARNING ENVIRONMENTS TO PREPARE ENGINEERS FOR THE DEVELOPMENT OF COMPLEX AND HIGHLY INTEGRATED AERONAUTICAL SYSTEMS

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ABSTRACT

Embraer, one of the largest aerospace companies in the world, was founded in 1969 to accomplish the vision of the Brazilian government to develop the capacity of designing and manufacturing Brazilian airplanes. Out of current 19,000+ employees distributed worldwide, the company has 5,900 engineers. In order to have recently graduated engineers prepared to tackle its future challenges, Embraer created the PEE – Engineering Specialization Program in partnership with ITA – Aeronautics Institute of Technology in 2001. PEE comprises a Technical Master's Program and has already prepared more than 1,400 alumni, graduated in 22 classes; out of them around 1,000 are currently Embraer employees. The main objective of PEE is to prepare future engineers to be specialists that will work in multidisciplinary teams, to accomplish the lifecycle design of complex and highly integrated systems. PEE has the duration of 18 months and consists of three phases. The first phase aims to provide the students with the fundamental knowledge on lifecycle design, covering topics from Marketing Analysis and Research & Technology, up to aspects related to operation, maintenance, and end-of-life disposal. In the second phase, the students select their area of specialization and Master Thesis topics related to one of the following tracks: a) Materials and Structures, b) Aircraft Systems and c) Manufacturing. In the third and last phase, multidisciplinary teams, organized by students coming from the three tracks, take part in a Conceive-Design project. Out of the innovations in teaching and learning methods that have been adopted, this paper presents results on: a) extensive use of visual communication tools and mock-ups in the "Design Room", to share created knowledge and technical data and b) involvement of current and former key Embraer specialists in mentoring the students.

KEYWORDS

Conceive-Design Experiences, Experiential Learning, Engineering Workspaces, Visual Communication, Mentoring, Standards: 5, 6, 7, 8.

INTRODUCTION

Embraer is one of the largest aerospace companies in the world and it was founded in 1969 to accomplish the vision of the Brazilian government to have, in the country, the capacity of designing and manufacturing airplanes. Out of more than 19,000 employees distributed worldwide, the company has 5,900 engineers dedicated to Research & Technology and Integrated Product Development.

In order to have recently graduated engineers prepared to tackle our current and future challenges, Embraer created the PEE – Engineering Specialization Program in partnership with ITA – Aeronautics Institute of Technology (www.ita.br – in Portuguese) in 2001. PEE comprises a Technical Master's Program and has already prepared more than 1,400 alumni, graduated in 22 classes, out of which, around 1,000 are current Embraer employees. Embraer, (2015). Due to regular turnover and the need to cope with new technologies, every year the company hires more than 100 engineers. The selection process of new engineers is crucial for success. In 2015, more than 5,900 candidates from the whole country applied for 40 positions in PEE. In addition to Technical Engineering Knowledge and English proficiency, the selection process comprised personal presentations, group dynamics and interviews involving ITA faculty, HR specialists, future managers and former PEE alumni.

The main objective of PEE is to prepare future engineers to be specialists in several departments of Embraer´s Vice-Presidency of Technology and Engineering. These engineers will be part of multidisciplinary teams, to accomplish the lifecycle design of complex and highly integrated systems, such as airplanes, its systems, manufacturing processes, suppliers, maintenance centers etc.

To address the objectives described above, this paper presents some theoretical aspects connected to the themes of designing systems of systems, the use of multidisciplinary teams in product development, knowledge management and the connection between PEE pedagogical approach and CDIO philosophy. In addition, it provides information about the Engineering Specialization Program and some results about the special arrangement of the "Design Room" and the important role of the "mentors" in the development of the young engineers' competencies. As a wrap up section, final comments and suggestions for future learning points are presented.

THEORETICAL ASPECTS

Systems of Systems

The starting point of educating engineers to work in the design of commercial aircraft is to provide them with the perspective that airplanes are systems of systems. Airplanes are independent complex systems that are connected to many other complex systems (other airplanes, airports, satellites, air traffic controllers, maintenance centers etc.), and that have to achieve some level of common performance, such as safety, scheduling, costs, etc.

As pointed out by Altfeld (2010) the design and development of new aircraft comprises many complexities such as volumetric (size), systems, design, customization, process, and multicultural aspects among others. The aircraft itself is composed by several different systems such as structures, flight controls, hydromechanical systems, electrical systems, avionics, cabin and so on. Consequently, it will require the competencies of professionals from many engineering areas such as Mechanical, Electrical, Materials, and Production Engineering among others.

To cope with this multidisciplinary approach, the engineers and others specialists are organized in teams called "Integrated Product Development Team" (IPT). These teams are composed by representatives of all appropriate functional disciplines such as customers, program management, engineering, manufacturing, test, logistics, and suppliers among others. Once such a team is organized, the specialist must know that his role changes from being a member of a particular department, who focuses in a given discipline, to a team member who focuses on the product and its associated processes.

Multidisciplinary Teams for Product Development

According to Ulrich & Eppinger (2008), to be competitive, companies depend on the ability of creating new products that meet customer needs and that can be produced at low costs. Firms that aim to create these products have to realize that this challenge requires the creation of cross-functional teams, involving people from Marketing, Design and Manufacturing areas among others. The challenge is to emphasize that the team must work toward a common goal.

In order to create product development teams that are effective, the way the specialists are recruited, selected, trained and organized is a critical success factor. There are some challenges to be taken into account (Ulrich & Eppinger, 2008): trade-off analyses, technology dynamics, complexity, time pressure and economics. Other aspects to be taken into consideration are creativity, satisfaction of societal and individual needs, team diversity and team spirit.

In the front-end process, **concept development**, emphasis is given on the following activities: identification of customer needs, establishing target specification, concept generation, concept selection and setting final specification (Ulrich & Eppinger, 2008). During this phase, other aspects are economic analysis, benchmarking with competitive products and building models and prototypes.

According to Altfeld (2010), the rationale behind the effectiveness of multifunctional teams is to assure that the “right decisions” are made with participation of the most important stakeholders: engineering, manufacturing as well as customers, suppliers and certification authorities. Those stakeholders should be represented jointly in **the design and development processes,** and be encouraged to actively influence them.

Lean Product Development

In the end of the 80s, the MIT unleashed a worldwide study searching for answers for the loss of competitiveness and market share by the American manufacturers of the automotive industry. After a huge number of visits in different countries and factories, the IMVP – International Motor and Vehicle Program (Womack, Jones, & Roos, 1990) - realized particular characteristics in some Japanese companies, for instance Honda and Toyota. The way of doing more quality in less time and less cost comparing to the mass production found in American and European companies was considered lean by one of the IMVP members and the term is used until our days. In the brief words of Taichii Ohno, manager at Toyota and recognized as the founder of the TPS - Toyota Production System, "all we are doing is looking at the timeline from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value added waste" (Ohno, 1988 cited in Liker, 2004).

In addition to the observations made in the manufacturing environment, a great difference was noted in the product development process. One important and general finding about launching of a new product, comparing the Japanese versus American and European companies, stated that the Japanese manufacturer would need approximately 1,7 million engineering hours over 46 months against 3 million engineering hours during 60 months for Occidental manufactures. Twice more expensive and one third longer lead-time. Through further investigations devoted to this topic, the authors selected four relevant differences between the designing methods: (1) leadership, (2) team work, (3) communication and (4) simultaneous work. In a brief explanation, the technical leader, Shusa - Chief Engineer - had true power over the whole team during all project phases and, according to Sobek, Ward & Liker (1998), "must demonstrate both exemplary technical expertise and fluency in synthesizing technical knowledge into clever, innovative designs". The team under Shusa's command work together during the whole project and over continuous problem solving and decisions based on visual knowledge. They make it possible, for different technical groups, to develop concurrent solutions and to integrate through decisions taken in the last possible moment, aiming to cause few rework and construct a perfect final solution. (Morgan & Liker, 2006).

The Obeya Structure can be seen in the Figure 1.

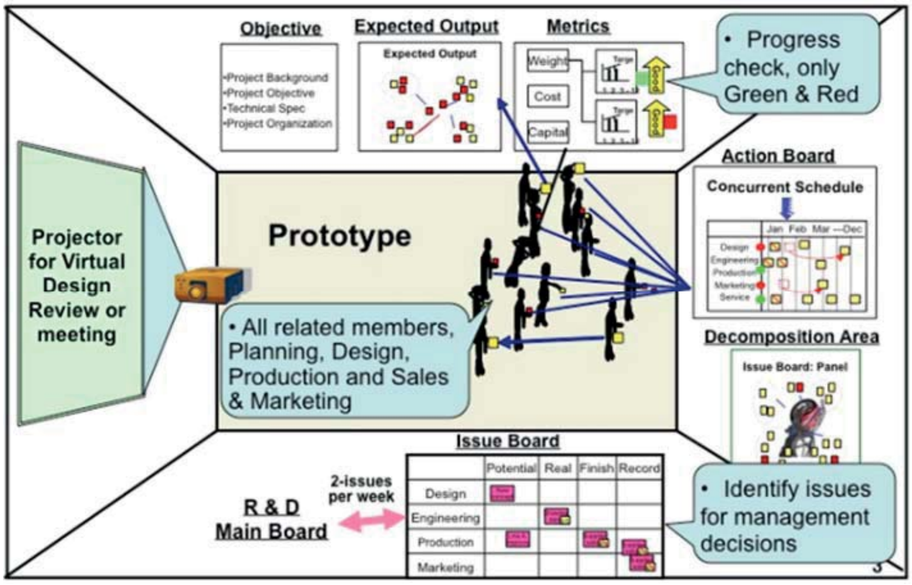

Figure 1. The Obeya Structure (Tanaka, Horikiri & Flynn, 2010)

To understand the origin of Obeya, it is important to know that one of Toyota's great success in sales and public appreciation is the Toyota Prius, the first fuel-electric hybrid car to be mass produced and introduced in the end of 1997. For Liker & Morgan (2006) it is not only a success as a product but also as an extraordinary development process. In the beginning of the project Toyota's highest-level executives took an atypical decision of choosing a CE-Chief Engineer who was not creating a career in that direction. As Uchiyamada did not feel he was qualified for the CE role and the coming decisions in the project, the first action was to be surrounded by a cross-functional team of experts in a big room, obeya in Japanese. In his own words, it is a place where "the chief engineer gathers the team of people responsible for that project. That is where simultaneous engineering can be even more effectively implemented by all the key people coming together in this area." (Morgan & Liker, 2006).

In Ward's (2007) opinion, "almost all defective projects result from not having the right knowledge in the right place in the right time. Therefore, usable knowledge is the basic value created during development." In a complete description, Ward states the learning cycle as the left side of the Figure 2.

Knowledge Management

Surprisingly, the authors of this paper have identified a similar diagram in an Andragogy reference. One of the core adult learning principles is "problem centered" among other five not mentioned in this text. Kolb (1984) (cited in Knowles, Holton III & Swanson, 2005) defines learning as "the process whereby knowledge is created through transformation of experience". In his Experiential Learning theory, Kolb suggests a four-step cycle as shown in Figure 2 in the right side. One of Kolb's suggestions for the stage "Observations and reflections" is discussion in small groups (Knowles, Holton & Swanson, 2005).

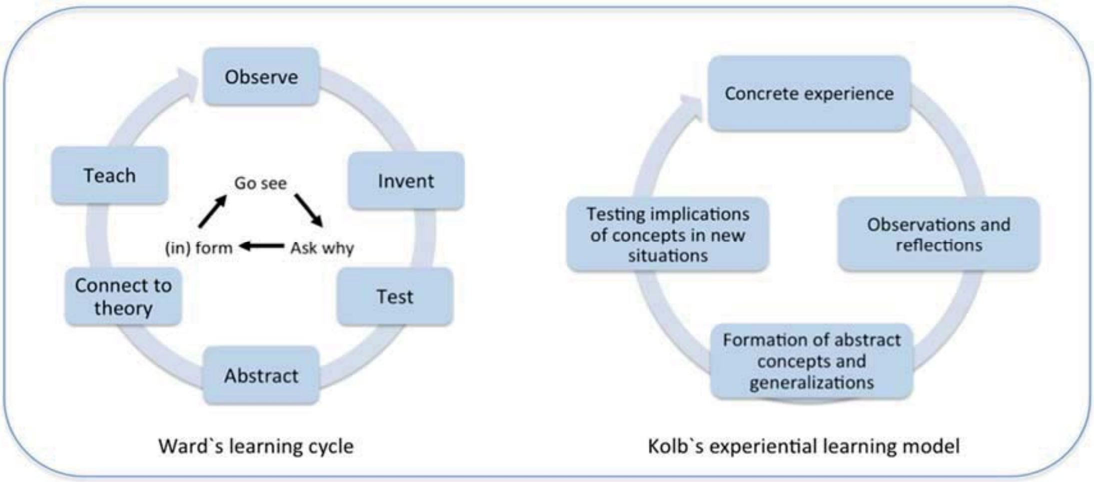

Figure 2. Ward's and Kolb's learning models

One of the important aspects discussed in this paper is the crucial role experienced engineers have in the education of the future workforce, acting as mentors, helping the students to cope with their conceive-design challenge. Nonaka & Nishiguchi (2001) discuss the concept of **Ba**. Ba refers to a physical, virtual and mental space, shared by two or more individuals. According to those Authors, social relationships established among those individuals have a strong influence on the scale and knowledge creation.

Nonaka & Nishigushi (2001) describe a model of knowledge creation, based on a spiraling process of conversions of tacit and explicit knowledge, involving the four stages of socialization, externalization, combination and internalization. **Socialization** refers to process of transferring tacit knowledge among individuals by means of joint activities in the same environment. **Externalization** is another very important process where the tacit knowledge is expressed by concepts, diagrams models or prototypes that can be understood by others. **Combination** is the process of converting explicit knowledge in more complex and systematic explicit knowledge through elaboration of documents, for example. Finally **Internalization**, which is the process of embodying explicit knowledge into tacit knowledge, or "learning by doing".

The last and essential point to be addressed in this paper in the importance of social relationships in organizations (Nonaka & Nishigushi, 2001), presented in the chapter "Bringing Care into Knowledge Creation". They state that care can help organizational knowledge development. Employees, who help each other, are accessible and have high degrees of kindness characterize high care organizations. In these organizations, individuals are supported by a social network, which make possible the process of sharing tacit knowledge with other employees.

CDIO Standards and Syllabus

The objective of PEE is to prepare engineers to work in Integrated Product Development processes, organized in multidisciplinary teams, to emulate the Front-end phases: Conceptual and Preliminary Designs. Although not adopting the CDIO Standards "formally", since 2004 the group in charge the coordination of PEE Program have been using the CDIO model as a reference model to guide the improvements that have been implemented. With respect to CDIO Standards, the results presented in this paper are related to Standard 5, Design-implement experiences and Standard 6 Engineering workspaces, particularly in the way the ideas of Morgan & Liker (2006) related to obeya have been implemented. Standard 7 is also followed in an indirect manner since the students develop their conceive-design and interpersonal skills working together in the same room with the participation of ITA faculty and Embraer current and formers specialists, composing a group of 20+ mentors. The way the Conceive-Design projects are planned, organized and managed is in consonance with Standard 8 (active learning).

With respect to CDIO Syllabus v 2.0, PEE focuses on the following items. In terms of Personal and Professional Skills (2), special emphasis is given on Problem Solving and on System Thinking. Moving to Interpersonal Skills (3), PEE focus on Team Work and on Communications skills. Finally, on Conceive-Design Project (4), the most important competencies addressed are 4.2 (Enterprise and Business Context), 4.3 (Conceiving & System Engineering) and 4.4 (Designing). Although implementation is not completely covered by PEE, mainly because the problem presented to the students is the development of a new aircraft (vehicle, suppliers, production line, tests, maintenance, etc.), emphasis is given on experimental prototypes (interiors, wind tunnel models, etc.).

ENGINEERING SPECIALIZATION PROGRAM (PEE)

PEE has the approximate duration of 18 months and consists of three phases. Figure 3 presents the general structure. **Phase 1** aims to provide the students with the fundamental knowledge on lifecycle design, covering topics from marketing analysis and research & technology, through product (airframe and aircraft systems) and manufacturing processes, up to aspects related to operation, maintenance, and end-of-life disposal.

In **Phase 2**, the students select their area of specialization and Master´s thesis topics related to one of the following tracks: a) materials and structures, b) aircraft systems and c) manufacturing. In the last phase, **Phase 3**, multidisciplinary teams, organized by students coming from the three tracks, take part in a Conceive-Design project.

Phase 3 of PEE is a Conceive-Design exercise applied to an aircraft. It is not limited to complying with a prescribed technical specification, but might involve market research, technical specification generation and business case construction. The conceive-design challenge is presented to the students in a broad sense, usually requiring them to generate value to the aircraft client (for instance, through competitive price and operational efficiency targets) and to the Embraer stakeholders (for instance, through profit margin and market share targets) by addressing a given market niche. The niche is chosen from one of the business areas of Embraer: Commercial, Executive or Defense. It should be stressed that the most important Phase 3 result is neither the aircraft characteristics nor its business case, but rather the learning in the technical multidisciplinary design integration and in the social-technical design process.

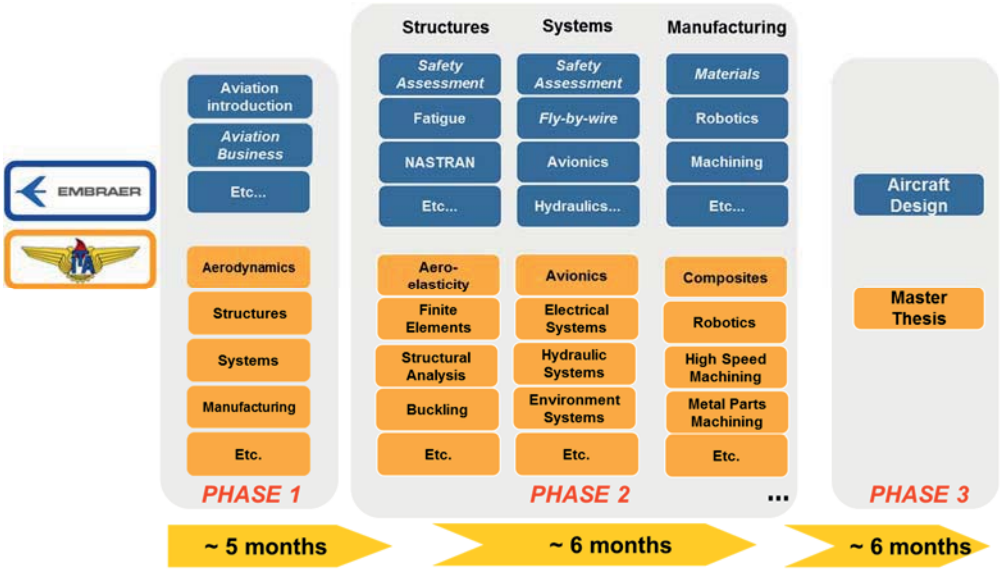

Figure 3. General structure of the Engineering Specialization Program (PEE)

The duration of Phase 3 is approximately 6 months. The student class is normally divided in two teams by the PEE management and each team is encouraged to present and defend, in a technical and business sense, a different solution to the challenge. This provides a healthy competition between the teams, although they still may share technical knowledge and information sources. After the teams have been defined, they become self organized and the teams have full autonomy to choose technical solution alternatives. Each entire team is co-localized to simulate the real engineering environment they would be facing in a real Embraer engineering project.

A group of integration and multidisciplinary mentors from several Embraer technology areas helps the PEE teams. Although there are regular weekly meetings involving all the students and mentors, they and other Embraer specialists are available all the time. Since 2012, some “Lean Product Development” concepts and methods were implemented, aiming in Phase 3 to help the students in the learning process and to be in accordance with Embraer’s new development practices. Some ideas taken into consideration are: a) developing towering technical competence, b) build in learning and continuous improvement, c) establish customer-driven value, d) front load the product development processes to explore alternative solutions, and e) extensive use of simple and visual communication tools for organizational learning.

Intermediate Phase 3 design results are presented to a team of Embraer technical specialists and managers, and the Final Presentation is done to an audience that includes Embraer high-level technical management.

RESULTS

In the context of this paper, it is important to take into consideration some aspects: the design on a new airplane may last 5-6 years, the aircraft manufacturer will have to support the airline for 20 years and the end of life has to be carefully considered in the front-end process. Since the scope is the education of future engineers through conceive-design projects, the following product development phases are used by PEE: Strategic planning of new products, planning, customer needs, product specification, conceptual design, preliminary design, detail design, manufacturing preparation, testing, product launching, customer support, and end of life. The big challenge in preparing future engineers to work effectively on the development of a new aircraft depends on the creation of an education environment that emulates these processes with an adequate level of fidelity for them to understand the “rules of the game”.

Obeya System

The first attempt of introducing the obeya system for the PEE design-conceive phase was based on the hypothesis that the team leaders (students) were in the same shoes of Takechi Uchiyamada: no experience in leading a complex development process such as the one they would face in the moment they were selected or, in PEE’s case, elected as the chief engineer. This hypothesis was clearly confirmed after the first class and the coordination of PEE stated the obeya system as the process of managing the Phase 3. One of the very first perceptive results were that the rooms got very different solutions in visualization and people organization, clearly attributed to the different leaders and formation of the teams. Other important result that may be kept analyzing the last six teams is that, qualitatively speaking, it seems that the developing time decreases. Even with the timeline being the same or slightly different, from class to class, the results improve in quality and depth of the engineering solutions presented by the students. In Figure 4 it is possible to see some examples of different results: (1) Integration Board; (2) mock-up of the landing gear bay; (3) mentors and students interacting with the visual knowledge; (4) systems integration mock-up.

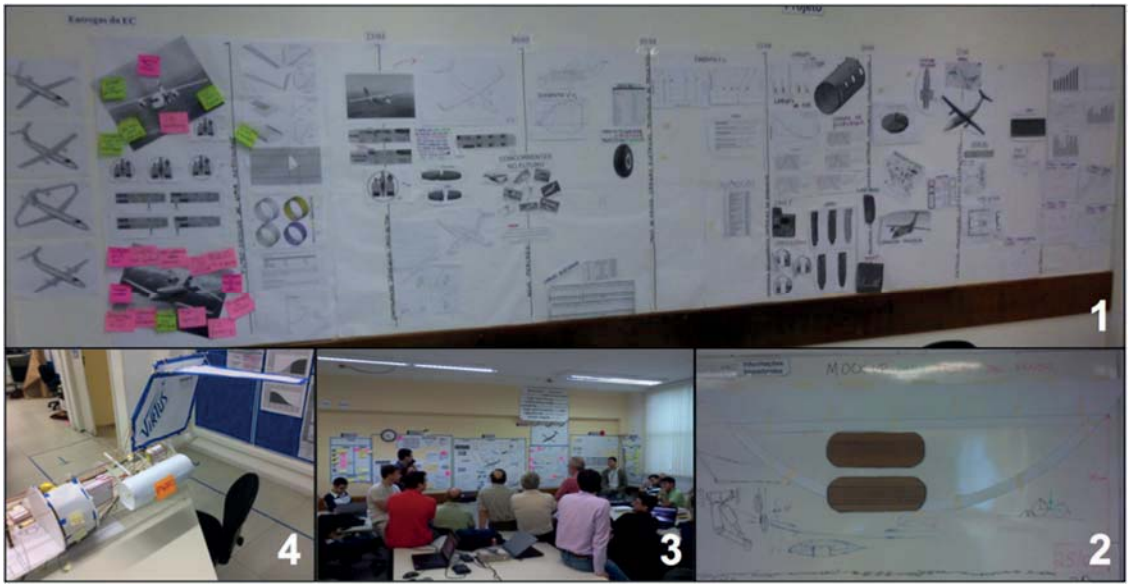
Figure 4: Obeya system examples

Mentors

Phase 3 mentors are senior technical specialists coming from different specific areas of aircraft design and project management, such as: aeronautics, structures, systems, manufacturing, maintenance, market intelligence, project planning, human factors, logistics, certification, etc. Most of them are “volunteers” from the Embraer’s workforce, but some are retired Embraer employees or external specialists. Figure 5 presents a group mentors. The number of mentors may vary during Phase 3 classes, but is usually around 20. The number of students varies from 20 to 30, per design team. This represents ratios student/mentor of 2 to 1, depending on the size of the class.


Figure 5. Group of mentors on phase 3 of PEE

The purpose of the mentors is to help the students choose and refine their technical and business solutions to the Phase 3 Conceive-Design challenge. This is typically done by indicating technical alternatives, information sources or methods and by critically questioning the student design decisions. It should be noted that the students keep the autonomy to choose their solutions; they are not bound to the mentors´ suggestions or preferences. This allows Phase 3 to be open to new ideas from a younger set of engineers, instead of just applying the

Embraer technical “state of the art” solutions as represented by the mentors´ experience. The students are required, nevertheless, to justify their choices. The mentors care that the students really understand their technical choices, and are not just defining them arbitrarily.

Since aircraft design can be considered as a big trade-off exercise among several disciplines and requirements, mentors from different areas might sometimes suggest conflicting solutions. This reflects the real social-technical environment that the students would be facing in a real engineering project. Although agreement between the mentors is usually reached, based on their own expertise and experience, there is an Integration Mentor who can be called in to intervene and suggest a technical solution, if needed.

Positive results have been observed via focus groups organized by the coordination of PEE six months and one year after graduation, with former students from PEE classes. Common expressions are: “*I did like the integration between us and the mentors*”, or “*most of the people helped us very much”.* Post-Morten meetings with mentors, to reflect on Phase 3 and to collect strengths and opportunities of improvement, are also in place. It has been observed by the coordination of the program the enthusiasm of mentors, who usually ask: “*When the next Phase 3 will take place? You can count on me*”.

FINAL COMMENTS AND SUGGESTIONS FOR FUTURE LEARNING

Out the observation of the last six classes of PEE, some important aspects could be observed. The first point refers to the conceive-design experience represented by Phase 3 of PEE, when young engineers learn from their mentors not only by spoken words or written documents, but also through active learning, via group discussions, debates and feedback from the mentors. While young engineers prepare charts of trade-off analyses and present their conclusions to the mentors, listening to their comments, they learn via externalization.

The preparation and execution of Preliminary Design Review presentation (PDR), shown to the mentors and the board of the company, to demonstrate that their projects are technically feasible, consist on conclusion of a truly integrated learning experience. In addition to the development of technical knowledge and systems skills, the young engineers also improve personal and interpersonal skills in the context of the company.

It is important to remark that the students and mentors are highly committed to their tasks in Phase 3, and their interaction has a very positive effect on the motivation and enthusiasm of both of them. The level of care developed between mentors (experienced employees) and students (young engineers) in the PEE program is a very important success factor that leads to social-technical integration as well as development of competences by the trainees.

The engineering workspace represented by the obeya system and its various parts, not only shows the knowledge acquired, but also guide the students to construct the rationale that support their decisions. Observed time reduction and improvement in technical quality of the projects presented by the students appear to be a consequence of the implementation of obeya system and increasing use of mock-ups and simulations during the conceive-design experience. The lean development system is vaster than the obeya and its full application takes time and constant energy. PEE succeeded in implementing the visual management and the use of mock-ups and will keep doing it, but there are other fronts to be addressed, to increase the results in the learning process.

A suggestion for future work is to design and implement an evaluation scheme to measure the impact of PEE program on the real work performed by the engineers after their graduation and hiring by the company. The idea is to collect data from alumni, their respective supervisors and peers to evaluate quality improvement, rework reduction and other measures of individual or collective performance, which could be attributed to the program.

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LEARNING ASSESSMENT – A PALETTE OF METHODS IN A MASTER'S PROGRAM

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ABSTRACT

There are several different examination methods to assess students' achievements. These assessment methods should be matched with the course learning objectives, support deep understanding of concepts and active learning as well as different learning styles among the students. The objective of this paper is to share and reflect on the experiences of different assessment methods applied in a master's program in Ergonomics and HTO (Humans, Technology and Organization) at KTH in Sweden. The paper is based on the authors' observations and experiences as main teachers in the master's program and student evaluations. The pro-gram consists of five courses representing different areas within Ergonomics followed by a project course and the Degree Project. The students have multidisciplinary backgrounds and difference in work experience, which calls for special attention regarding what means to use to support the students' deep understanding and active learning. To support the students' cross-disciplinary collaboration and individual learning processes different assessment methods have been developed. In the first five courses, there is a written exam to assess theoretical knowledge as well as reflective and application knowledge. This is supplemented by an array of other assessment methods to stimulate the development of a multidisciplinary view. These include seminars, laboratory exercises, as well as individual and group assignments. In the group assignments, the groups are mixed with students from different educational backgrounds to demonstrate the need to encompass several perspectives to understand different phenomena. For all courses, the learning outcome is also assessed by oral presentations. This palette of assessment methods are used through-out each course in the master's program. However, sometimes challenging to develop assessment methods to fit students with different backgrounds, the variety of methods allows for students to demonstrate their knowledge and understanding through different means and in different contexts.

KEYWORDS

Examination, ergonomics, HTO, assessment methods, CDIO Standard: 11

INTRODUCTION

There are several different examination methods to assess students' achievements. These assessment methods should be matched with the course learning objectives, support deep understanding of concepts and active learning as well as support different learning styles among the students (CDIO, 2016). Earlier studies have described different study approaches and their outcomes on students' learning (Ramsden, 2003). In a surface approach, the students memorize facts and details without much reflection about the implications of their meaning (Marton & Säljö, 1976), while in a deep approach to studying, the students reflect on the meaning of theories and how they can be applied to real-life situations. Ramsden (2003) put forward that deep teaching/learning approaches are related to higher quality outcomes as well as higher students' satisfaction. As the examination form in itself affects the way the students study and learn (Biggs, 2003), it is important to develop examination forms which constitute deep learning processes (Hult, 1998).

The objective of this paper is to share and reflect on the experiences of different assessment methods applied in a master's program in Ergonomics and HTO (Humans, Technology and Organization) at the Royal Institute of Technology (KTH) in Sweden. Ergonomics is a multi-disciplinary field and defined by Corlett and Clark (1995) as: "The study of human abilities and characteristics which affect the design of equipment, systems and jobs. It is an interdisciplinary activity based on engineering, psychology, anatomy, physiology and organizational studies."

The paper is based on the authors' observations and experiences as main teachers in the master's program since 2007, student evaluations and reflection on the students' results.

LEARNING ASSESSMENT

As assessment methods strongly influence the students' learning, the assessment forms must be related to the course objectives. This highlights the importance of formulating good learning objectives as well as to develop methods to assess to what extent the students reach these objectives (Lindberg-Sand, 2008). According to the CDIO approach, learning assessment should not take place only at the end of the course, but different methods for assessment should be used for the students to demonstrate their learning throughout the course, and some assessment methods can also be used as teaching methods (Crawley et al, 2014). Toohey (1999) has divided examination into a number of methods to assess different aspects, see Table 1.

Table 1. Description of Use of Assessment Methods (Toohey, 1999)

Assessment method	Assessed aspects
Objective tests	Broad fact-based knowledge of the syllabus
Essay examination	Higher level of thinking
Open-book exams	Problem solving and interpretation of knowledge
Case study or problem-centred exams and assignments	Performance close to professional practice
Practical/professional tasks	Knowledge application and skills
Production of works of art	Knowledge application and skills
Oral presentations and seminars	Ability to organize information and develop arguments
Reflective tasks	Reflection on practice, growth in understanding, reasoning and development of professional attitudes

These assessment methods should be based on the qualifications needed for the students in the future. Looking at the required qualifications in their profession, engineering students will need to understand how models and theories may be applied in different contexts. As they then will have access to literature, open-book examinations are more realistic and will probably encourage the students to study with a deeper approach for the examination (Toohey, 1999). Furthermore, a deep approach may be encouraged through four principal factors (Biggs, 1989):

- An appropriate motivational context
- A high degree of learner activity
- Interaction with others, both peers and teachers
- A well-structured knowledge base

In a CDIO approach, Crawley et al. (2014) highlight the importance of sound learning assessments for student and program success. This includes assessing the students' achievements from multiple and diverse sources; integrating teaching and assessment, so that improved assessment also improves teaching; and assessing the students in different teaching-learning contexts. In the CDIO standard 11 (CDIO, 2016), it is further stated that the assessment methods should address both disciplinary knowledge as well as personal, interpersonal, and system building skills. A variety of methods also allows for different learning styles and results in increased reliability and validity regarding the assessment process.

DESCRIPTION OF THE MASTER'S PROGRAM

The education presented in this paper is a master's program in Ergonomics and HTO taught at the Royal Institute of Technology (KTH), Sweden. Three main teachers collaborating since 2007 manage the program. Their competences and research areas cover complementary multidisciplinary areas such as mechanical engineering, physiological ergonomics, cognitive science, Ergonomics/Human Factors in general, work organization, group dynamics, and industrial management and engineering.

The students that are admitted to the program may have a background in technical science, health science as well as behavioural science. About 25-30 students are admitted every two years. The aim is to have one third of the students with each background to create good cross-disciplinary working groups. Approx. half of the students come directly from undergraduate studies, and the other half have worked for several years The professional group of students include consultants, self-employed people, teachers, representatives for Swedish authorities within occupational health and safety, etc. The master's program can be followed as fulltime study in one year or as halftime study in two years. The students meet for two to three full days every four weeks and study on their own or with other students between the meetings.

The program consists of five six-credit courses representing different areas within Ergonomics: 1) Human, Technology, Organization (HTO); 2) Physical Ergonomics; 3) Cognitive Ergonomics; 4) Organization, Change Management and Work Environment Legislation (here named Organization); and 5) Research Methods and Study Design (here named Method). These courses are followed by a project course and the Degree Project of 15 credits each. The overall learning objectives for each course are presented in Table 2 below.

The overall purpose of the master's program is to provide a system's view on the interaction between human, technology, and organization at work in order to enhance human wellbeing, design of technology and organisation to increase overall system performance. The students are to attain this holistic view during the program, which is described in the syllabus as:

The students will have knowledge about:

a) how to analyse work and work activities as well as how to design workplaces which promote safety, health and wellbeing for the individual and operations performance (e.g. productivity, absence of disturbances, and quality),
b) how to manage projects and change processes, especially how to integrate Ergonomics and HTO in development processes,
c) regulations and professional roles, such as consultants, experts and facilitators, and
d) the interests of different stakeholders in working life, the importance of cross-disciplinary collaboration as well as how Ergonomics specialists and practitioners may collaborate.

Table 2. Overall Learning Objectives for Each Course

Course/credits	The students should after fulfilled course be able to:
HTO 6 credits	• Understand and apply various HTO perspectives on operations, • Analyze the activities and jobs from different HTO perspectives, • From different perspectives propose measures to improve the interaction Human-Technology-Organization in a way that promotes human health and wellbeing, as well as the efficiency of the system as a whole.
Method 6 credits	• Understand the differences and relationships between different scientific perspectives and methods, and develop a well thought out approach to these, • Apply knowledge of how to plan an investigation and to collect, process, analyze and interpret data in different types of studies, • Master some common methods of research and investigation in Ergonomics / HTO, • Critically review research papers and studies in Ergonomics / HTO.
Cognitive ergonomics 6 credits	• Understand and practically apply knowledge of human cognitive conditions in the interaction human-machine interface, • Analyze and suggest improvements to the human-machine interface, • Understand and evaluate how the allocation of functions between human and machine affects the interaction between human-machine and system performance, • Visualize and apply cognitive aspects of an HTO analysis.

Organisation 6 credits	• Define and discuss basic concepts that deal with the construction, distribution and coordination of work, • Explain the design of the work and production system and its relationship with job satisfaction and productivity, • Suggest and motivate changes in an existing work organization with the support of the basic concepts and principles within the area, • Develop a concept for successful improvement.
Physical ergonomics 6 credits	• Understand and be able to apply knowledge of human physical capabilities, limitations and needs in working situations. • Understand the overall picture regarding the interaction between people and work, and how this affects the quality and efficiency of the system, • Understand the origins and prevention of musculoskeletal disorders, • Explain the meaning of work organization from a physiological point of view, • Perform physiological and ergonomic measurements and calculations, • Give proposals for the design of workplaces and equipment.
Project work 15 credits	• Demonstrate the ability to search for and acquire the necessary knowledge within a chosen project area, • Demonstrate the ability to professional written and verbal communication by reporting results in oral and written form, • Demonstrate the ability to critically review and discuss other project works, • Independently and in collaboration with others be able to apply the acquired knowledge and plan a project task relevant to the course.
Degree Project 15 credits	• Be able to apply relevant knowledge and skills acquired in the main field to a given problem, • Within given frames, even with limited information, independently be able to analyze and discuss complex issues and handle larger problems on the advanced level in the main field, • Demonstrate the ability to reflect upon and critically review their own and others' scientific results, • Be able to document and present their work with strict requirements on structure, format and language, • Demonstrate the ability to identify the need of further knowledge and take responsibility for own knowledge development.

ASSESSMENT IN THE MASTER’S PROGRAM

Assessment – Overview

The philosophy of the structure and teaching in the master's program described above is that the different courses are linked together through a theme from the HTO course and by the different courses "hooking" into each other regarding distinctions, interactions, perspectives, etc. This is partly reflected in the assessment methods to help the students’ acquiring and applying a systems thinking and how different subsystems in the HTO-system affect the whole and vice versa.

The students’ multidisciplinary backgrounds and difference in work experience call for special attention regarding what means to use to support the students’ deep understanding and active learning. This difference constitutes a dynamic learning environment with high potential for collaboration and knowledge sharing across academic disciplines. The need to apply several perspectives for problem solving is also acknowledged as the program proceeds over the wide span of Ergonomics, covering human physical and cognitive aspects, human-machine interaction and organizational issues as well as the systems view of HTO. To support the students' cross-disciplinary collaboration and individual learning processes a variety of assessment methods have been developed. In all first six-credit courses, there is a written exam to assess theoretical and applied knowledge. This exam is written in class with or without access to course literature, or at home during a limited time. Especially for home examination the students have expressed that the written exam constitutes an important learning process. The written exam is in all cases complemented by an array of other assessment methods to stimulate the development of a multidisciplinary view. These include seminars, laboratory work, as well as individual and group assignments. In the group assignments, the groups are mixed with students from the three main educational backgrounds to demonstrate the need to encompass several perspectives to understand different phenomena and to foster a multidisciplinary and systemic approach which is a cornerstone in the masters' program. For all courses, including the project course and the degree project, the learning outcome is also assessed by oral presentation. In some cases, this also includes opposition of another group's work. The project course and the degree project are also assessed through a project report.

The students have appreciated the variation in assessment methods although they expressed different personal preferences. The combination of case study analyses, reflective group assignments, seminars, laboratory exercises and final written exams in different forms has been appreciated as part of a good learning process.

Example of Assessment – the Course Organization

In the course Organization, the students' achievements are assessed through four different means: Literature assignment, discussion of recorded lectures and interviews, poster design, and written home exam. These are described below.

Literature Assignment

The assignment is based on two scientific journal articles for which the students individually reflect on ten questions. The assignment is presented in a written reflection of about 1200 words prior to a seminar, in which a selection of the questions are discussed. Grade pass/fail.

Film Discussion

The film discussion is based on five film sequences on theoretical models and an interview of an experienced change manager. The film sequences have been recorded and uploaded on a digital course platform. The students are given five questions to reflect on the film sequences, write down in bullet form (1-2 pages) and be prepared to discuss in a seminar during a course meeting. One example of a question to reflect on could be: How can you take into account motivation theories during change processes and in organizational design? Grade: pass/fail.

Poster Design

In this assignment the students work in groups of three to four students. The groups are assigned by the teachers and consisting of students with different backgrounds. The task is to design a poster on any topic which is related to the course content. It can be based on own experiences or some phenomenon that the students want to study in depth. The students are here expected to search literature outside the course literature. The poster could be designed in different ways, but the size should be at least three A3-pages. The poster is uploaded on the digital course platform and printed. The poster is also orally presented (during approx. 10 minutes) at a vernissage during a course meeting. Grade: pass/fail.

Written Home Exam

The written home exam consists of three questions of overall and reflective character. The answers are written in a digital template with predetermined maximum space of two pages for each question. An example of a question could be to discuss some organizational philosophies that have influenced the design of current production systems, in what way these philosophies have influenced the design and how the student relate to these philosophies. Criteria for assessing the exam are the student's relation to and balance between a) relevant theory and facts, b) understanding and application of theory, and c) own reflection. The exam is distributed nine days before the deadline, including two weekends to facilitate for half-time students. The written home exam is graded A-F, which is also the final grade for the course.

Example of Assessment – the Course Cognitive Ergonomics

In the course Cognitive Ergonomics, the students are examined by five assignments assessed by different methods: The assignments which are further described below consists of 1) Cognitive laboratory exercises, 2) Design of human-machine interface, 3) Hierarchical and cognitive task analysis, 4) Literature assignment, and 5) Written open book exam.

Cognitive laboratory exercises

In this assignment the students perform a number of exercises based on a software program regarding information processing in the human brain. The exercise includes e.g. 'Visual search test' and reflections on how the results from the exercises could be applied in human-machine interaction design. The assignment is conducted in groups of three students assigned by the teacher and embraces individual outcomes as well as reflections of how to interpret the outcome in group. The assignment is uploaded on the digital course platform and assessed by the teacher as well as discussed in class to make sure the students have understood how to apply the theoretical knowledge in design assignments. Grade: pass/fail.

Design of human-machine interface

The students are now prepared to implement theoretical and practical knowledge by analyzing an existing product and suggest specific improvements according to design principles. Also this assignment is done in groups of 3 students assigned by the teacher to stimulate discussion between the different backgrounds among the students. A document embracing 1000-1500 words are handed in by each group on the course platform and each group present their suggestions for other groups in seminars to discuss different design solutions. The students are given oral and written feedback. Grade: pass/fail.

Hierarchical and cognitive task analysis

This assignment includes a deep reflection regarding obtained knowledge and skills in analyzing human performance from different perspectives and suggestions regarding a redesigned product. This assessment is based on a written document (1800-2200 words) that is uploaded on the course platform and oral presentation in seminars. Grade: pass/fail.

Literature assignment

To further stimulate the students to deepen their knowledge in a specific aspect, a literature search on scientific papers in the domain is made in groups. A written analysis of two articles per group (around 1000 words) is made. The articles are presented orally and discussed in seminar groups and assessed in terms of written as well as oral presentation. Grade: pass/fail.

Written open book exam

The course ends with an open-book exam which requires that students have some depth in their theoretical knowledge and also have the ability to reflect and apply the knowledge on a deeper level. An example of a question could be: Below follows a description of accident "X". Analyze what happened on the following perspectives: a) describe the sources of error from a cognitive ergonomic perspective, b) describe the undesirable effects associated with the automation that you can derive from this example, c) describe briefly the accident based on the interaction Humans-Technology-Organization. Criteria for assessing the exam are the student's relation to and balance between a) relevant theory, concepts and models b) understanding and application of theory, concepts and models and c) critical reflection and personal reflections. The exam is graded A-F, which is also the final grade for the course.

ANALYSIS AND DISCUSSION

A master's education with a system perspective where human interaction with technology and work organizational context is studied require an extensive breadth of objective knowledge while at the same time requiring a depth of analysis, reflection and application. This requires an assessment arsenal, or palette, covering the different types of knowledge objectives described earlier for each course.

The three main teachers that are responsible for the overall planning and developing the master's program have thus put great effort in developing appropriate and varied assessment methods within and across the courses in the program. Students also have different learning styles and preferences, partly depending on their undergraduate discipline but also due to personal preferences, which further accentuates the importance of a broad approach in assessment methods. Defining the assessment methods according to Toohey (1999) shows that a variety of assessment methods are used in each course, see Table 3.

Table 3. Assessment Methods in the Courses with Toohey's (1999) Terminology

Course	Objective tests	Essay	Open-book exam.	Case & Problem -based	Pract. & Prof.	Seminars oral pres.	Oral exam	Refl. tasks
HTO				x		x		x
Res.method..	x			x		x		
Cog.Erg.			x	x		x		
Org.				x		x		
Phys.Ergon.	x			x		x		
Project course				x		x		
Degree Project				x	x	x		

Overall in the master's program, there is a strong emphasis on problem-based assessment, which encourages the development of understanding and application of knowledge. In all courses there are also seminars and oral presentations. All these assessment methods facilitate deep learning (Toohey, 1999). In the master's program the students are involved to a high degree in their learning process, both in individual elaboration of the course content and in interaction with other students in different group tasks, and there is a great deal of group work when the students interact with each other. This in combination with problem-based tasks and distinct knowledge bases in each of the different courses highlight the complexity of real world phenomena and trigger the students to a deep learning approach (Biggs, 1989).

A challenge in developing assessment methods has been the different levels of pre-understanding that the students have in the courses, from having very limited knowledge about a certain area to sometimes being specialists in an area with thorough knowledge and work experience. The challenge is then to identify a suitable mix of assessment methods that constitute learning for all students and obtain the learning objectives regarding different learning aspect within each course according to Table 2. Therefore it is even more important to use different kinds of assessment methods, which address different depths in knowledge, understanding and application. Further, as the students are expected to relate the content of each course to a systems perspective, more than domain-specific knowledge is required. This means that even if students have more extensive knowledge in one field they gain knowledge of how it contributes to various applications of a holistic approach and those who have little pre-understanding still get sufficient knowledge and understanding to be able to apply it in different contexts.

CONCLUSION

This paper has described and reflected on the variety of assessment methods used in a master's program to fulfil learning outcomes and encourage deep learning. These include for example written exams, oral presentations, seminars, and problem based tasks, in which the students learn on an individual base as well as in group work. This palette of assessment methods are used throughout each course in the master's program and recurrently reflected upon in relation to the development of the courses and the students' learning processes. However, sometimes challenging to find assessment methods to fit students with different backgrounds, the variety of methods allows for students to demonstrate their knowledge and understanding through different means and in different contexts.

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STUDENT COMPETENCE PROFILES – A COMPLEMENTARY OR COMPETITIVE APPROACH TO CDIO?

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ABSTRACT

For students to develop independent learning strategies, it is essential to have an understanding of what it is they are aiming for. For this reason, every educational programme in Sweden has learning outcomes as stated by the Swedish Higher Education Authority. However, these are rather formal and sometimes described in a way that is not easy, either for teachers or for students, to implement in teaching and learning activities. A challenge is to both apply CDIO-standards and comply with the Swedish Higher Education Authority's stated learning objectives. At the same time, we should uphold students' motivation to develop their competences and teachers' understanding of which teaching and learning activities are relevant, and how and what to assess in students' learning to contribute to all of these approaches. The aim of this paper is to describe the development of a competence profile. The idea is primarily based on the Vitae Research Development Framework, but with inspiration from several other frameworks and approaches. The competence profile is designed to support students´ individual professional industrial design engineering competences. It allows the students themselves to map their knowledge, skills, experiences and qualities, and also provide support for teachers' feedback and assessment. In other words, the student competence profile is used to describe what students are supposed to be able to do (prior to courses), what the learning activities are supposed to contribute to (during courses) and for formative and summative feedback of how well it has been done (during and after courses). It also allows a visualisation on how different courses contribute to the overall programme objectives.

KEYWORDS

Competence Profile, skill development, self-regulated learning, learning objectives, learning outcomes, Standards: 2, 3, 11

INTRODUCTION

What exactly are the goals of higher education? A summary of the objectives of the CDIO initiative could result in a general goal of independent engineering students who are capable of learning and developing their knowledge and skills in a self-regulated manner.

The overall objective of this paper is to discuss learning objectives and outcomes for Industrial Design Engineering students at Luleå university of Technology (LTU) and how to support them in meeting those criteria. If students are to develop independent learning strategies, it is important that they have an understanding of what they are striving for (Tinto, 2003). In Sweden, the Higher Education Regulation (1993:100) stipulates learning outcomes, which specify the knowledge, skills and judgment capability MSc in engineering students should demonstrate in order to achieve their final degree. One challenge with these outcomes is that they describe the competences engineering students should have at the end of their education, but does not clarify what competences we as teachers should include in learning activities, provide feedback on or assess in a clear and straightforward manner. The learning objectives refer to the the final level at graduation. Several of our students are finding it difficult to know their level of accomplishment during their studies. To meet the Swedish Higher Education Regulation is a requirement, it is something every higher education body in Sweden has to do. Meanwhile, there are several other frameworks that support skills development and independent learning strategies.

The MSc programme in Industrial Design Engineering (IDE) joined the CDIO initiative in 2015, as one of four test pilots at LTU. The aim was to reform the educational programme with support of the framework offered by CDIO. A challenge with this is however to both exercise and fulfil the CDIO standards, whilst we at the same time are required to meet the Swedish Higher Education Regulation. In parallel, teachers and faculty who work with educational reform want to know what learning activities best accomplish both regulations and CDIO standards and what competences they should assess in courses. At the same time, we also need to maintain students' understanding of, and motivation for, developing their competences as Industrial Design Engineers, i.e. to strive for their particular professional engineering practice capabilities. For that reason, we developed a competence profile, with the purpose of serving as a framework for both students and teachers to discuss, plan, and receive feedback on specific IDE competences and criteria for those. Using the competence profile as an illustration, we in this paper address the following questions:

- How can an independent learning strategy be supported, and what would be gained, through implementing a framework for competence progression?
- How can the three approaches: Swedish Higher Education Regulation, CDIO syllabus, and the IDE competence profile, co-exist, and contribute to students’ self-regulated learning?

INDUSTRIAL DESIGN ENGINEERING

Students who apply for Industrial Design Engineering at LTU sometimes have a vague understanding of the professional practice that their education leads to, or what responsibilities they are expected to participate in, in their future professional practice. In our experience, many students are attracted by the artistic design elements, and at the same time consider it reassuring to have an engineering degree. The challenge is to get those different practices, disciplines, and topics that the education and its courses consist of, to actually work together in a constructive and supportive learning path for the students. IDE students can for example take a course in Form studies while they at the same time take a course in Solid Mechanics.

Industrial design engineering is an area that can be broadly described as consisting of industrial design and engineering design, i.e. an area that is on the border between a more design-oriented and a more engineering-oriented practice. An industrial design engineer in professional practice is often involved in facilitating various disciplines in a development process. One way to describe the competences and qualities needed for this is ‘T-shaped people’, who have deep analytical skills (the vertical bar of the T), while they at the same time have a broad understanding of other skills and disciplines (horizontal line of the T) (Amber, 2000).

As a professional practice, Industrial design engineers, have according to Eder (2008) the purpose of creating future solutions (processes and artefacts), through the development of understanding of use and users, i.e. the interaction between human and the solution. In this perspective, accomplishing this involves identifying the best solution to satisfy the needs of potential stakeholders, users and clients, through thinking which solution best assists human actions,. Eder further describes that this requires competences in understanding form, aesthetics, usability and ergonomics as well as skills in implementing technical functions, manufacturing, safety and reliability and several other factors.

Smets and Overbeeke (1994) describe that practitioners in the field of industrial design engineering need technical knowledge, knowledge of user experience and product expression. It renders an industrial design engineer student needs to develop engineering skills, i.e. competence to develop the product's function and purpose, and industrial design skills, which, according to Ulrich and Eppinger (2012), cover form and user interaction. Ulrich and Eppinger also believe that the design of products that meet customer needs should include expertise in both engineering and industrial design. This can be said to be the essence of Simon's (1969) proposal of the development of a 'science of the artificial', i.e. to achieve a fundamental foundation between the various practitioners who are involved in the creative process of developing future solutions that satisfy human needs. According to Simon, it has not before been possible for these various practices to cooperate, because they have such different languages.

In Brännberg, Gulliksson and Holmgren's (2013) view, engineers should be defined on the basis of their education. Their argument is that there are so many different types of engineering education that it is difficult to identify unifying elements. The origin of the concept 'engineer' is the Latin word 'ingenerare': meaning creating, which can be compared to the origin of design in the Latin word 'designo': i.e. to designate, to create. Although the concepts are very similar, and in some professional practices are used synonymously, some engineering fields do not use the term 'design', but describe it as various forms of 'engineering'. In our experience, the concept of design, particularly in Sweden, is often misused to describe only the aesthetic expression of the final product, while we emphasise it as both constructing and designing (Wikberg Nilsson, Ericson Törlind, 2015). Cross (2006) describes this dilemma as the major challenge for the field, that is, to find means of communication within and between practitioners involved in the creative professional solution development. The basic idea, as Cross sees it, is that there are specific skills that a design engineer should have, regardless of which professional practice they work in. For that reason he suggests focusing on what he describes as designerly ways of knowing, thinking and acting. Brown formulates this as the concept of 'design thinking', which can be described as an approach for using the designer's method of matching human needs with what is technically feasible, and has a viable business strategy (Brown, 2008).

SUPPORT IN HIGHER EDUCATION

The next sections include identified students' needs in higher education, identified both by students themselves and through research on student support.

Student's views of support

The Student Mirror is a survey carried out by the Swedish Higher Education Authority[1], focusing on quality in higher education. The 2007 Student Mirror includes a survey of 11,119 students at Swedish universities. According to this study, students' experiences of support for professional development are disapointing. The categories deal with the relationship between students and teachers, and the results show a rather negative image:

"To discuss and converse with teachers and tutors provides you with a perspective on your education. It is often only in the discussion that the student gets the opportunity to expose their knowledge and thoughts to others." (Student Mirror, 2007 Authors' translation)

The survey includes the question of whether the students have discussed with the teachers or supervisors outside scheduled course activities, discussed future plans with teachers or other persons connected with the university, discussed course requirements or responsibilities or otherwise interacted with the teacher or tutor in contexts other than courses. The results show that 90% of those students perceive that they rarely or very rarely discuss with teachers or supervisors outside scheduled course activities. Likewise, they state that they rarely discuss future plans. It is further revealed that 70% of students report that they rarely or have never discussed the course requirements or responsibilities with a teacher or tutor. Only 12% state that they have discussed future plans with teachers or the equivalent at the university.

The questions included in the survey also deal with the extent to which teachers and supervisors provide the neccecary support for the student to grow and to develop competences, whether teachers have helped students to manage non study-related commitments, have encouraged contacts between students, or motivated students outside the course.

"The teacher's support can be of different types, both intellectually and socially, and can contribute to a good learning experience. The support can also be an important prerequisite for the students to develop and grow as people. " (Student Mirror, 2007 Authors' translation)

According to this survey, it is only on rare occasions that teachers have supported students to deal with non-course-related commitments or have provided support for students to develop their own competences.

RESEARCH ON SUPPORT

Research covering aspects needed for students to pursue their education with good quality identifies five conditions: clear expectations, support, feedback, engagement and learning, which are described in more detail in the coming sections.

Tinto (2003) believes that students are more likely to pursue their studies if teachers and faculty have high expectations of their success. Students are greatly affected by what faculty expect of them individually. According to Tinto, students also need study environments that provide academic, social and individual support. Most students need support at some time during their education, Tinto stresses that this is particularly important during the first year. Support should be offered in a structured form, but it is equally important to have daily support from teachers

[1] http://www.hsv.se (2007-09-04)

and faculty. Astin (1984) similarly argues that support should be given in the form of advice, guidance and support. Astin believes that this support should be individual.

McHugh, Engstrom and Tinto (1997) believe that students are more likely to continue and develop their competences in a learning environment that provides frequent feedback on their individual performance. Different forms of on-going assessment and evaluations should offer the student the necessary information on how their performance can be improved to better meet the requirements. Rendon (1994) also points at the importance of formative feedback to students concerning their competences Biggs and Tang (2011) discuss that formative feedback, i.e. feedback that occurs during the learning process when the student has the opportunity to improve their performance, better supports students' motivation and their will to work more constructively towards certain goals. Ramsden (1993) points out that the feedback situation needs clear criteria and objectives to stimulate students' intellectual challenge, and their dedication and efforts to achieve the goals.

Students' competences grow best in a learning environment that welcomes them as appreciated members of the institution (e.g. Tinto, 2003; Astin, 1984; Rendon, 1994). Commitment, in this perspective, involves both teachers and others being involved in the individual student's education, and also for both teachers and the institution to have a clear objective to motivate students to develop their competences in the field. Rendon (1994) argues that committed students are those who put consistent effort into studying, meaning spending time on campus, actively participating in student organisations, and interacting with teachers and other students outside of course activities. Students with low comittment often neglect their studies, spend little time on campus, do not take part in outside-of-curriculum activities, and have little contact with teachers and other students. The latter, according to Rendon, risk failing their studies, i.e. not achieving the required quality of the learning outcomes. In anticipation of this, students need to be confirmed and to feel that they are capable of learning. With such confirmation, they gain confidence and feel that they are accepted and seen as valuable. When students are not confirmed, they feel frustrated, subordinated, despairing and are become silent. Confirmation outside the classroom, but within the educational framework, can be in the form of conversations with other students, teachers, counselling, coaching or other guidance (Rendon, 1994).

The main condition for students to succeed in their higher education is a learning environment that fosters learning, says Rendon (1994). The more time and energy students devote to their own development and learning, and the more intensely they engage in their own education, the better they perform, and the more satisfied they will be with their education (Rendon, 1994). Commitment seems therefore to be a key to learning: students who are actively committed in their education learn more. To create commitment and persistence in learning, the entire institution needs to actively support students' understanding of learning objectives and how to achive learning outcomes (Wikberg Nilsson & Gedda, 2013).

For this reason, Boekaerts (1999) argue that self-regulated learning has emerged as an important part of education. This involves research on learning styles, metacognition and regulation styles, and theories of the self, including goal-directed behavior. It can be summarized into processing modes, learning processes, and regulation of the self. In this perspective, teachers and researchers would benefit from integrating these three layers into a comprehensive model of self-regulated learning. In support of this is Schoenfeld's (2011) argument that what people choose to do is a result of their resources (knowledge and available materials and other resources), their goals (conscious or unconscious goals they are trying to accomplish), and their attitude (their assumptions, values and abilities). Clear guidelines and support could for that reason contribute to student skill development and probably thereby also to student success.

EXISTING FRAMEWORKS

There are a variety of legislative and non-legislative frameworks for supporting students in their competence development. Some of these are described in upcoming sections.

Swedish Higher Education Regulation

The Higher Education Regulation is developed by the Swedish Government, and is in turn subordinate to the Swedish Higher Education Law. This stipulates the conditions for managing higher education, for universities governed by the state. The Higher Education Regulation describes the learning objectives for each higher education degree. These objectives are in other words not negotiable, but are goals of the education that must be met in order to attain a certain university degree. It is divided into three sections with different criteria of 1) student's knowledge and understanding, 2) skills and abilities, and 3) judgment and attitude.

The CDIO framework

The CDIO framework is described as an innovative framework for developing future engineers[2]. In summary, it covers development of engineering students' skills, in order to become professional and independent so that they can participate in an engineering practice directly after their education (Crawley, Malmqvist, Lucas & Brodeur, 2011). CDIO's 12 standards serve as a guideline for educational reform and evaluation and provide a framework for continuous improvement. They also provide evidence for each standard, illustrating how the standard can be met.

There is a broad consensus in engineering education that is in accordance with the objectives of the CDIO initiative (Cloutier, Hugo & Sellens, 2010), i.e. that there is a need to develop engineering education and future engineers who have the expertise to apply conceive-design-implement-operate skills in developing future products, processes and systems. Crawley et al. (2011) emphasises that the 12 standards include developing consistency between objectives, learning activities and evaluations, in accordance with Biggs and Tang's (2011) description of 'constructive alignment'.

The 12 standards address major aspects of higher engineering education; aspects which are essential for teachers and faculty to mutually and continually discuss and develop. Crawley et al. (2011) argue that there are different needs that today's engineering courses should contribute to: they must help to develop students' technical skills, while at the same time contribute to a variety of individual and social skills, such as having the skills to work in teams and the skills to meet ethical, corporate and societal needs. An important aspect of this framework is the description of the need for skills in the form of 1) disciplinary knowledge and reasoning (learning to learn), 2) individual and professional competences (learning to be), and 3) social skills: teamwork and communication (learning to be together).

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[2] http://www.cdio.org

Alverno's ability-based curriculum

Alverno College in the US has over 30 years' experience of working with ability-based curriculum strategy. Their focus on eight core abilities represent what is described as "the very building blocks needed to create an effective and relevant learning experience."[3]

Riordan and Sharkey (2010) describe the implementation of the ability–based learning strategy as involving the entire college in the question of what is most important that the students learn: what is it that students must not miss in your area? The result is that the whole institution agreed on eight abilities, which were seen as common and fundamental to all disciplines and areas. Each skill is described by a number of criteria. To get a degree from Alverno require all students to have achieved at least level 4, then it is up to each educational programme to identify abilities that are vital, and thus determine the level students must achieve. Hakel (1997) believes that this is due to the focused performance: *"You get what you measure. If you want performance, then you have to measure performance".*

An important ingredient in Alverno's ability-based framework is their focus, primarily, on learning and, secondly, on education. According Hakel (1997), it covers a different mindset from 'how should I teach this' to 'how should students learn this'. Far too often from Hakel's perspective, what students learn is something else than what was actually intended, which is also different from what was actually taught. To detail the abilities that are central for students, and to start a discussion about how students can learn that, and how students can demonstrate that they have learned, is in this perspective central. An important aspect, according to Hakel, is to provide constant, inevitable and formative feedback. At Alverno, this includes self-evaluation, peer-review, teacher assessment, and external evaluation. The framework consists of students documenting evidence of their performance, which is then assessed through self-assessment, peers, faculty and external assessment. The point of this, says Hakel, is to compete against oneself, not against others.

Vitae - Research Development framework

Vitae Research Development Framework RDF) (Vitae 2011) is a framework and career development tool for researchers at all levels, from graduate student to highly qualified research leaders. The RDF was introduced in the UK in 2010 (Bray & Boon, 2011) and was developed to plan, promote and support personal and professional career development of researchers. The idea was that the tool would enable researchers to assess their knowledge, skills, behaviours and personal characteristics against clear criteria.

The RDF comprises a matrix of different attributes with up to five different quality levels. A total of 63 areas (RDF uses the term descriptor) are organised in four main areas and 12 sub-domains. For example, within the sub-domain D3 Commitment and Impact, the area of education is outlined with four different skill levels. To achieve level 1, the researchers are supposed to contribute in teaching and supervision of projects at the basic level. To achieve the highest level of competence, the researcher is required to lead educational programmes and their evaluation and quality assurance, as well as actively promote a culture that links research and education, and act as a mentor for others.

[3] www.alverno.edu/academics/ourability-basedcurriculum/ (2016-04-27)

The framework is implemented in an on-line tool that helps the researcher to self-evaluate the level of competence he or she is at the moment, as well as a desired level to strive for. The choices are recorded and the researcher must provide evidence they have achieved a certain competence level. The process can be described as an iterative deliberative process (Bray & Boon, 2011), where the researcher can return, adjust and change their previous choices. In the tool, the researcher can also set objectives (areas and skill levels) that he or she should achieve, how it should be measured and when it should be implemented.

COMPETENCE PROFILE

In early 2015, during the process of the current CDIO framework implementation and educational reform of Industrial Design Engineering LTU, we identified a need to better govern teaching and learning activities toward learning objectives and outcomes. The reason for this was for both students and teachers to recognise competences that are particulary relevant in this MSc engineering education, without having to search in both the Swedish Higher Education Regulations and CDIO Syllabus. In short, we saw a need for a common framework that could suppport teachers to e.g. plan learning activities, provide formative feedback during courses, and assess learning outcomes, and support for students' self-regulated learning by assessing their knowledge, skills, behaviours and personal characteristics against clear criteria.

A challenge for Industrial Design Engineering is that one department does not give all courses within the programme: instead three institutions provide some of the courses, without insight into specific graduate coucome for IDE. Luleå University of Technology, for example gives the same general basic courses in mathematics, physics, economics and chemistry for all disparate engineering degrees: space engineering, mechanical engineering, architecture, civil engineering, computer engineering, industrial design engineering etc. This represents a difficulty for the students to realise how the course contributes to their individual skills development, and also makes it difficult for teachers to provide examples and learning activities for the individual programmes.

This is the background to the work with developing a framework that supports both teachers' and students' understanding of what competences they need to develop to be able to work in the field of industrial design engineering. In 2015 the implementation of CDIO began. It meant that work with the Competence Profile included both discussions about the Swedish Higher Education Regulations and how they could be filtered down to more straight-forward descriptions of the competences that are specific for industrial design engineering, as well as CDIO's syllabus. To exemplify, we describe one of the Swedish Higher Education Regulation objectives:

"Demonstrate the ability to in both national and international contexts, orally and in writing, and in dialogue with different groups, clearly present and discuss their conclusions and the knowledge and arguments that form the basis for these"

This objective clarifies what the student should be able to demonstrate at the end of their education, but does not illustrate what qualities the student needs to have in order to progress toward the final examination. An interpretation of the competences this objective requires could include oral and written communication, dialogue with different groups, and the ability to express themselves in both Swedish and English. This can be compared with CDIO's Objective 3.2, Communication, which is defined in Table 1.

Table 1. CDIO objective 3.1 Communication (Cloutier, Hugo & Sellens, 2010)

3.1	**COMMUNICATION**
3.1.1	Communication strategy
3.1.2	Communication structure
3.1.3	Written communication
3.1.4	Electronic/Multimedia communication
3.1.5	Graphical communication
3.1.6	Oral presentation
3.1.7	Inquiry, listening and dialogue
3.1.8	Negotiation, compromise and conflict resolution
3.1.9	Advocacy
3.1.10	Establishing diverse connections: networking

The CDIO syllabus covers the Swedish Higher Education Regulation and more. It thus provides a good overview of the communication skills that are valuable for an engineer, while providing education leaders and teachers further indication of important competences to practice in teaching and learning activities. However, it does not provide support for discussing quality or progression. On the other hand, Alverno's ability-based curriculum provides several criteria for self-evaluation for each learning objective, see Table 2. This illustrates the criteria for self-evaluation of oral presentation.

Table 2. Self-evaluation of learning objective for communication (Hellertz, 2004)

	COMMUNICATION
1	Talks without reading from, but with assistance of, notes
2	Seizes attention and clarifies content, in a, for this particular audience, relevant manner, making clear demarcations, and refers to relevant sources
3	Uses verbal expressions that demonstrate clear focus, an understandable terminology etc.
4	Effectively convey information, e.g. through adequate voice strength, varied tone, use of body language, eye contact etc.
5	Uses conventional rules for formulation, pronunciation, sentence structure etc.
6	Uses a meaningful and effective structure and disposition
7	Supports and develops theme, using quotes, examples, personal comparisons etc.
8	Uses relevant media (OH, PowerPoint, video etc.)
9	Conveys an appropriate content

Our idea was to develop a framework that could support students' understandings of important qualities for an industrial design engineer, and a self-regulated learning strategy of progression towards certain objectives. The framework should support both teachers and students in understanding how and with what quality, a certain competence should be developed. The framework consists of eight different competence areas, visualised in Figure 1.

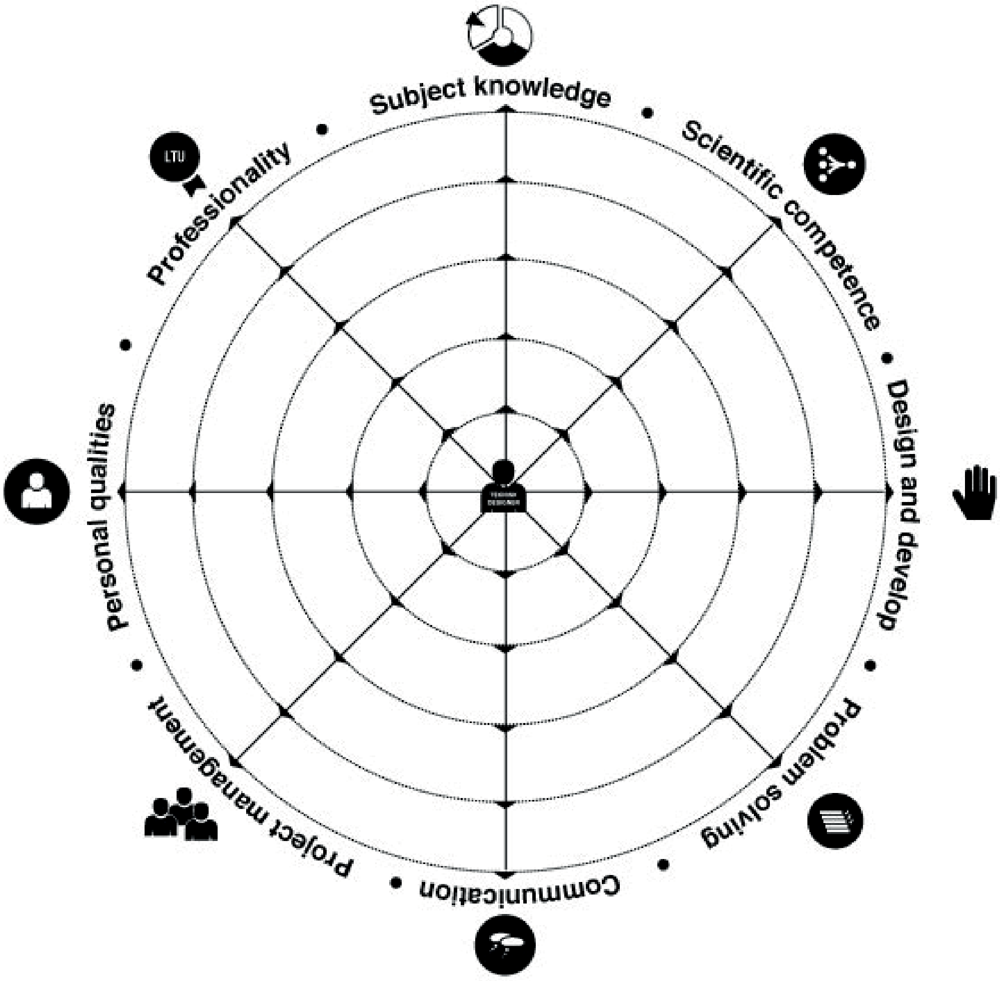

Figure 1. The IDE Competence Profile

The eight areas were developed in discussions with students, teachers, and alumni of what competences that was most important that the student had developed during the education. The Competence profile development has been an iterative process, where the framework was first discussed, introduced and implemented in an introductory course during autumn 2013, and then further developed in several steps and implemented in later courses. Each competence area is in this model divided into several criteriaompetences where student starts as a novice and can progress to an expert. For the competence area Communication skills, the sub areas and the criteria's areis listed in Table 3.

Table 3. Competence Communication for Industrial Design Engineering at LTU.

COMMUNICATION				
Oral communications				
NOVICE	**ADVANCED BEGINNER**	**COMPETENT**	**SKILLED**	**EXPERT**
Execute a presentation in a structured and factual way, keeping track of time, and through the use of appropriate aids.	Motivate and defend basis of ideas and arguments in a confident and convincing manner	Select and apply a range of presentation techniques for different audiences and situations	Convininingly formulate answer to questions and discuss the basis of arguments with different people	Present, defend and argue in English in a credible manner
Written communications				
NOVICE	**ADVANCED BEGINNER**	**COMPETENT**	**SKILLED**	**EXPERT**
Understand use and format a basic template	Apply a variety of reporting methods (lab reports, project reports, workbook, pm etc.)	Evaluate, assemble and convincingly formulate work, results and arguments in a credible manner	Select and develop structure, content and format of written communication for different audiences	Ccommunicate in writing in English
Visual communication				
NOVICE	**ADVANCED BEGINNER**	**COMPETENT**	**SKILLED**	**EXPERT**
Understand basic tools and techniques for visual communication	Apply a broad range of visual communication techniques (sketch, rendering, physical model, simulations, animations, 2D and 3D models)	Analyze and argue for visual communication technique, create a visual communication also of the work process and its results in a convincing manner	Select, argue for and design visual communication for different target groups	Professionally and convincingly, combine different visualisation techniques to communicate process and results

Table 4. Competence Design and develop for Industrial design engineering at LTU.

DESIGN AND DEVELOP				
Think and act innovatively				
NOVICE	**ADVANCED BEGINNER**	**COMPETENT**	**SKILLED**	**EXPERT**
Explain and use basic creative methods	Challenge current solutions, apply creative methods	Apply creative methods and approaches to create novel solutions	Select and customize creative methods and approaches to fit context and problem situation	Facilitate and create creative processes and workshops tailored both to the team and the problem
Prototype and test				
NOVICE	**ADVANCED BEGINNER**	**COMPETENT**	**SKILLED**	**EXPERT**
Understand and use simple prototypes to evaluate features and characteristics	Apply and use different types of prototypes to evaluate the features and characteristics.	Explore the solution space by creating and evaluating prototypes with a user centered approach.	Create prototypes in an iterative process to explore, test, analyze and evaluate the functions and features	Carry out design projects in which prototypes are used throughout the entire process to ensure user experience and usability

The purpose of the matrix is to support students' independent learning strategy, i.e. that they have the opportunity to self-evaluate their competences both with and without teacher intervention. It also provides support for teacher’s planning of teaching and learning activities, and in feedback situations. The idea is also to eventually use it to set standards for graduate outcomes, i.e. to get a degree require all students to have achieved at least level 3. The goal is to implement the competence profile throughout industrial design engineering curriculum.

During 2015-16 the Competence profile has been tested in three courses, where the students have used it as a self-assessment guide. Students’ comment have been e.g. “it supported to identify my weaknesses”; “it was a pedagogical tool for my own development”; and “it helped me understand what to develop and learn in the education”. Future work is to further discuss with both students and teachers which courses should have learning activities that can contribute in developing a specific competence, i.e. teaching and learning activities that contain elements who ensures practice of a particular competence at a certain level. For this to be possible requires learning activities of self-evaluation, peer-review and teacher assessment of competences, sessions in which the student receives formative feedback on their performance, and what they need to do to develop their competences.This should ideally also be reflected in curricula and study guides, so that students themselves can adjust their own competence profile, and visually see how their competences develops in and through teaching and learning activities. At the moment, we are implementing this in a visual representation of the curricula, in which the students can see what the courses’ teaching and learning activities can contribute to their individual competence development, see Figure 2.

Figure 2. An example of how the Competence profile is aligned in one of the courses in a visual representation of the curriculum.

In addition, the idea is to use existing workbooks, learning portfolios, and implement a self-evaluating scale of what the students themselves think that they achieved during the teaching and learning activities. Afterwards, this can be used in feedback sessions where teachers and students discuss how they can develop their competences before summative assessment. This would provide a framework for a self-regulated learning strategy, in which the students focus on these competences, which are required for their professional practice, and that also makes it easier to understand how learning activities constructively are aligned toward their final degree.

DISCUSSION

A comparison between the Swedish Higher Education Regulation objective 9, CDIO learning Objective 3.1 and the competence profile Communication Skills illustrates that the competence profile contributes both in fulfilling the Swedish Higher Education Regulation and the CDIO syllabus. An interesting aspect is that visualisation competences are left out in the Swedish Higher Education Regulation degree outcomes, while CDIO expresses the need for graphical communication as an aspect of communication. For industrial design engineering students, visualisation competence is essential for their future professional practice, consequently it is an important skill to develop during education. Otherwise, we believe that the comparison illustrates that both students and faculty are supported by the Competence Profile, both in meeting the Higher Education Ordinance requirements, as well as the CDIO initiative engineering expertise, and that it also provides support for student developing a self-regulated learning strategy of competence in a clear and straight-forward way.

We believe that self-regulated learning strategies can be one important complement in higher education that have potential of contributing to higher quality and student success. It is a framework that supports students' independent learning strategies towards outcomes based on clear criteria. For the various functions and roles involved in implementing higher education, student's independent learning strategies is often an implicit demand that in our experience is rarely discussed with the students. The Competence profile is designed to support an independent learning strategy, and to create a professional framework for developing and planning teaching and learning activities,, as well as promoting students' personal and professional development. An independent learning strategy is supported as it allows the students themselves to map their knowledge, skills, experiences, and qualities, and take action for change. It is also valuable as basis for formative and summative assessment. In other words, the Competence profile is employed to describe what students are supposed to be able to do (prior courses), what the learning activities are supposed to contribute to (during courses) as well as for formative and summative assessment of how well it has been done (during and after courses).

Finally, to conclude the question of what can be gained by introducing a new framework. We believe that the competence profile provides a framework that is easy to understand and implement for both students and teachers. It supports actual implementation through the easy-to-use design. The Competence Profile states the individual characteristics that are required for achieving an MSc degree in Industrial Design Engineering at LTU. It covers the Swedish Higher Education Authority's requirements, but in a more straightforward, way. It also allows an visualisation on how different courses contribute to the overall programme objectives. The second question of issue for this paper was how these different approaches to learning objectives can co-exist. In our experience, overall the student competence profile is a valuable framework that supports both educational development in a CDIO implementation, and students in developing necessary competences for their professional practice. The student competence profile therefore in our view completes, not competes with, the CDIO syllabus.

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MOTIVATING AND ENVOLVING PROJECTS IN SIGNAL PROCESSING CLASS

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ABSTRACT

Several courses in engineering sciences can be highly theoretical with limited possibilities of practical application and therefore, for many students, these subjects are seen as a mandatory burden that they have to take, instead of an interesting topic that they really want to learn about. This is often the case of "Signals and Systems"*related subjects in Electronics and Electrical Engineering programs. These subjects are characterized by having dense mathematical contents and a wide variety of abstract concepts, requiring the students to deal with a lot of equations and properties seen in previous math courses. Due to this theoretical teaching approach, the learning process is further complicated as students have difficulties to recognize possible applications of these new concepts presented in class.

For this reason, we have introduced a series of practical projects in the Signals and Systems courses we teach, aiming to actively involve students in their learning process while motivating them by the practical application of the theoretical content seen in class.

Usually, these course projects are formulated as programming exercises using high-level computing languages such as Matlab, and its graphical environment Simulink, with good results. However, we go further with the design of these new projects, where this programming software are used as a tool and not as the main core of the project. To do that, these projects involve students working with hardware development, design, and testing, as they create and control the systems all by themselves. Note that hardware development is not limited to electronics or electrical issues; on the contrary, it is desirable that students expand their vision to other application areas closer to their regular life experiences, such as acoustics, visual arts, music and special effects.

The approach, implementation and evaluation of these projects have been done through cooperation between the University of Campinas, Brazil and Pontificia Universidad Javeriana, Bogota, Colombia, by professors teaching Signals and Systems related subjects, which enriches the project and serves as a foundation for future work in teaching and learning between the two universities.

KEYWORDS

Signals and systems, projects, hardware, cooperation, Standard 8, Standard 11.

BACKGROUND

Since some years, the Pontificia Universidad Javeriana, Bogota, Colombia, was linked to the CDIO initiative (Gonzalez et al., 2013).

For this reason, we have started several projects ranging from the reform of the curriculum to the implementation and monitoring of Active Learning more formally in some classes, with the support of several teachers and the Chair of the Electronics Engineering Program. With that, some innovations were made possible in different classes, one of these was Signals and

Systems, as it has some special characteristics that make it attractive for the new implementations.

Among the features of the course, which facilitate the implementation of these innovations, are first the availability of teachers motivated to face this challenge. Further motivations are the fact that the course is considered difficult, as it is highly theoretical. In addition, the course possesses a large amount of supporting material, which has been generated over time, and finally cooperation and acceptance of students, who have seen better results, in learning and motivation.

Several activities have taken place and have been implemented gradually, many of which are based on the premises of peer instruction proposed by Professor Eric Mazur (Fagen et al., 2002)., but adapted to our environment. The results of this activity were shown at the conference of CDIO in Chengdu, China, in 2015 (Cruz et al., 2015).

Exactly because such good results were obtained that the opportunity arose for cooperation with the University of Campinas in Brazil, exactly in the same class, Signals & Systems, sharing information and results, while respecting the independence and culture specific to each university.

Projects was one of the areas where improvements were made. They were previously concentrated on the use of software, so we wanted to make a change to include more interaction with real life and application of academic knowledge once they were acquired.

This paper will show the projects developed, its evolution and new implemented projects, then it will show the results obtained with the students in their learning process.

All the work related to the implementation and evaluation of these projects has been done through cooperation of Universidade Estadual de Campinas, Sao Paulo, Brazil and Pontificia Universidad Javeriana, Bogota, Colombia. This cooperation serves as a foundation for future work in teaching and learning between the two universities.

DESCRIPTION

Signals and systems is a course of third year of Electronics and Electrical Engineering programs. In this course, the students have to deal with very dense mathematical contents, a considerable amount of equations and concepts previously seen on the math courses. Unfortunately, it seems that these basic subjects negatively influence the student’s learning process and giving them an extra as they make it harder for students to recognize the possible applications of these new concepts presented in class (Cruz et al., 2015).

For this reason, we have introduced a series of new practical projects to the Signals and Systems courses we teach, aiming at involving the students in their learning process and also motivating the application of the theory just learned.

Usually, the projects have been based in programming with software as Simulink or Matlab, with good results.

Along with the development of these projects they have also been introduced some modifications to the traditional assessment methods (written tests) and added assessments include oral presentations, assessment with peers and creating posters, all based on the standard 11 CDIO . (Cruz et al., 2013) (Cruz et al., 2015).

EVOLUTION

Software projects

These projects are highly theoretical, they need programing skills, and the results are mathematical with low practical development, even though they might be useful to reinforce some particular concepts. On the other hand, they are cheap to develop and require very few resources.

In these projects, the students receive the files and the information about the process they should do, and then, they do the process and give us a result.

Some examples of these projects are shown below:

Project: DTMF (Dual Time Multi-Frequency)

When we used to dial numbers in our telephones, a way to recognize these numbers in destination is using the DTMF signaling. In this project the students must recognize the dialed numbers in a file (given by teacher), using time segmentation and FFT for tone recognition.

Activities

1. Students must generate in software the DTMF signaling.
2. Program must decode automatically the sequence of numbers with DTMF signaling.

Project: Filtering a noisy signal using Matlab.

Filtering is a good chance to hear a noisy signal before and after we apply a filter. In this way, a noisy signal is given to the students and they have to detect and to identify the bandwidth of the noise, to design the filter and finally apply it to the signal.

Activities

1. Hear the noisy signal and see its spectrum.
2. Define the noise bandwidth and design and adequate filter.
3. Apply the filter designed to the noisy signal.
4. Hear the signal before and after the filter.
5. Design and to apply different filters in order to choose subjectively the best result.

Project: Signals vector space

Vector space is a very challenging topic for students because of its highly mathematical contents, which requires from students a great capacity for abstraction in order to visualize and understand many concepts associated with vector spaces.

When we tell them, vector space is highly useful in cellular communication, they show their interest, so the project is to create a simple communication system, to send four symbols and the receiver has to understand what the transmitter is sending. So far, it sounds very basic and not very challenging for them. But, in addition to this, they have to add noise to the symbols transmitted and the receiver still should recognize them. They are challenged to determine how strong noise power can be before the receiver starts to make mistakes in detection.

Activities

1. Students must generate the four symbols as required.
2. The program should receive the symbols with no errors.

3. Power noise in transmission should increase as much as receiver does make less than one error in 40 symbols.
4. Group with higher power noise in transmission has a bonus.

With these projects, students must apply theoretical concepts to solve them. They find some theoretical problems when these are applied, given as a result an active leaning, then it has feedback made for students and teacher in the classroom. (Standard 8: Active Learning)

Software projects with practical results

We presented some different projects with more practical component, with very good results in motivation and learning.

Projects are useful to apply concepts related to the common life. They are still development in software, but their results are more than a mathematical equation (sounds or images) keeping them cheap to develop and require very few resources, using only the software and some basic recording equipment.

In these projects, the students have to create the files and with their concepts, should create the process to solve the problem and give us the result. The results are not unique and should vary from team to team.

Some examples of these projects are shown below:

Project: Voice characteristics modification

In this project, we show in a practical way the transformation of the signals in time domain (time reflection, time scaling and time shift). Usually, the examples are drawing signals on the blackboard; with this project, the students are able to hear the modifications of the signal, especially in human voice.

Activities

1. First, we will need a recording of some fragments of the human voice.
2. Time shift. They have to play in earphones a song by the left channel, and then the name of the singer by the right channel. File must play with at least five different songs and singers.
3. Time reflection. We will need a recording of a palindrome phrase (“Madam, I'm Adam” or “Satan oscillate my metallic sonatas”) and that phase must be play normally and in reverse.
4. Time scaling. The same previous phrase must be play with different speed (between 0,65 and 1,35 times the normal speed)

Project: Period and Power of signals coming from musical instruments

Power and energy of a signal are seen in class and some examples are solved on the blackboard, assuming the function is known. However, in real life, the function describing a signal is not always known and its energy should be measurement.

To deal with this concept, students have to measure three different kinds of instruments (same classification or similar characteristics), with the same recording conditions, try to guess the order of the results and finally compare them with the measurements.

Activities

1. Choose three different kinds of instruments (same classification or similar characteristics).
2. Recorder the sound of the instruments, keeping the same conditions.
3. Guess the order of power of the instruments.
4. Measure the period of the signals and calculate the mean power in a period.
5. Compare the results of the measurement with the guessing results

Results with these projects have been highly satisfactory, students recognize and can apply the concepts easily and they can have the results beyond software data and relate the concepts to the world around them.

However we want to go further, using the software as a tool and not as the main core of the project. So, more recently, we have prepared new projects, design by us, to provide students a new experience, where in addition to measuring signal characteristics, they can make their own designs, motivating them even more.

Practical projects

These projects involve students working with hardware development, design, and testing, as they create and control the systems all by themselves. Note that hardware development is not limited to electronics or electrical issues; on the contrary, it is desirable that the students expand to other application areas closer to their regular life experiences, such as acoustic, visual arts, music and special effects.

Some examples of these projects are shown next:

Project: Elephant in a Bottle

In this project we exemplify the importance and strength of the concepts of impulse response and convolution in a ludic way.

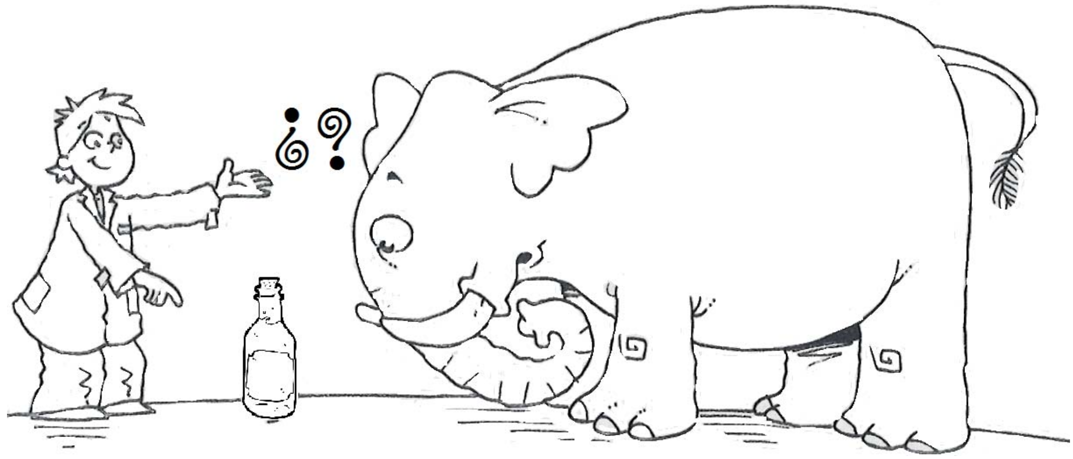
The objective of this project is to solve the famous riddle "how to fit an elephant into a bottle" using for that the tools so far learned in the course.

Note that it might be hard to deal with the elephant´s body using signals and systems, but we can easily work with the sounds it makes.

And we can place the sound of the elephant into the bottle by simply convolving the elephant´s sound with the bottle´s impulse response.

Activities

1. First, we will need a recording of the sound made by an elephant. It is easiest to look for it in the internet, but you can also go and chase an elephant into the wild to record it.
2. We then need to characterize the acoustic behavior of the bottle. To do so, you have a bottle, a microphone and a computer. Think how you can measure the impulse response of bottle. Make sure to check the quality of your measured response.
3. Now we need to "surgically" insert the elephant in the bottle
4. To conclude, write a report on what you learned from this experiment.



http://2.bp.blogspot.com/-SdkNV17a7uI/U2zW76ddgeI/AAAAAAAAAts/1O6f_9QPfEg/s1600/elefante.jpg

Figure 1. How do you put an elephant in a bottle?

Project: Manufacturing an unconventional musical instrument

In this project, we exemplify the importance and usefulness of concepts as frequency, time-frequency relationship, tone generator and spectral component in a practical way.

We are using the fact, that statistically 30% of the students play a musical instrument.

Previous to the project, some examples of unconventional musical instruments were shown. They may build a copy of these or create a new one.

The objective is that they use the frequency response to tune up their notes in each instrument.

Activities

1. Watch the videos given on the videography about different kind of unconventional musical instrument.
2. Manufacture an unconventional musical instrument with at least eight notes of the musical scale. It can be percussion, wind or string.
3. Tune up the musical instrument using a commercial software.
4. Students must play a song with the instrument, with at least 25 notes.
5. To conclude, students should present the instrument and print a poster about the process and the results.

Some examples of the musical instruments made are shown in Figure 2.

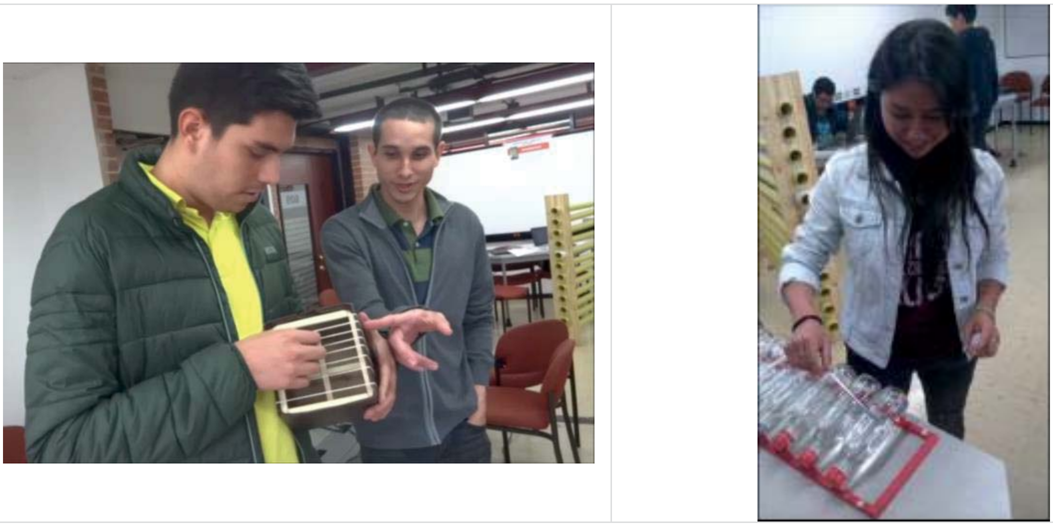


Figure 2. Examples of unconventional instruments made by the students

Project: Subsampling video

Sampling concept is widely used in signal processing and for this, there are many examples of how to use it, however the effects of subsampling usually do not interest the students, because they do not usually apply subsampling.

With this project, we want to give the students the opportunity to visualize the subsampling effect and the change of phase and to understand Nyquist sampling theorem.

Students have to choose a physical phenomenon, record it on a video with a fix sampling rate and to change the frequency of the phenomenon until it shows a different behavior. The best results were obtained when water falling down to different speed was recorded.

Activities

1. Understand Nyquist sampling theorem.
2. Choose a physical phenomenon to record.
3. Video must have the description of the phenomenon (text or audio).
4. The video should not be edited to show the physical phenomenon.
5. Students should present a poster about the process and the result of the experiment.

You can watch some videos with “water falling up”, in these links (they are in Spanish):

https://www.dropbox.com/s/ndjy1gd0fim33ew/se%C3%B1ales.mp4?dl=0
https://www.dropbox.com/s/4cjv88fbt6xapmu/poryectoMUESTREO.mp4?dl=0

We are very happy with the results and the product made by the students.

At first there was some opposition and resistance to this type of project, maybe they were afraid of the unknown, but at the end, some students of the last year asked why they did not have these kind of projects before.

Evaluation process is less stressful for the students, because they feel more confident to show their work and the acquired knowledge, after they are finished the projects. Sometime in class when they are showing their projects, the questions made for their peers are more difficult than teacher does. Standard 11

RESULTS

Results have been quite good in several aspects such as, Motivation (students are waiting for the next project), Participation (as the groups change each time, students are more involved in the project), Compliance (at the beginning, the projects had some of opposition –those implied more effort-, but after the students seen the results, they were glad), learning (students shown their projects and results, feel more confident and they are able to speak using better the concepts and explanations), linking theory and practice (projects can be done previuosly or after that theoretical topics subjects are taught), and even better grades.

In addition to the comments by both current students as some older students and the quality of the products presented, a measure based on the SSCI (Signals and Systems Concept Inventory) was conducted. The Signals and Systems Concept Inventory (SSCI) is a 25 question multiple-choice exam designed to assess students' understanding of core concepts taught in undergraduate linear signals and systems courses, which are an integral part of electrical and computer engineering curricula (Buck et al., 2005).

When applied as a preliminary test, still in the first week of school, and a final test in the last week of school, the SSCI measures the gain in understanding of these fundamental concepts resulting from participation in the course offered. It also allows the evaluation of the conceptual errors more often committed by students.

In the table below, we can observe the results obtained in one of our classes.

Table 1 using SSCI. Results obtained by a group

#	First week (PRE)	Last week (POST)	Relative Gain	Gross Gain
Student 1	80%	92%	60%	12%
Student 2	64%	68%	11%	4%
Student 3	36%	56%	31%	20%
Student 4	40%	48%	13%	8%
Student 5	52%	80%	58%	28%
Student 6	32%	68%	53%	36%
Student 7	52%	64%	25%	12%
Student 8	40%	72%	53%	32%
Student 9	52%	68%	33%	16%
Student 10	80%	92%	60%	12%
Student 11	32%	76%	65%	44%
Student 12	40%	60%	33%	20%
Student 13	52%	56%	8%	4%
Student 14	52%	80%	58%	28%
Student 15	48%	72%	46%	24%
Student 16	56%	76%	45%	20%
Student 17	32%	52%	29%	20%
Student 18	48%	64%	31%	16%
Student 19	40%	44%	7%	4%
Mean	**49%**	**68%**	**38%**	**19%**

The second column shows the mean score in the pretest (PRE), the third column shows the mean score in the final test (POST), the fourth column shows the relative gain, calculated as $<g>$ = (gross gain) / (100-Pre), and the last column shows the gross gain, calculated simply by gross gain = Post-Pre.

International comparison

From SSCI article (Buck et al., 2005), we can compare our performance with other 20 courses in Signals and Systems, 15 of these considered traditional methodology courses, and five considered as active methodology. In this article, the 15 traditional courses had an average relative gain $<g> = 0.20 \pm 0.07$ while the five active courses had an average relative gain $<g> = 0.37 \pm 0.06$. Our performance matches the average of the other evaluated active methodology courses.

CONCLUSIONS

Students usually ask for changes in methodologies, but when a chance of change is offered they initially present fear and resistance to change in and out of their comfort zone. So, We should not be afraid to try new teaching methods or assessment, considering that these will help in the learning process of students, although there is initial resistance from them.

The implementation of this type of methodology, requeiren a greater effort on the part of teachers, because like what happens with students, they go out of their comfort zone and should do more work, which involves more resources, including more dedication and preparation time, which is not necessarily valued from academic administration.

Developments and changes in the projects have proved effective with regard to student motivation and to engage beyond the lecture. They are committed to developing projects and are very proud to show their results. They feel more confident of learning obtained. This can be seen in them, the way in which made their presentations and how they speak

The average students' performance was very good when compared to other groups (schools abroad) who took the same test. Our results are on a par with other classes who worked with active learning methodology, and the result is significantly better than other groups who worked with passive methodology.

Working with partners in different Universities and in different countries is very useful to share experiences, ideas and knowledge, unfortunately, even knowing this advantage, it is not always easy to implement cooperation as there might be conflicts of interest or even administrative bureaucratic difficulties.

In our project, it was very gratifying to share experience and likewise be able to compare the results and see that what works for our institution or our particular course can also work in many other places.

Project implementation favors the use of different assessment methodologies, which gives students a greater opportunity to show their skills and knowledge acquired, and gives the teacher a greater range of being able to provide feedback to the student on aspects that could be improved.

Although it was not raised as an objective in the process, is evidence that students achieve better academic and results the same way, students feel their grades are rewarded for the effort and work done.

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CEP - CDIO ENABLING PLATFORM AS A CATALYST FOR COURSE INTEGRATION

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ABSTRACT

This contribution presents and discusses a CDIO enabling platform (CEP) used within courses at the Department of Management and Engineering, Linköping University, Sweden. The platform consists of a physical setup manifesting several potential real R&D situations, including production aspects. When present in courses, it is combined with the scenario technique based on a potential business case. The physical hardware of this teaching platform is a modular multi-utility bicycle, commonly referred to as a cargo-bike, together with assembly and welding fixtures.

From a learning theory perspective, lack of course integration and curriculum progression is problematic. For instance, the rationale of constructivism tells us that new knowledge is largely based on and created from previous knowledge. It follows that courses must "talk" with each other in the sense that students are able to use newly acquired knowledge from one course directly in another.

CDIO implementation is yet another aspect where issues of insufficient course integration and progression adds to the problem. CDIO is basically about bridging the gap between theory and practice. And since heavily theory oriented traditional courses are hard to align with the CDIO syllabus, an implementation process may benefit from solutions that foster course integration.

CEP enables and facilitates the implementation of the CDIO standard in several ways. Furthermore, from the curriculum perspective, the platform may serve as a catalyst for course integration. This paper discusses and exemplifies both these issues, CDIO implementation and course integration, using an intermediate computer aided engineering course during the third semester of the program, where the learning outcomes also includes innovative thinking and oral presentation techniques.

KEYWORDS

Integrative learning, Course Integration, CDIO Enabling, Hardware, Experiential learning, Scenario technique, Standards: 3, 4, 5, 6, 7, 8

INTRODUCTION

A program syllabus often addresses the CDIO framework by looking at the whole program which results in theory-heavy “C”-courses during the first years of the program, and large project courses at the end. However, the heavy theoretical start-off is usually pointed out as the main driver for drop-outs. To deal with this, one often finds one or a few practically oriented courses during the first year of the program, also known as cap-stone courses, aimed at placing the students in the correct engineering context, meeting their expectations of their chosen profession and so forth. Nevertheless, the surrounding courses often remain with their traditional theoretical didactic approach, thus missing making connections with existing applications, etc.

Furthermore, for a long time, and in particular after the advent of the IT era, there has been an increasing demand for integrative abilities among members of society as a whole, but perhaps especially when it comes to those who are set to develop new products and services. When we examine how the traditional training of the new developers (i.e. students on technical programs), one could raise concern over the lack of utilization of integrative possibilities. After all, studying at a technical institution is definitely a multi-disciplinary experience, aimed at a multi-disciplinary profession. Most engineers, even specialists, are expected to continuously process and act on information from different disciplines.

From a student perspective, the absence of multi-disciplinary challenges is perhaps less obvious if the courses are given in series, but even more if given in parallel (which is often the case). Curricula that offer courses like isolated sources of knowledge hardly resemble what awaits after graduation, and from the experience of the author of this paper, this is something most students are aware of. This is where integration between courses becomes an issue.

The lack of utilization of integrative opportunities, among others, is a driver for change in higher engineering education curricula. Not only regarding the purpose of multi-disciplinary training of the students, but there are also other potential benefits of a more integrated learning environment, as will be discussed in this paper. This contribution will also present and discuss a proposal for a new curricula model. At the center of the model is a physical platform that serves multiple (integrative) purposes.

FRAME OF REFERENCE

Previous research

The founding idea for the learning platform presented and discussed in this contribution originates from previous research at Linköping University concerning so-called Low-cost Demonstrators (Hallberg, 2013). They are meant to serve as a cost-efficient cross-disciplinary resource during a product development process, without any intention of reaching product-like maturity. Figure 1 illustrates the fundamental role of such a demonstrator.

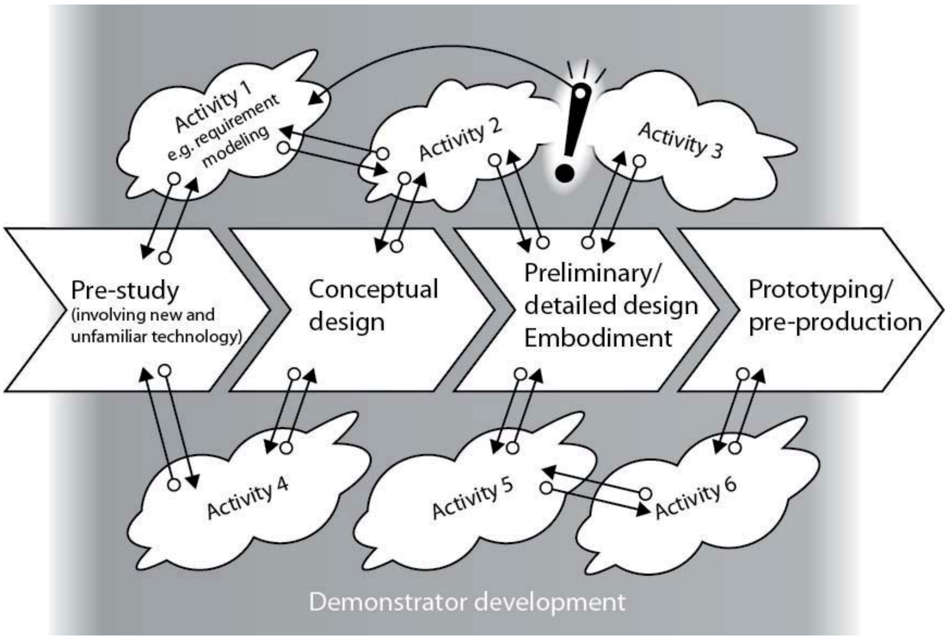

Figure 1 A product development process supported by a parallel demonstrator development process (the grey background)

Furthermore, and connected to applying physical manifestations during courses, previous research on a freshman course on the Mechanical Engineering program at Linköping university shows the possibilities of using a low-cost approach when letting the students design and build a simple catapult as part of a basic CAD course. However, by building the catapult the students are forced to apply their knowledge of, for instance, calculus, mechanics, and physics (Hallberg, 2012).

Learning Theory

If we look at CEP as a (physical) platform for creating and exchanging knowledge, utilized by students and members of a faculty, it is necessary to apply different aspects of learning theory when discussing the role and functioning of the platform.

Experiential learning

The theories of Kolb (1984) are fundamental when discussing learning, or creation of knowledge, by interacting with the surrounding environment, which obviously is the case when working with physical learning platforms. Kolb defines learning as the process whereby knowledge is created through the transformation of experience, also known as experiential learning. This model is composed of four elements: concrete experience, observation of and reflection on that experience, formation of abstract concepts based upon the reflection, and finally testing of these new concepts. The process then starts over with the concrete experience that follows from observations of the testing. Kolb calls this the learning cycle, which can be seen in Figure 2. This spiral of learning can begin with any one of the four elements, but typically begins with a concrete experience.

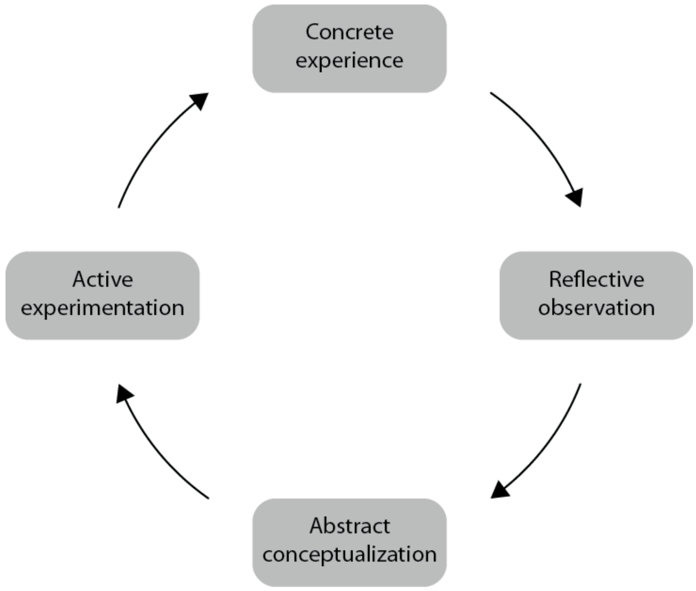

Figure 2 Kolb's learning cycle.

Moreover, with the theory of experiential learning and its further evolvement, Kolb has made conclusions about what he refers to as "learning spaces" (Kolb et al., 2005). The concept of learning spaces is a framework for understanding the interface between students' learning styles and the institutional learning environment. Furthermore, and relevant to this contribution, Kolb stresses the importance of promoting learning in higher education through institutional development.

Integrative Learning

The concept of Integrative Learning is basically about connecting different disciplines throughout the curricula – also referred to as interdisciplinary education. Several references relevant for this contribution can be pointed out. As one of the early recognizers of integrative learning, Huber and Hutchings (2004) state that [… Fostering students' abilities to integrate learning—across courses, over time, and between campus and community life—is one of the most important goals and challenges of higher education. The undergraduate experience can be a fragmented landscape of general education courses, preparation for the major, cocurricular activities, and "the real world" beyond the campus. But an emphasis on integrative learning can help undergraduates put the pieces together and develop habits of mind that prepare them to make informed judgments in the conduct of personal, professional, and civic life. …]

From an analysis of integrated programs, Froyd and Ohland (2005) conclude that [... The most significant long-term outcome of integrated programs may be faculty development. Significant collaboration among faculty is required to implement a successful integrated program and may lead to the development of faculty learning communities through which faculty grow in their understanding of learning and teaching…] and that […Design projects have the potential to help students make connections among subjects, material, and applications. The process orientation of design holds promise for improving the systems thinking of engineering students.] Finally, Froyd and Ohland state that [… The implementation of integrated curricula has helped expand the use of cooperative learning and student teams, especially in design projects. The use of these pedagogical approaches and the clustering of students in multiple classes have aided the formation of learning communities. Learning communities have likely played a role in improved retention and improved learning outcomes…]

Recent conclusions about engineering students' perception of their chosen profession have been drawn by Singer et al. (2015). Singer finds [… sufficient evidence to indicate that the integrative learning module is useful in integrating the humanities, social sciences, and engineering, and helping further develop students' perceptions of engineers. …] and continues to conclude that [… With subjects often taught in isolation /…/ students often fail to understand the true applications of math and science concepts, which may limit their ability to choose engineering as a career. …]

Furthermore, Singer states that [… students using contextualized, integrative, and interdisciplinary approaches may be able to develop better higher order thinking skills to solve complex engineering problems While one course alone may not be able to solve limitations in the entire curriculum, it facilitates a transition toward integrative, interdisciplinary, and wholistic thinking, making it easier for students to accept other similar courses, and with time develop the skills to integrate ideas, processes, and knowledge between different courses, and continue developing these skills throughout their careers. …]

Regarding curricula integration and its effect on avoiding drop-outs, Walden and Foor (2008) observe that [… student experiences with departments and faculty where students were not effectively integrated into the formal and informal environment and did not connect with curricular content contrast with student perceptions of a department and faculty who offered the promise of inclusion in a supportive environment with student perceived relevant curriculum. …]

Problem Based Learning

Edström and Kolmos (2014) conduct a structured comparison between the CDIO framework and the model of problem/project based learning, concluding that [… The fundamental idea of CDIO is the integrated curriculum, where discipline-led and problem/project-led learning are meaningfully combined. For existing programmes, it is often necessary to increase the share of PBL activities. But that is not sufficient; a curriculum is not integrated just because it contains both problem/project-led and discipline-led courses. The synergy comes from integrated learning experiences, where students simultaneously acquire disciplinary knowledge and professional engineering skills. ..]

THE CDIO ENABLING PLATFORM

This section will describe CEP - a CDIO enabling platform, first conceptually and then by reporting on the current status of the platform at Linköping University.

In academia, it is common for of engineering design program curricula to be outlined such that courses that cover different disciplines are given in parallel. Stakeholders of this project are represented on the board of studies representing the Mechanical Engineering bachelor program at Linköping University. Each 30 ETCS credit semester on this program is divided into equal periods stretching over roughly 8 weeks of studies. Furthermore, each period contains two 6-credit courses given in parallel at full speed and another 6-credit course stretched out over the whole semester and thus given at half speed. See Figure 3 for an example.

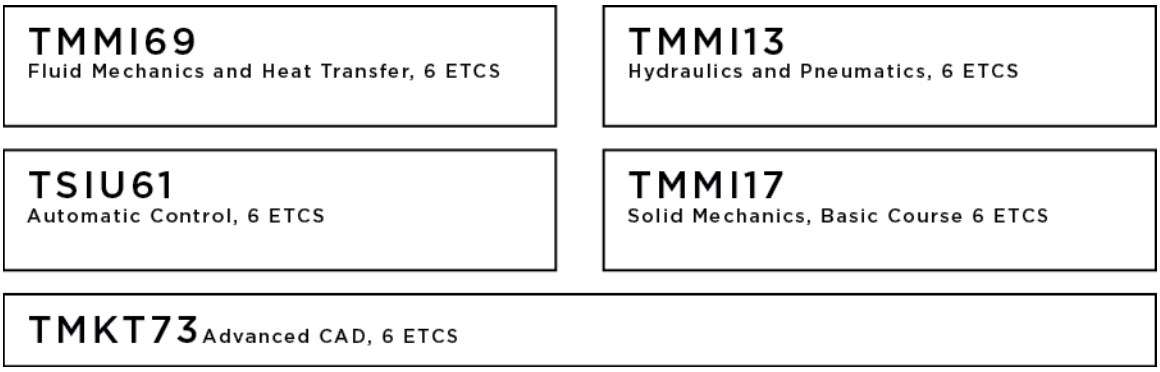

Figure 3 Outline of the 3rd semester of the Mechanical Engineering bachelor program at Linköping University

These stretched-out courses are traditionally identified as typical CDIO courses. This is probably due to the greater allocated time frame, which in turn makes it easier to implement a Design-Implement-Operate phase during the second half of the semester. The full-speed courses, on the other hand, tend to be dominated by a conceive phase with minor traditional laboratory exercises at the end of the course.

As regards the third semester of the mechanical engineering bachelor program, this is exactly the case. See Figure 5. The question now is whether the “DIO-part” of the stretched-out course can “serve” the surrounding “C-heavy” courses with a clearer Design-Implement-Operate phase, enabling them to reach a similar CDIO-implementation level to the stretched-out course. What are the obstacles and what would the benefits be?

The concept of CDIO enabling

The stretched-out TMKT73 is basically an intermediate CAD course with a typical CDIO arrangement where students spend almost the whole first period conceiving advanced approaches to CAD-modeling, e.g. top-down functionality, skeletons, programming, automation tools, analyzing, and PLM. The second half is organized around a fictitious product development project where the students form engineering teams that are set to win a sub-contract, supplying the development and manufacturing of a novel utility bicycle with modular capabilities, see Figure 4. These kinds of vehicles are referred to as cargo bikes. In order to provide the project scenario with sufficient realism, a rear module of such a cargo bike was prepared in advanced, consisting of both a detailed CAD-model and a physical counterpart, complete with standard components and manufacturing fixtures for welding and assembly. The concept of involving physical representations and enabling hands-on experiences in CAD-courses is based on previous experience of successful results regarding learning achievements (Hallberg, 2012).

With the Design-Implement-Operate phase of TMKT73, the reason for building a project scenario around a cargo bike has been well thought-through. A vehicle like this is able to stage, but yet simplify, a number of mechanical engineering challenges. Bicycles are fundamentally simple and familiar products, largely consisting of standardized components and thus suitable for learning situations with inexperienced students. However, with the advent of e-bike technology and large automotive supplier companies like Bosch and Yamaha entering the market it is very convenient to make reference to and build an industry-like case.

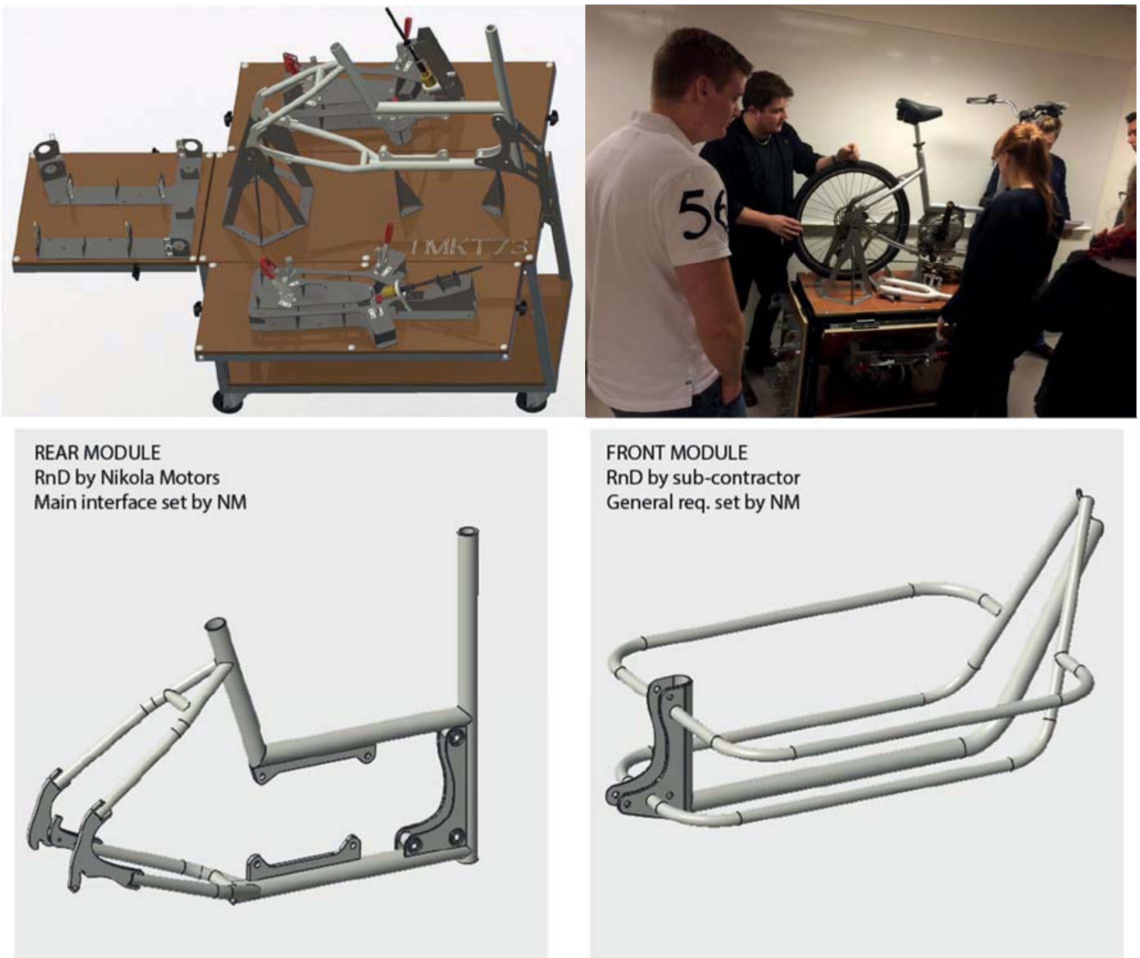

Figure 4 The complete CAD-model of the current CEP (top left), its physical counterpart in a classroom situation (top right), and explanatory pictures from the project description of TMKT73 (bottom)

However, the TMKT73 is surrounded by four other courses during the semester, representing four separate disciplines. They are during the first period fluid mechanics and heat transfer (TMMI69) and automatic control (TSIU61), and during the second period of the semester hydraulics and pneumatics (TMMI13) and solid mechanics (TMMI17). Taking a holistic view of these disciplines and at the same time considering the cargo bike project assignment in TMKT73, one realizes that they could all be relevant for any vehicle development project.

After examining the existing need for active learning (i.e. laboratory exercises) within the surrounding courses, the examiner of TMKT73 (and also author of this paper) has launched a study to investigate how the four disciplines can be represented or integrated into the cargo bike project. We are therefore looking for what we call integrative interfaces between the Design-Implement-Operate phase of TMKT73 and the active learning components of the other courses. See Figure 5.

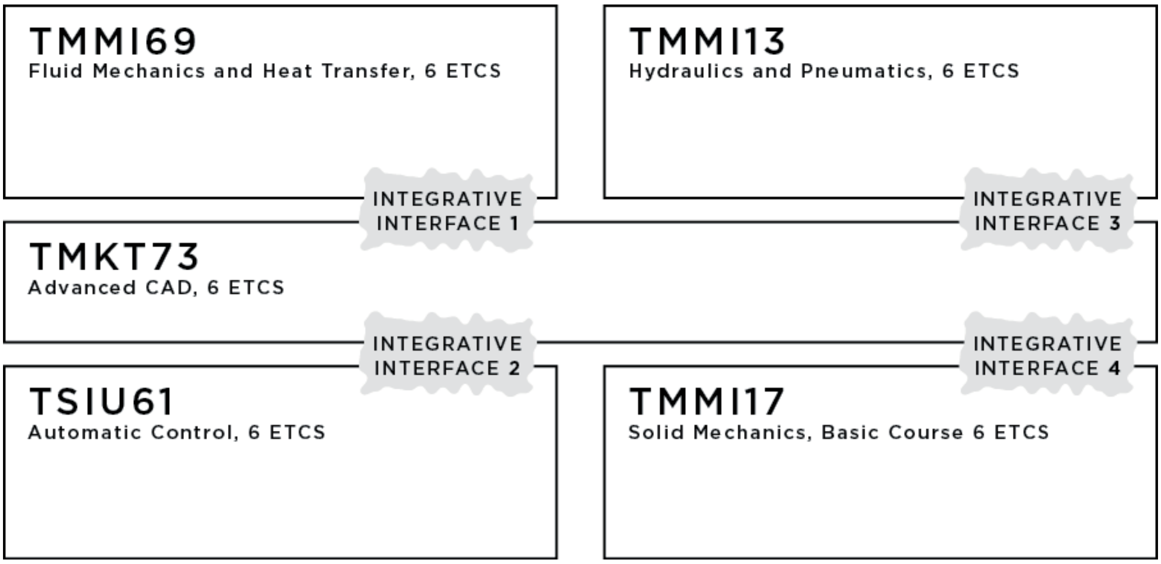

Figure 5 Outline of the 3rd semester of the Mechanical Engineering bachelor program at Linköping University

When considering the presence of both the digital and the physical model of the cargo bike intended for the project scenario in TMKT73, it is natural to search for the integrative interfaces there. By doing so it is also natural to introduce the term *platform*, which is justified both literally and metaphorically.

- Metaphorically speaking, we picture the platform in a wider meaning, more like an organizational unit that different stakeholders on a particular semester gather around to create and process knowledge while executing the curriculum. Examiners and program planners could use the platform as a base to build and organize courses upon.

- Literally speaking, referring to the actual presence of the physical artefacts that resembles the platform, i.e. the assembly station with welding fixtures seen in Figure 4. For instance, the station is equipped with wheels and may thus easily be moved around between different classrooms, workshops, labs, etc. Also, the fact that the chosen product (the cargo bike) is modular opens up for developing different (front-) modules serving different purposes in parallel courses without ruining the overall scenario.

Current status

It is crucial that the platform is manifested in a way that allows for interaction with the surrounding courses. A foundation for the current platform has been under development since mid-2015. It consists of a modular cargo bike including assembly and welding fixtures together with a highly flexible and parametrized CAD-model residing in a PLM system.

However, only the rear module of the cargo bike has been fully realized with the purpose of serving the project scenario in TMKT73 during the fall semester of 2015. This was a first test of the concept of a CDIO-enabling platform and is currently undergoing evaluation. During the fall semester of 2016, the idea is to incorporate one or more of the surrounding courses to actively make use of the platform.

To achieve this, a project was initiated during the spring of 2016 to develop and realize one or more front modules of the CDIO-enabling platform. The modules would include integrative interfaces that allow the other courses to interact with and co-exist on the same platform. Such interfaces could, for instance, be arrangements for enabling drive-by-wire or self-balancing capabilities (TSIU61 Automatic Control), well thought-through structures that can provide material for laboratory exercises (TMMI17 Solid Mechanics), innovative hydraulic or pneumatic arrangements, e.g. active damping systems (TMMI13 Hydraulics and Pneumatics).

The search for integrative interfaces was conducted within their final year project by students on the very same program that the platform is intended for, i.e. the mechanical engineering bachelor program. Thus, project team members were themselves students some eighteen months prior to the development of the interfaces. Results were based on both interviews (of the examiners concerned) and regular concept generation by the design team. Another requirement was that the implemented integrative interfaces should be motivated by at least three CDIO standards. Preliminary outcomes from this project are shown in Figure 6.

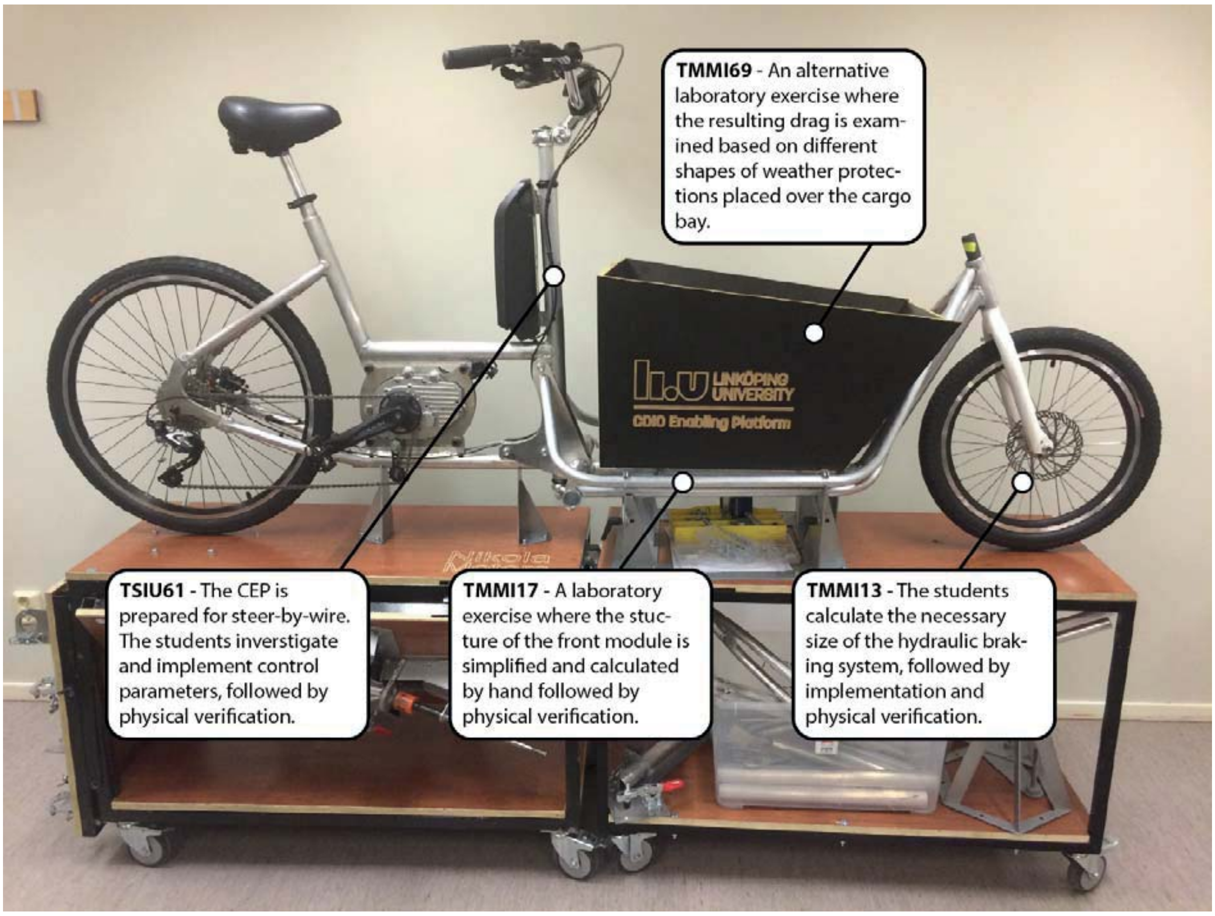

Figure 6 The CDIO Enabling Platform rear and front module coupeld together. The call-outs show tentative integrative interfaces on the platform.

DISCUSSION

The CEP described in this paper could rightly be questioned depending on how institutions choose to implement the CDIO syllabus on their programs. It is true that when a program as a whole is treated as the subject of implementation, the implementation process consequently allows for conceive/theory-heavy courses during the first years of the program, compensated by applied and practically oriented project courses during the final years. To some extent this is unavoidable and this is also typically the way technical programs are organized today. However, there are a number of drawbacks to this kind of CDIO implementation. One of the more obvious is that theoretically oriented courses tend to be a driver for drop-outs (Walden and Foor, 2008). One of the underlying reasons is that such courses lack a clear connection with the profession the program is supposed to aim for and that the student has based his or her decision upon. The CEP proposed here could therefore also be considered for implementation on programs that have already gone through a CDIO implementation process.

But there are also other issues that can be addressed using the proposed platform. Based on experience from the work on the board of studies representing the Mechanical Engineering bachelor program, issues that call for improvement can be identified:

- General inconsistency and incompatibility regarding the level of CDIO-implementation among the courses on the Mechanical Engineering bachelor program.
- General lack of communication between examiners of courses that are given in parallel.
- Among the examiners there is a general lack of awareness of their courses' position in the curriculum. This may in turn result in insufficient understanding on the part of the examiner regarding the student perspective, e.g. in terms of workload, etc.

The board of studies monitors the execution of the curriculum continuously. Well aware of the issues stated above, the board is constantly looking for ways of improvement. One way of addressing several of the issues above is to have all the examiners “semester-wise” gathered around the proposed CDIO-enabling platform. This would mean that the stretched-out course on each semester (TMKT73 in the case above) would act as the host of the physical platform and of the Design-Implement-Operate activities of all the courses on that particular semester. The expected outcomes from this approach (that would have to be measured and verified later) would be that the five examiners would have to communicate and synchronize their individual “DIO”-activities. Merely by doing so, one could expect understanding from the examiners regarding the student perspective on one hand and the other examiners’ situation on the other.

As we move forward discussing the proposed CEP, let’s take the viewpoints of the imagined stakeholders who to some extent are expected to benefit from the platform, and at the same time, where applicable, point out the potentially activated CDIO standards. The concept as a whole naturally addresses *CDIO Standard 3 – Integrated Curriculum* and indirectly *CDIO Standard 4 – Introduction to Engineering*.

Students

The students on an engineering program are the recipients of information taught by the institution. Notably, they are in transition from inexperienced high school graduates to being employable in the eyes of the industry. They should expect that every effort from the institution is aimed at preparing them for their life after graduation and their chosen profession. From this standpoint, the platform may play the following roles

- The platform places the learning activity, whatever it might be, in a context more similar to the industry. Especially combined with a scenario. This clearly addresses *CDIO Standard 6 – Engineering Workspaces*.
- The platform may serve as a catalyst for discussion about the role of the engineer (*CDIO Standard 6 – Engineering Workspaces*).
- Depending on the applied scenario, the platform enables and requires multi-disciplinary problem-solving which addresses *CDIO Standard 7 – Integrated Learning Experiences*.
- The actual presence of physical hardware may also foster implementation of *CDIO Standard 8 – Active Learning*. In the case of the above exemplified cargo bike, its modular properties make it especially suitable for designing and interaction with (simplified) subsystems (modules) of the whole system. If students are allowed to design such a subsystem, we can also address the *CDIO Standard 5 – Design Implement Experience*.

Individual examiners

After all, many examiners active on mechanical engineering programs are either trained product developers or at least have a view of where their discipline fits into the product development domain. However, many examiners are nevertheless comfortable as theorists or are forced to act as such while performing their duties. In these cases, the introduction of a physical platform/scenario based tool for learning could help and encourage examiners and teachers who would like to transform their teaching.

From this perspective, the CEP could facilitate implementation of the CDIO framework as a whole, but it also specifically points towards *CDIO Standard 9 - Enhancement of Faculty Competence*. For example, if the examiners are involved in the process of defining a platform, they will consequently have to apply their domain of expertise onto the platform and at the same time adapt to the other examiners and their domains.

Board of studies and program organizers

The people responsible for planning and organization of the program may use the CEP concept of CDIO enabling through a physical platform, such as the one presented in this paper, with the purpose of facilitating and ensuring CDIO implementation. Furthermore, the importance of promoting learning in higher education through institutional development is stressed by Kolb and others (Kolb et al., 2005). One can argue that CEP has the potential to play a vital role in such a development process.

Researchers

Naturally, the CEP could be utilized by researchers within the institution and thus facilitate the connection between research and undergraduate education. This would mean that researches take part in the planning and formation of the platform.

Industry

As mentioned earlier, one of the purposes of the CEP is to enable a more industry-like learning environment when executing a curriculum. However, the proposed concept could very well be introduced to industry partners in order for them to take part in the formation of a platform. One scenario could be that a representative of a company identifies a specific demand in terms evaluation of a concept. The platform and a connected scenario could then be arranged to allow the company to conduct evaluation studies while the students are working on the platform (where the concept is represented).

FUTURE WORK

Implementation of the proposed CDIO platform will continue and results will be evaluated during the fall semester of 2016. A survey study is being planned in order to measure the impact of the platform on the learning outcomes from the courses concerned.

Further development of the platform itself is also expected. Discussions are also going on about involving companies who could make use of the platform. Potentially, a company could "plant" a platform during a semester, providing the necessary hardware along with a scenario that would contain requirements or specific assignments that the company would benefit from.

A further question to be answered is if there are other semesters on the Mechanical Engineering bachelor program where the same approach could perhaps be applied, but not necessarily using the same platform.

Other discussions involve whether the platform could be used across multiple cohorts or even across different programs. For instance, one such suggestion is to let Industrial Engineering students practice project management within the current product development scenario in TMKT73.

CONCLUSION

Enabling integrative learning is one of the keys to making the learning environment relevant in the eyes of the students. Implementation of the CDIO framework is partly justified by the same principal – making the trained student relevant for the industry. Thus, what we see is a symmetry in relevancy. By enabling and fostering a multi-disciplinary learning environment throughout the curriculum of the engineering program, the students become better prepared for a future first employment.

A CDIO-enabling platform, as proposed in this paper, could serve as a general tool for program planners to ensure a multi-disciplinary learning environment. The platform consists of a modular cargo bike and assembly station that is used within a product development scenario.

The purpose of the platform is to enable and facilitate integration between parallel courses during the same semester in order to create a multi-disciplinary learning environment.

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BIOGRAPHICAL INFORMATION

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CONCRETE MIX DESIGN COMPETITION: IMPLEMENTING CDIO IN CIVIL ENGINEERING.

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ABSTRACT

One of the challenges of incorporating design education into a Civil engineering curriculum is that of scale. Unlike electrical and mechanical courses where CDIO based curriculum can be applied to small electrical and/or mechanical devices, civil engineering focuses on design, construction and commissioning of large scale networks within the built environment, such as water treatment and distribution, wastewater management, transportation networks, etc. This paper will describe the incorporation of a concrete mix design competition within a senior year technical elective course at the University of Calgary. Students are given a terms of reference and then full access to the laboratory during a 13 week course, during which they must develop a mix design that best meets the specifications. Apart from learning laboratory skills (slump testing, air content, compression testing), the students gain an understanding of the challenges of quality control and assurance during production. The paper describes the evolution of the competition and outcomes as part of describing the effectiveness of this approach to a laboratory course in a traditional civil engineering curriculum.

KEYWORDS

Civil engineering, concrete mix design, CDIO syllabus 1.2, 2.2, 2.2, 2.5, 3.1, 3.2, 4.1, 4.4: CDIO Standards: 5 (Design-Implement Experiences), 7 (Integrated Learning Experiences), 8 (Active Learning)

INTRODUCTION

Like many programs in Civil Engineering students at the Schulich School of Engineering at the University of Calgary take a minimum of one core course in Civil Engineering materials that includes an introduction to cement and concrete. These two materials form the basis of much of the civil infrastructure and are the world's most commonly used materials exceeded only by petroleum products (Ashby 2014). The introductory curricula for concrete focuses mostly on the mechanical properties of the constitutive materials (aggregates and cement), laboratory and the field quality control and quality assurance tests needed to receive and accept the material at the job site. In secondary-level courses, the students learn more about the cement chemistry and variations to the most common concrete mixes (such as high strength concrete, high performance concrete, lightweight concrete, etc.). In 2001, a change was made to the Civil Engineering curriculum at the Schulich School of Engineering that resulted in development of a lab-based course that took the students deeper into the knowledge base of concrete mix design with the addition of a fourth year technical elective in concrete materials. The course has evolved since then, from focussing solely upon concrete mix design to one that is divided into two components: concrete mix design and structural design of reinforced concrete. Learning outcomes are defined for both halves of the course and the learning outcomes for the concrete mix component are as follows:

Part 1: *"Practical examination of concrete mix design (Portland cement), processes and systems to improve performance and sustainability of Civil Engineering structures."* At the end of this portion of the course, the students will be able to:

1. Develop a concrete mix design from experimentation,
2. Plan and execute experiments, while working independently in the fresh and hardened concrete laboratories, using appropriate instruments, careful data collection, and safe practices
3. Communicate the results of your work in a professional manner through a final report.

The course is timetabled as a three hour per week lecture with a three-hour laboratory session. Keeping in mind that an undergraduate course should be approximately 100 hours in length, the learning outcomes for part 1 are achieved through 100% laboratory work in the form of the "High Performance Concrete Competition (HPC)". With one introductory lecture, the students are presented with a fourteen page terms of reference for the competition that outline not only rules of the competition, but also describes the scoring process, penalties and bonuses, reference costs and materials sources (along with transportation costs) and the grading rubric for the final report along with a team peer evaluation form. As an added sweetener, there are monetary prizes as well.

HIGH PERFORMANCE CONCRETE COMPETITION

The competition focus has changed each year with students having to design high strength concrete, high performance concrete, self-compacting concrete, low-slump or high slump concrete, and/or concrete of a tightly specified strength. Regardless of the focus, the competition objectives have not changed and have been encapsulated in a quote from TaoTeh Ching 43 which is the opening statement of the HPC competition rules: *"The best instruction is not in words"*.

Specifically, the competition objectives are:

- To learn about optimum mix proportioning, casting, curing and testing techniques through the manufacture and testing of concrete specified for compressive strength, density, elastic modulus, economy and sustainability.
- To obtain more practice in written communication.
- To work efficiently as a team towards a common goal.
- To win the competition by obtaining the best sustainability score according to the formula given below.

The 2015 – 2016 competition required that students develop a concrete with a target compressive strength range of 35 +/- 3 Mpa, which is considered normal strength in Alberta, but the concrete was for a marine application in Vancouver, B.C. The mix had to have a slump of 100 mm. This somewhat sparse and cryptic specification required decoding as they had to research a) what normal strength concrete is in B.C. to first ascertain whether their concrete would be considered thusly and if not, what additional measures would be needed to make it so and, b) they had to research climate records to determine if frost protection is used/needed in the Vancouver application (it was not).

The competition is meant to be a learning experience and there is money on the line, but the final grade for this component of the course is based upon the final report, not the score in the competition. As students get deeper into the experience, this fact has to be repeated frequently as they forget that the journey (as reported in the final report) is the actual basis for their grade and not the final outcome in the form of a score.

Students self-select into groups of four and have to register their team and testing plan with the technical manager before they are given clearance to start work in the lab. Prior to that milestone, the very first thing they must do in order to start work is to develop their mix design philosophy: which requires research, debate and teamwork. The mix design philosophy was guided by their interpretation of the competition rules and scoring (for example, are they going to try and maximize the use of recycled material in their mix, or are they going for the best consistency between mixes…). Each team was allowed to make and cast three trial mixes prior to the competition casting day and with fixed competition casting and testing dates (October 28th and Nov 25th, respectively), the students had to work quickly in the first week to start their testing programs. Concrete compressive testing is done at 3, 7, 14, 21 and 28 days after casting which meant that within the bounds of a 12 week course that started on September 11th, most teams made their final mix design choice without one of the mixes having the full 28 day results to guide their final decision. Teams had to be registered with the lab tech by October 4th (three weeks into the term) and it was obvious to most students that the sooner they got busy, the better their chances of success would be. Registration with the Technical Manager (TM) required not only a full testing schedule (casting, demolding, grinding, compression testing etc.) but also a complete list of materials required to make their mixes and estimated quantities. Non-standard materials (such as recycled aggregate, rubber crumb, etc.) had to be supplied by the students and they could only be brought into the lab once a WHMIS/MSDS sheet had been supplied. Storage containers for non-standard material also had to be provided and students had to be ready to remove the material once the competition was over. Space was a limiting factor in some cases!

The Technical Manager(TM) responsible for the lab provided hands-on training for some of the equipment (for example, the compression testing and grinding machines) as well as overseeing all testing (fresh mix and hard concrete). Students were expected to do all lab tests/procedures on their own and the TM provided invaluable assistance to the students as a sounding board. While the students have a set three-hour lab session in their weekly schedule, they are in fact, given full and free use of the lab to develop their mixes, but all work has to be recorded/booked into a master schedule to avoid overcrowding. The maximum amount of time that can be booked at one time was one hour. This was to train them to work quickly as the final competition casting had to be done within a 30 minute window: teams that exceeded the 30 minute time limit on competition casting/testing days were assessed a time penalty. In addition, no work could be done after hours and students were required to work in teams for safety. Time and human resource management skills were required to fulfil the tight schedule which so students learned about teamwork on an operational level.

In the days prior to the competition-casting day, students were found to be discussing and arguing the merits of their designs, which, as a professor, was gratifying to overhear! Competition casting took place under the supervision of the Technical Manager and Teaching Assistant who certified the mix components on a ‘competition form’. Once cast, the concrete cylinders could be cured under various conditions to simulate real world production: fog room, ambient air, ambient water bath, or hot water bath, as well as combinations thereof. Each curing regime had an associated energy cost which had to be accounted for in the final scoring and economics.

After casting, students could test for compressive strength at 1,3,7, 14 and 21 days which allowed them to track how strength was gaining within their cylinders and make curing regime adjustments accordingly. For example, if the cylinders were in a hot water bath and were found to be gaining strength quickly, they could remove them from the bath and place them in to the cooler fog room. This adjustment would have a cost implication.

Scoring

The competition score was determined using the following equation:

$$\text{Score} = (S) - F_1 - F_2 - F_3 - F_4 - F_5 + F_6 - F_7 \qquad (1)$$

Where:

S		Is the mean compressive strength (MPa) for three cylinders successfully tested at 28 days during the competition compression testing. This must be between 32.00 and 37.99 MPa. Cylinders out of this range were rejected and a penalty applied to the Standard Deviation fctor as described below.
F_1	SD	Is a factor that applies a penalty or bonus to the standard deviation (MPa) of the compressive strength measurement on the three test cylinders. (If one or more test results are judged to be void as described above, then SD = 20 MPa).
F_2	D	The average density of the concrete, kg/m^3.
F_3	E	The elastic modulus (GPa). A penalty was applied to concrete that was excessively brittle.
F_4	AE	Accuracy of the estimated strength. Students had to estimate their final average strength prior to the competition compression testing that took place 28 days after competition casting. This factor was a very practical challenge for the students as in future clients will request a set strength and over delivering will have cost implications to the company and under-delivering will have design implications for the structural engineer who is counting on a fixed strength.
F_5	A	The air content (fresh concrete). This was the ‘hidden’ test for the students in 2015-2016 as the engineering of the air content is important for freeze-thaw protection, but inclusion of air-entraining agents has a cost associated and would not be used in the Vancouver marine environment.
F_6	C	The cost of the concrete in \$/m^3 and imposes a penalty or a bonus for economy of design based upon materials cost only (not including carbon content or energy costs). Teams using non-standard materials had to substantiate in writing the cost of any materials other than the stock materials supplied.
F_7	Co	Consistency, measured by the slump, which was set at 100mm. This factor is perennially the hardest specification to meet and in 2015-2016, the winning mix was the only one that met the slump target.

In addition to the score calculated above, students had to calculate the sustainability of their mix for one cubic metre of concrete using the following formula:

Sustainability Index = (Score * Energy (MJ/m^3)) / Emissions (kgCO2E/m^3))……….(2)

To calculate the cost in terms of dollars, energy and emissions for all the components as well as the available curing regimes students were given set values as shown in Table 2

Table 1: Delivered Costs, Energy and Emissions

Material	Cost CDN $ (delivered to F block SSE)	Total Energy MJ/tonne	kg CO_2E/tonne
Type 10 cement	$ 110 per tonne	8,030 (manufacturing)	1210
Type 30 cement	$ 130 per tonne	8,030 (manufacturing)	1210
Coarse and fine aggregate (virgin)	$ 9 per tonne	110 (mining, crushing)	8
Fly ash	$ 40 per tonne	-5 (capture)	-10 (scrubbin
Silica fume	$ 750 per tonne	-5 (capture)	- 8
Air entraining admixture (Micro-Air)	$1.45 per litre (avg. dosage 50-75 ml /100 kg cement)		15
Superplasticizer (Rheobuild 1000 / Glenium 3030))	$2.50 per litre (avg. dosage 500 ml/100 kg cement to double the slump).	115 (manufacturing)	200 (manufacturin g)
Water		5 (WTP, WWTP, distribution)	
Ready-mix operations		205 (manufacturing)	19
Fly Ash Landfill Avoidance		-54	-18
Silica Fume Landfill Avoidance		-54	-18
Transportation - truck		2.54 / km	0.3 / km
Transportation - rail		0.41 / km	0.03 / km
Recycled C&D aggregate	To be supplied by student	80 (crushing)	7.9
Fog Room	0.50 /tonne /day	5.25/day	2
Waterbath – ambient	0.10 / tonne/day	5	
Waterbath – 30degC	0.75/ tonne/day	6	2
Waterbath – 50degC	1.00/tonne/day	6.2	2

All compression testing occurred exactly 28 days after the competition casting. All team members had to be present to reinforce the teamwork component of the competition. Results were reported during the compression testing and elastic modulus testing was completed by the Technical Manager over the following three days.

Reporting

All teams had to self-report their results using a standard spreadsheet to the professor and the results were revealed to the class on the final day of term. The spreadsheet not only checks the students' self-reported scores, but also calculates delta values to determine ‘closest to the pin’ values and standard deviation. Prizes (and prize money) was awarded in the following categories:

- Best Sustainability Score - $500
- Best Consistency (lowest standard deviation of three cylinders) - $100
- Closest to the required strength (35MPa) - $100
- Best Estimate - $100
- Best Slump (closest to the specification) - $100
- Highest use of recycled materials (on a volume basis) - $50
- Worst Sustainability - $25 (a consolation prize).

The HPC competition report forms 30% of the students’ grade and has proven to be an excellent way to not only involve them in the design process, but also to teach them valuable technical skills in the laboratory and field as well as operational teamwork skills. Students peer evaluate their teams to adjust their final grade according to the effort expended using a process described in Cowe Falls 2015.

OUTCOMES AND LESSONS LEARNED

Student feedback on the HPC has been very positive and comments have been clearly noted during the annual Universal Student Ratings of instructors (USRI) at the University of Calgary.

The success of the HPC is largely due to the support of not only the department of Civil Engineering, but also local industry suppliers, alumni who act as mentors to the students and the technical staff of the department. One of the greatest challenges is the number of students who are registering to take the course. In the first year, there were 32 students and that has doubled to 78 in 2015-2016. The result has been that when the competition first started, students were able to make five trial mixes prior to their competition mix and now with the limitations of time, the students only have time to make three mixes prior to the competition.

The most visible outcome of including the HPC in the Civil curriculum is the standing of the Universitie’s Great Northern Concrete Toboggan Team which began a steady run of podium finishes for the toboggan design as well as the technical component awards (best technical report, best use of fly ash, best mix design, etc.) after the initial offering of the course. This successful run for the team continues to this day.

I would like to especially note Dr. Robert Day who passed away suddenly in 2015. The HPC competition was his brainchild and hundreds of students have benefitted from his pedagogy and vision for this experiential learning course.

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Robert Day, Ph.D. P.Eng (deceased) was a Professor in Civil Engineering at the Schulich School of Engineering, the University of Calgary. His area of research was in cement and concrete mixes and was the initiator of the High Performance Concrete Competition in 2001. He passed away in 2014.

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ACTIVE LEARNING IN ELECTRONICS ENGINEERING AT PONTIFICIA UNIVERSIDAD JAVERIANA

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ABSTRACT

The present article shows a selection of different courses' activities designed to develop the disciplinary and CDIO competences. These activities utilize the active learning methodology in the classroom and promote the students' centered learning. There are presented two categories of activities, their development in introductory courses, and the ones done in advanced courses. For the introductory ones, the evolution of the Introduction to Engineering course is shown, as well as some activities that develop the criteria related to group formation and evolution, ethics, social responsibility, and problem solving among others. For the Introduction to Engineering specific case, the activities are developed in a design and implement project context. This article presents the evolution of the course during several semesters additionally to the thematic chosen for the projects. The activities complement the project and give elements for the disciplinary, interpersonal and problem solving competences development.

For the advanced courses, four examples are shown: Logic Circuits, Design of Digital Systems, Processor Architecture, and Signal and Systems. In these courses, activities are centered in the disciplinary competences development and in the association of engineering concepts with reality. In all cases, it is presented the courses evolution, the characteristics and advantages of the new approaches, the way on which students receive these activities, and an evaluation of the obtained results. Finally, the general conclusions, and the improvement proposals for the activities and for the courses orientation are presented.

KEYWORDS

Active learning, Engineering Education, CDIO approach, Standards: 1, 4, 8.

INTRODUCTION

During the last four years, and in favor of the improvement of the Electronic Engineering program in the Javeriana University, a curriculum review was done based on the CDIO (Crawley, et al. 2014) initiative. This review affected directly several courses changing their methodology from a theoretical structure to one based on product design projects. Several pilots have been made to prove the impact and results of the methodology implementation, all which provided positive outcomes.

Different perspectives from students and professors were obtained in order to evaluate the courses and the reactions generated by the change. The learning results were also valued, as well as the progress made in the level of competence of the abilities expected to be learned on those courses. Based on these perspectives and evaluations, changes to the courses were proposed and implemented. At the present time, improvement actions are continuously applied in order to identify benefits and disadvantages of the new methodology. This process also has provided very important evidences and tools that are used to in the program improvement model.

In the present article, it is presented, in the first place, a brief description of the active learning methodology. Then, it is shown the utilization of the methodology in the Introduction to Engineering freshman course, its evolution and results. In the next section, it is found the approach given to the senior courses of Logic Circuits, Design of Digital Systems, Processor Architecture, and Signal and Systems. Finally, conclusions and future work are presented.

ACTIVE LEARNING IN ELECTRONICS ENGINEERING

Many of Electronics Engineering courses are highly theoretical and abstract. Students often have difficulty understanding complex abstract concepts and transferring their knowledge to real life, especially in the engineering practice. A good way to help students in their learning process is to include active learning strategies in engineering courses.

Active learning is one of the key concepts in the CDIO approach. ***CDIO Standard 8*** addresses the importance of using active and experiential learning strategies. These strategies involve engineering students, as active participants, in their own learning and reflection of their learning process (metacognition). When students take on roles that simulate the practice of a professional engineer (i.e. designing projects, case studies or simulations), active learning becomes experimental learning (Crawley et al., 2014).

This student-centered learning engages students in thinking about concepts and helps them make better connections between old and new concepts. By using active learning strategies, such as role-plays, case studies, problem based and project organized learning, students usually showed improved learning over strategies in which students take a passive role in the learning (Bruff, 2009).

ACTIVE LEARNING IN FRESHMAN COURSES: ENGINEERING INTRODUCTION

This section describes our experiences using Active Learning in freshman courses. These courses have been designed to follow ***CDIO standard 1- context***, which promotes the learning of fundamental concepts under the context of Conceiving, Designing, Implementing, and Operating systems, products, and services in the real world (Crawley et al., 2014). ***CDIO standard 4 - Introduction to Engineering*** is a framework for engineering practice and introduces essential personal and interpersonal skills. Freshman courses also have been formulated to include Active Learning approaches ***(CDIO Standard 8)***.

These first-year courses aim to show the student the nature of the discipline, the professional role of an engineer, and his social responsibility. Introduction to Engineering helps to develop some basic skills such as teamwork, oral and written communication, planning, time and resources management, model construction and strategies to solve problems. The Introduction to Engineering course demands 216 hours of student work during an academic period of 18 weeks. It has a weekly session with supervision of teacher of 4 hours and it requires from every student a weekly dedication of independent work of 8 additional hours on average.

The Evolution

Introduction to Engineering began as a theoretical and practical course based on engineering challenges. Students had to solve those challenges using tools learned independently through investigation or given to them in class. In spite of the efforts to create challenges that motivated the students to actively participate and helped them develop important and basic skills, the theoretical component of the course was too wide. This caused a lack of time to develop the challenges, which resulted in nonfunctional final products that frustrated and discouraged the students.

The perceptions of the students were consulted in order to collect indicators for the evaluation of the course. As a general finding, two main failings were taken into account. The first one showed the necessity of more time to develop the projects, which implied less theoretical classes. The second one established the need of a higher accompaniment of the professors and instructors in order to support and guide the students' progresses.

Based on these difficulties, it was made a transformation to the course based on the CDIO approach. The course was divided in two parts. The first part presents to the student the nature of the discipline, the role of a professional engineer and his main abilities as well as his social responsibility. The second part is based in a design and implementation project that brings the student closer to the product construction process and to the development of those basic skills.

Freshman courses under the CDIO approach have been taught since the first semester of 2014 with positive results. The topic of the first pilot course was energy efficiency. Students participated in designing and building an electric car (Figure 1). The objective was to improve the car's energy efficiency through its features, such as weight, shape and size. At the end of the course, it was made a competition to select the faster and more efficient car. As a general perspective, students and professors highlighted the motivating learning process that included the correct understanding of the concepts.

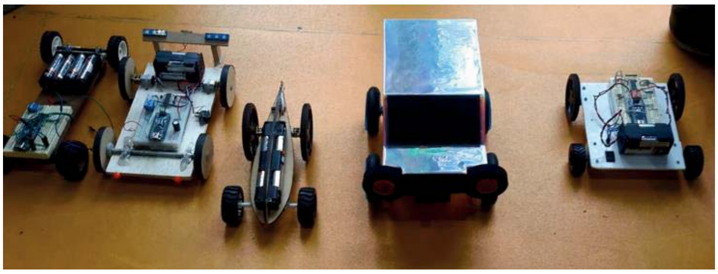

Figure 1. Electric car project. – Pilot 2014-1

In the second period of 2014, the course's project was the automation of the process of transportation of goods in a port to a railway. Students had to face a collaborative design challenge in a consortium model. Each group had to develop a part of the transportation process that had to be integrated at the end and work as a unity. Figure 2 shows the general idea of the proposed project. The experience in the course was based on collaborative learning and communication between groups, points that were satisfactorily achieved.

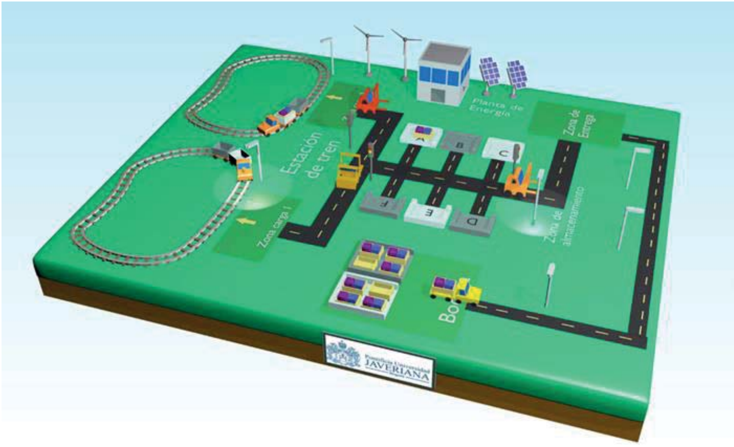

Figure 2. Automation of the Process of Transportation of Merchandise in a Port. – Pilot 2014-2

The project developed during the first period of 2015 was based on disability. Each group interviewed a person with disability in order to find a problem of their daily life. After finding it, students presented and developed a solution, utilizing the CDIO design phases. Abilities such as the understanding of ethical and social responsibility, oral communication and context knowledge were specially improved. In Figure 3 are shown two of the projects developed by the students.

Figure 3. Disability Projects: Robotic Hand and Color Sound. – Pilot 2015-1

IoT and domotics were the topics chosen for the second period of 2015. Again, student selected their work teams and chose a specific topic belonging to the proposed ones. In Figure 4 can be seen two projects developed by the students. The methodology showed again its advantages to develop important abilities such as teamwork. Teams collaborated, participated and organized to design and implement the different projects. In addition, disciplinary abilities, such as the correct utilization of several engineering tools, was correctly applied, showing the growth and learning achieved with the methodology.

Figure 4. IoT and Domotics Projects. – Pilot 2015-2

During the academic cycle, different workshops are offered. These seek to show the student basic tools and knowledges that can be used in the development of their projects (Giraldo et al., 2014). Some examples are: soldering workshop, robotics approach through LEGO mindstorms kit, introduction to electronics through Arduino, and assembly of circuits in protoboard. Other workshops are used to introduce abilities like oral and written communication, the engineering tasks, ethics and social capital among others. Figure 5 shows the icebreaker workshop “Caricature Drawing” where each student learns how to look at himself and others in a different and fun way. Conferences with experts on the topic are also used, and it is proposed to include the support of the industry by visiting companies or having meetings with their leaders.

Figure 5. Icebreaker Workshop “Caricature Drawing”.

ACTIVE LEARNING IN SENIOR COURSES

Digital Area

The courses of the digital area, Logic Circuits, Design of Digital Systems, and Processor Architecture, can be easily used to apply active learning processes. In these, students learn by developing projects under the guidance of the professors. The mistakes and problems found are used to feedback the teamwork and the course in general.

Logic Circuits

The Logic Circuits course does not develop the contents in a traditional way. Many techniques, where the learning of the contents is a mechanic process, were eliminated. Some examples of these techniques are Karnaugh maps, algebraic minimizations and the teaching of all the different flip flop types.

During the first half of the course, the student focuses on understanding the requirements of the client, the restrictions of the problem, and determining the inputs and outputs of the circuit to be designed. These steps allow him to develop a block diagram that clearly describes the architecture of the system. This process is made for three different designs, each one with a higher complexity than the last one.

The course has a maximum of twenty-four students divided in groups of three. The groups propose solutions for the requirement and share their ideas with the other ones in order to find solutions for the problem. The professor acts as a guide whose main role is to orientate the proposals into viable solutions inside the logic circuits domain as well as shortening the extension of them so they can be developed in the available time. Students have different roles inside the group and are divided in Architects, Designers and Reviewer, roles that alternate on the three designs. Each student has to make their own written part according to their role. It is normally seen that at the beginning, while they learn to understand the function of each role, the architecture writings are clearer than the other ones.

After this task is completed, a playful activity is done to help the students understand the concepts of synchronous and asynchronous systems. This ends in selecting the synchronous one after recognizing its advantages and how it is more appropriate for the designs developed.

In the second part of the course, the first two requirements are retaken and the design of each block is made. After it, the VHDL description is also made as well as the configuration of a FPGA device in order to test and verify the functioning of the system and that it actually solves the necessity of the client. Classes are used as a meeting point in the same way they were used while developing the architectures. There are spaces where students share their designs and solutions to the problems they found.

Digital Systems Courses

The Digital Systems course is a continuation of the Logic Circuits course, therefore the methodology is maintained. Students conform groups of three students that during the first part of the course work in the third requirement of the last course. Because that requirement is quite complex, the architecture was not completely defined. They have to complete the architecture as well as the block diagram, and finish in the implementation and verification with the FPGA device.

Generally, in this case, there are more than two courses with twenty-four students, and this is used to implement a role-play in the second half of the semester. On it, each one of the courses receives a requirement and each team makes a proposal of the architecture to solve the problem. When the architecture is finished, the team gives their solution to a team of another course, which now has to design and implement it. In the same way, the first team also receives the proposal of another course’s team. Students use an online forum to ask questions between them, give corrections or modifications of the architectures. It is established that the only valid changes are those that appear in the forum. While this task is done, professors of the courses guide their students and periodically revise the forum in order to follow up the development of the projects.

Processor Architecture Courses

The Processor Architecture is the last course of the line and its methodology is very similar to the mentioned before. In the course, the students have only one project to be done during the entire semester. They have to develop the architecture, design and implementation of their own processor. During the proposal of the architecture, a playful activity is made (a play) in order to help the students understand the difference between hardware and software and do not end up designing both of them as hardware. A processor’s simulator is also used so the student can practice the writing of programs using machine language. Each one of the blocks is analyzed in detail, and especially in the ALU there are proposed different implementation models. At the end of the course, teams must hand in their processors working and running a program chosen since the beginning of the course.

Signals And Systems

Signals and Systems is a third year course of Electronics and Electrical Engineering programs. This course is highly theoretical with high mathematical content, so the students have to deal with several concepts previously seen on the math courses. This combination makes even harder the student's learning process and gives an extra difficulty to recognize the possible applications of the new concepts presented in class (Cruz et al., 2015).

Several activities of Active Learning have taken place and have been implemented gradually (Cruz et al., 2013), many of which are inspired in teaching models used by Professor Eric Mazur (Fagen et al., 2002) of Harvard University. A model we have used is Peer Instruction (Fagen et al., 2002) (see Figure 6), but also we have used other tools and models that have been applied in accordance with cultural differences, technology available, budget and program needs (Cruz et al., 2013) (Cruz et al., 2015).

Figure 6. Active Learning in Class Using Peer Instruction Model.

Although at the beginning the students presented some reluctance and resistance to methodological changes, since they did not want to get out of their comfort zone, they wanted a change. The results of it have been highly satisfactory, with very good reviews and acceptance by students. It was also obtain significant improvements in their interest and motivation for the class and its activities, increasing attendance rates and even getting higher grades.

CONCLUSIONS AND FUTURE WORK

This paper provides examples of the application of active learning strategies in courses of Electronics Engineering at Pontificia Javeriana University under the CDIO approach. Active learning involve engineering students as active participants in their own learning. By using new strategies, such as, role-plays, case studies, oral presentations, problem based and project organized learning, students can easily transfer their knowledge to real life, especially in the engineering practice. The results have been highly satisfactory. Active learning activities improved teaching methods, including engaging students in the learning process. Students showed interest and motivation for the classes and their activities.

As future works, new pilots on different courses are being designed. Elements of Technology, Instrumentation and Electronic Measurements, Fundamental of Design, and Capstone Project are some of the selected courses to implement active learning methodologies. A new challenge is presented since some of these courses are already based on project learning, but are not used to develop non disciplinary abilities and therefore are separated from the CDIO approach. Another course that will keep experiencing changes is Introduction to Engineering since it is constantly evaluated to include new strategies that can provide even better results. A future change to the course is an annual implementation in which in the first semester students develop the theoretical design, and on the second semester they implement it.

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DEVELOPING AN ONLINE PROFESSIONAL DEVELOPMENT CURRICULUM FOR STUDENTS ON INTERNSHIP

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ABSTRACT

Engineering internships provide students with an opportunity to apply their knowledge in real world settings. Internship students also gain firsthand insight to the value of developing their personal and interpersonal skills. This integrated learning experience is an important element of CDIO. This paper describes the development and implementation of an engineering professional development internship pilot course. First, the attributes most beneficial to be developed on internship were determined. Next, these attributes were distributed over a year-long internship based level of experience and applicability. Lastly, course modules were developed, including module content and assignment for each topic. The first cohort of students are two thirds into the pilot program. Their feedback and insights on the effectiveness of the course are shared. The results discussed in this paper will be useful to institutions looking to develop or improve their engineering internship or work term programs. The curriculum design has been modeled to ensure an integrated learning experience while students apply their disciplinary knowledge during a professional work experience.

KEYWORDS

Cooperative Education, Engineering Internship, Professional Development, Online Learning, Standards: 7, 8.

INTRODUCTION

Year-long engineering work terms (internships) provide students with an opportunity to apply their knowledge in real world settings. Internship students gain firsthand insight to the value of developing their personal and interpersonal skills. This integrated learning experience is an important element of CDIO, and internships provide an excellent opportunity for students to conceive, design, implement, and operate products, processes and systems (Crawley, Malmqvist, Östlund, & Brodeur, 2011, p.297).

Interns are typically required to maintain a full-time student status. Their home institution therefore, has the responsibility to ensure the successful acquisition of learning outcomes, independent of their internship experience. Institutions must take on an active role in the professional development of students on internship in order to enhance their experience and learning. This paper describes the development and implementation of an internship course focused on engineering professional development.

BACKGROUND

The growth of cooperative education in the first half of the 20th century was motivated by the needs of industry to better prepare engineers (Haddara & Skanes, 2007). And this need still exists today as engineering education moves towards an outcomes based approach focused on both technical and professional skills. These professional skills are often difficult to teach in a classroom setting, and internship provides an excellent opportunity to develop these attributes in undergraduate engineering students.

Engineering Internship

Internships can be defined as "structured educational strategies that integrate classroom learning with practice work experience through productive work placements in fields related to the students' career goals" (Fifolt & Searby, 2010). The benefits of internships have been highly documented. Haddara & Skanes (2007) provide a thorough review of studies which show the positive benefits for new graduates, including increased starting salaries, higher levels of responsibilities, improved confidence (particularly in females), increased career satisfaction, as well as benefits to the employer and the institution (Haddara & Skanes, 2007).

Internship experiences provide students with opportunities to practice their skills in an authentic engineering environment. It has been shown that the effectiveness of an internship experience can be improved with mentoring and support during the experience (Fifolt & Searby, 2010). The transition from the classroom to the workplace is challenging, and providing students with feedback and guidance can assist in this transition.

Engineering expertise is gained through exposure to multiple opportunities to practice skills on authentic tasks that require an integrated approach (Litzinger, Lattuca, Hadgraft, & Newstetter, 2014). Internship provides a venue where students can engage in engineering tasks in a real world setting. However, expertise is most effectively developed when students engage in "deliberate practice," where they practice with the intention to improve their skills (Litzinger et. al., 2014). A successful internship program should therefore encourage a practice of self-reflection and self-directed learning.

Online Learning

Online education has become a prominent field of interest due to the accessibility and flexibility the online environment provides. As outlined by Bourne, Harris, & Mayadas (2005), there are three important elements to consider when teaching engineering in an online environment: quality, scale and breadth. The online environment provides an excellent venue for internship students, as it easily scales to different locations and varied time commitments. The quality and breadth of an online professional development course for internship must also be considered.

MOTIVATIONS

At the Schulich School of Engineering, University of Calgary, approximately 400 students (about 75% participation rate) partake in an internship program between their third and fourth year of studies. Student internships can span over two 6 – or 8-month positions, one 12-

month position, or one 16-month position. Each experience is unique and provides the students with valuable insight into the engineering workplace.

While on internship, participants must maintain full-time student status with the University. This is accomplished by having the students register in a sequential series of internship-related courses: INTE 513.01, INTE 513.02, and INTE 513.03. Each course spans one term in length (four months). For students doing a 16-month internship, although there is a final term course (INTE 513.04), there are no requirements or fees associated with this course.

Prior to May 2015, students were required to write a report for each course while they were on internship. The three reports, which were increasingly complex in their requirements, had the following topics: 1) Roles, Responsibilities, and Goals; 2) Accomplishments, and Business/Industry Overview; 3) Comprehensive Engineering Report.

Each student was paired with a faculty member at the Schulich School of Engineering who served as a mentor. The faculty mentor was responsible for reviewing and assessing the reports submitted by the student, and provide feedback regarding the content and structure of the report. However, there were a number of concerns associated with this approach. Firstly, any confidential content was either removed from the report, or was blacked out, which was often the majority of the report. Secondly, the feedback received from the faculty mentor was often limited. The time commitment required to provide adequate feedback was challenging to fit into their already busy schedules. Some faculty mentors provided valuable feedback, whereas others did not make the time to provide significant feedback. Faculty also felt the reports had limited linkage to meaningful learning outcomes. The end result of this process was undesirable, in that students saw little value in generating these reports. For this reason, the academic internship curriculum was redeveloped and a Pilot program was launched Spring 2015.

DESIGN AND DEVELOPMENT

The environment of an internship course is different than traditional academic courses. Internship students have a wide variety of experiences including different locations (local, national, international), different situations (office work, field work), different skillsets required (technical design, project management, operations), and different levels of responsibility (small companies compared to large companies). For this reason, the course content had to be adaptable and flexible to each student's personal experience.

Course Goals

Before designing the course, it was important to consider what overarching goals and learning outcomes the redeveloped internship courses would provide. There were four target goals for the program:

1. Develop students' self-awareness skills in order to encourage students to reflect on their learning experience while on internship.
2. Provide students with skills not normally taught in the classroom that complement their work experiences.
3. Design a curriculum that provides high value content for low time commitment.
4. Provide valuable, personalized feedback to help students become progressively more effective and reflective in their work.

Each course requirement that the students were given was compared against these course goals to ensure we were developing a high quality program.

List of Skills and Attributes

The first step in the internship curriculum redevelopment process was to consult with engineering leaders and experts at the University to collect an extensive list of professional skills beneficial to cultivate in engineering internship students. The initial list of skills included almost 100 different topics that were categorized into nine areas of development:

- Communication
- Design
- Teamwork and Leadership
- Project Management and Economics
- Impact of Engineering on Society and Environment
- Ethics and Equity
- Ethics in Engineering Practice
- Professionalism at Work
- Personal Development and Wellness

These categories, and the associated lists of attributes were presented for input to the five engineering department heads and other stakeholders. It was important to not only consider which skills were important to include within an internship experience, but also when during the work-term a particular skill would be most beneficial. For example, a student early in their internship may have had little interaction with leaders in their organization, therefore leadership would be a topic appropriate for later. After this interactive discussion process was completed, the specific topics within these categories were chosen for the first INTE 513.01 pilot course.

Course Design

During a four-month work term, six topics were chosen and developed as online modules. Six was thought to be an appropriate quantity considering the typical responsibilities a student would already have associated with their internship job. The time commitment for each module was between 1-2 hours, and the assignment due dates were once every two weeks.

Module Streams

Six module streams were used as a framework for the INTE 513 pilot program, as depicted in Figure 1. The flow across each module stream allowed students to build on the topic with each term. However, it was also important to ensure there was flow across one course, with a clear connection for students between each module.

Assignments

All assignments were qualitative and included two elements. Firstly, students answered simple questions throughout the module in order to confirm their understanding and ensure they were actively engaged in the material that had been provided to them. These questions were checked for completion, however the answers were not reviewed in detail.

Figure 1. Overview of INTE 513 Pilot Module Streams.

Next, each module included reflective questions which asked students to apply the module content to their own work experience and reflect. For example, a module on *Engineer's Role and Organization Value* asked the students the following reflective question:

> How do your day-to-day activities as an intern follow your organization's mission and vision? Although the project/tasks may not have a direct impact, how do they fit within the organization as a whole? Consider how your tasks may contribute in very small ways towards the mission and vision.

The assignment questions were structured to ensure that students in a variety of different workplace settings would be able to engage in meaningful reflection. The questions were left open-ended so that students could reflect in a way that was useful to their own personal situation, while still being specific enough to achieve the module's learning objectives.

Online Format

An online format was chosen to provide flexibility for the students. Especially since many students are working in internship positions that are not local, it was important that there was no in-class requirement for the course. Some students also had limited access to the internet due to business trips, or field work in remote areas. For this reason, assignment due dates were always flexible, as long as students provided the instructor with sufficient notice for requesting an extension. Planning ahead and being aware of time conflicts is an important skill for students in the workplace.

Providing Written Feedback

One of the goals of the new internship courses are to provide students with valuable feedback. Graduate students were hired as teaching assistants (TAs) to mark assignments and provide personalized feedback and career insights for each student. The hiring process included an application and a formal interview.

TAs were hired based on three criteria: 1) Engineering industry experience; 2) Expressed an interest in mentoring undergraduate students to improve their professional skills; 3) Strong written English skills, as all communication with the students would be online. During the hiring process, the diversity of the group of TAs was also considered. Each student would hear feedback from different TAs during one term, and it would be beneficial for them to hear from diverse perspectives.

RESULTS – STUDENT FEEDBACK

The first cohort of students using this new format started internship in May 2015. This group included 277 students, and they have completed two thirds of the program, courses INTE 513.01 and INTE 513.02. The second cohort of students started in September 2015. This group included 83 students and they have completed the first term, course INTE 513.01.

The initial response to this new course structure has been mixed. Students enjoy the module content, appreciate the personalized feedback, and understand how the material not only helps them in their current internship position, but also how it is related to their future success as professional engineers. However, the students are aware they are the pilot group, and they also provided comments in order to help improve the courses going forward.

Feedback was collected at the end of each term. For each module, students were asked ten questions rated on a 5-point Likert-scale from strongly disagree to strongly agree on the content, assignments, and overall impressions of the course (see Table 1 for list of questions). The last few questions on the survey asked the students to rate the six modules based on the most interesting, the most valuable, and the largest time commitment. Open textboxes were provided throughout the survey for any further comments the students wished to include.

Table 1. Summary of the End-of-Term Survey Feedback Questions
(rated on a 5-point Likert scale of strongly disagree to strongly agree).

End-of-Term Survey Feedback Questions (for each Module)
1. Please rate the following based on the Module **theory**. a) The theory content was new information for me. b) The theory was an area I was interested to learn about. c) The theory was presented in an engaging way for me to learn.
2. Please rate the following based on the Module **assignment**. a) The assignment had clear requirements. b) The assignment improved my understanding of the content. c) The assignment was enjoyable to complete. d) My assignment grade was reflective of the work I submitted. e) The written feedback I received was beneficial.
3. Please rate the following based on the Module **overall.** a) This Module improved my professional skills. b) I can apply the skills learned to my engineering career.

Term 1 Results – INTE 513.01 Feedback

The following feedback is from the 83 students who started in September 2015 and have completed the first course, INTE 513.01. The quantitative results from the survey are provided in Figure 2. On average, 13% of students Strongly Agreed and 43% Agreed with the statements from Table 1. There were still 5% of students who Strongly Disagreed, 10% who Disagreed, and 29% who felt Neutral about the statements.

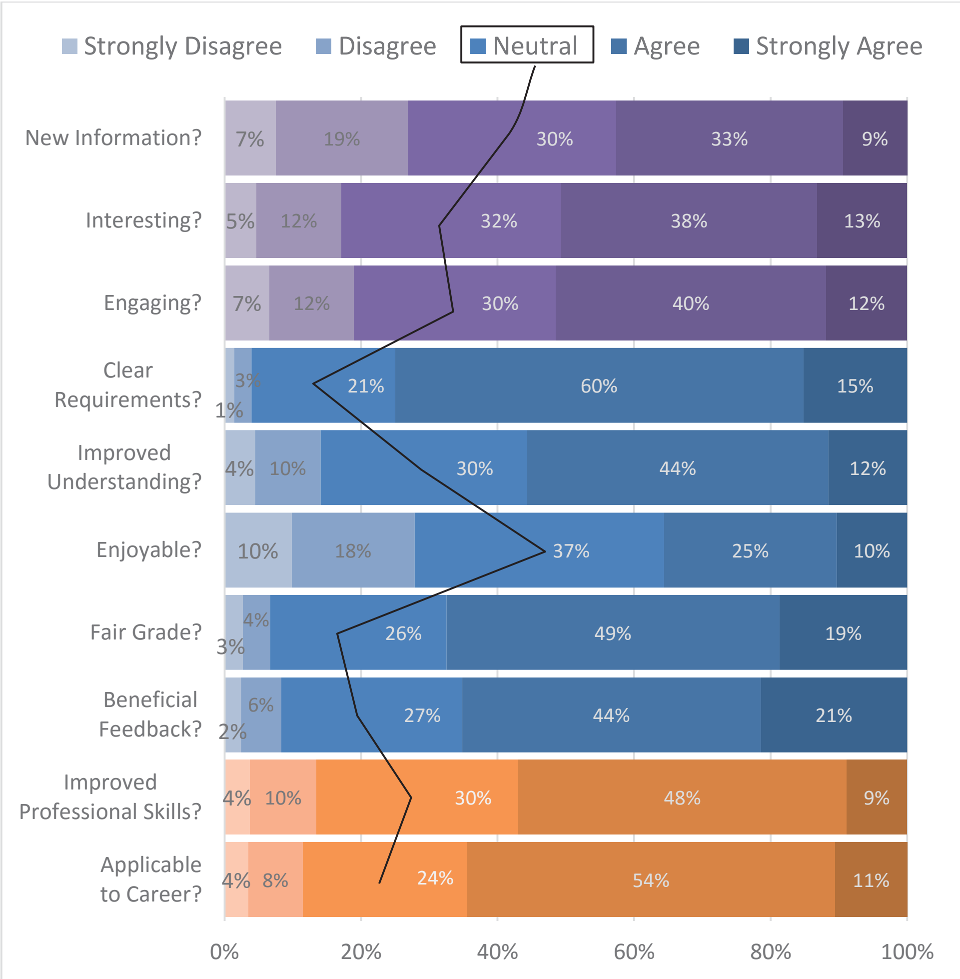

Figure 2. Results of feedback survey questions from Table 1 for the first term, including Module Theory (purple), Module Assignment (blue) and Module Overall (orange).

Looking more closely at the results in Figure 2, the areas student provided the strong positive feedback was in *clear assignment requirements*, *fair grades*, and *beneficial feedback* on the assignments. However, the area where students showed the strongest negative feedback was in how *enjoyable* they felt assignments were.

The students' written feedback comments were also analyzed. The positive feedback generally included comments on the fact that the topic was beneficial, informative, and applicable to the internship experience. Positive comments also mentioned the value that was provided in the TA feedback. Some examples include:

- *“I had fun completing [this] module. It was engaging and informative.”*
- *“I really thought the feedback I received about the [assignment] that I had was the most useful part of this module.”*
- *“This was an interesting module. Probably the most interesting out of the bunch.”*
- *“The course was well-designed. For the most part, it was applicable to the internship. It does prepare interns for the real world, to a certain extent. Assignments are clear and marking does not take too long.”*
- *“I much preferred doing these modules to writing reports. I feel like the modules were easier to manage, and also pushed me to talk to my coworkers and learn.”*

The student surveys were anonymous and the students were encouraged to provide honest feedback. They were aware this was a pilot year for the program, and that we were seeking feedback on areas of improvement. The negative comments from the students tended to focus on the content being boring or knowledge that the students already possessed. There were also many students who mentioned the time commitment required to be too high. Some examples include:

- *“Rather quite boring and rather obvious knowledge”*
- *“The INTE course takes up too much of the student's time, and it is visibly obvious that each and every module can be shortened and made more simpler.”*
- *“A lot of materials were covered within the company...And it's kind of boring to do them all over again.”*
- *“Honestly, this takes too much time.”*

Term 2 – INTE 513.02 Feedback

The term 2 feedback results are from the 287 students who started their internship in May 2015, and have completed both the first and second course. The quantitative results from the survey are specific to the second term course, INTE 513.02, and are provided in Figure 3. Unfortunately, this group of students was not surveyed on the first course, INTE 513.01.

On average, 15% of students Strongly Agreed and 42% Agreed with the Table 1 statements. There were still 8% of students who Strongly Disagreed, 11% who Disagreed, and 23% who felt Neutral about the statements. Compared to the term 1 results, the students had more extreme opinions, with higher percentages Strongly Agreeing and Strongly Disagree, and 5% less students giving a Neutral response to the questions.

The results in Figure 3 align closely with those from Figure 2, where students felt strongly positive about the *clear assignment requirements* and *fair grades*, though *beneficial feedback* was not as highly rated as in term 1. The strongest negative feedback in the second term was again how *enjoyable* the students felt the assignments were.

After two terms of completing the updated INTE 513 program, students provided lengthy and passionate responses in the written comments. Overall, the 272 students wrote a total of 384 comments, averaging over 35 words each. The comments provide excellent insight into the successes and challenges of the new INTE 513 program.

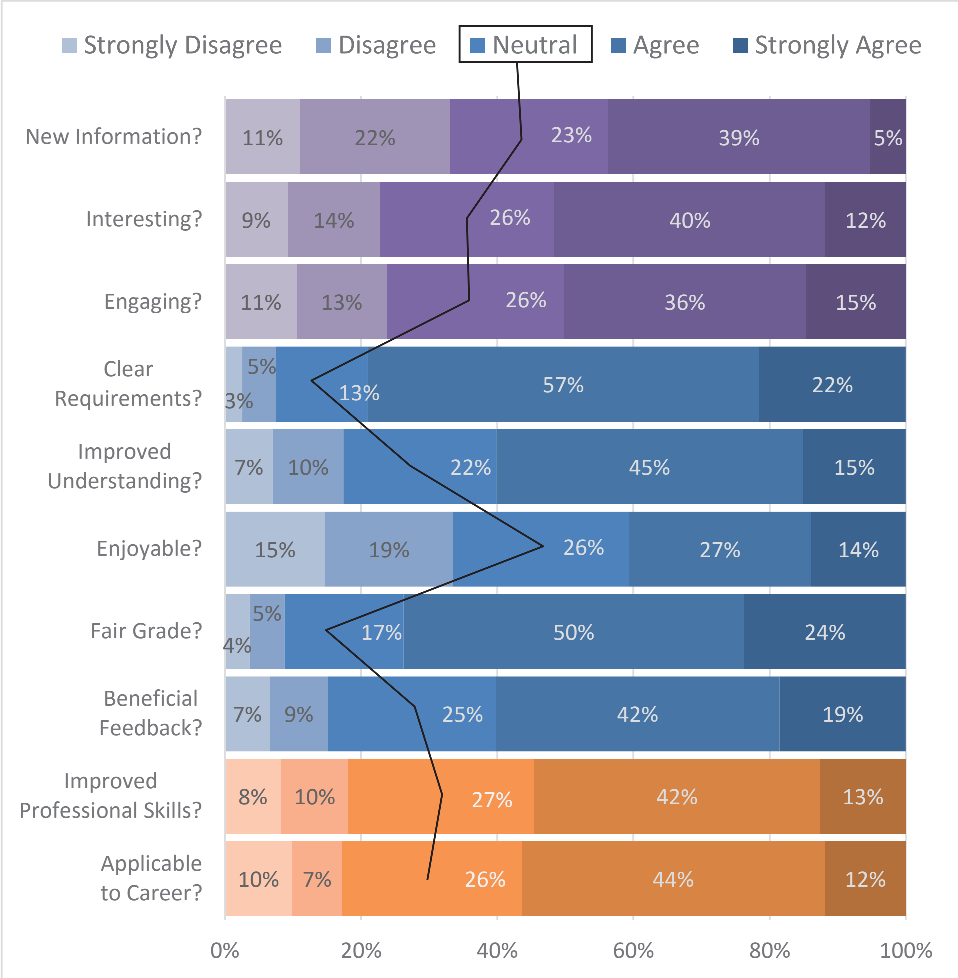

Figure 3. Results of feedback survey questions from Table 1 for the second term, including Module Theory (purple), Module Assignment (blue) and Module Overall (orange).

Most of the positive comments focused on the assignments which the students found most useful, excellent written feedback from the TAs, and elements of the INTE 513 program which they enjoy. Some examples include:

- *“The feedback I received from this assignment was the most useful to date. I feel like it was very effective and encouraged me to take more initiative in my work.”*
- *“I enjoyed this assignment and found it useful and relevant to work and internship.”*
- *“As someone who is not good with conflict this was the only module of the bunch that I felt I would be able to apply to career.”*
- *“I always value written feedback more useful than a number. This semester's feedback was more useful than previous.”*
- *“I really liked the course. I like these modules for 2 reasons: - They inform me about little areas I can work on. - They take little time.”*
- *“Great course, really liked the small learnings from the modules”*

Again, the student surveys were anonymous and the students were encouraged to provide honest feedback. The comments on areas for improvement tended to focus on the content being areas the students were already familiar with, too high of a time commitment, and lack of engagement during the modules. Some examples include:

- *“The theory content was something we have heard hundreds of times before.”*
- “*For the most part, the information was not new and I felt like I was writing things simply in order to get a grade.”*
- *“All the assignments should be shorter. Take way too long.”*
- *“I marked "Disagree" for the module being enjoyable to complete, because it is a little bit boring to answer questions off of a PowerPoint you are reading”*

DISCUSSION

The pilot implementation of an updated internship course for professional development has been able to provide students with valuable skills. The student feedback has been positive, with the majority of students expressing agreement to statements on the value and applicability of the topics. However, as this was a pilot project, there are still many areas for improvement.

Sustaining the Successes

It is evident that students value high quality, individualized written comments and feedback. Many students expressed their gratitude to the TAs for the comments provided and the perspective they were able to provide. It will be important to maintain this aspect of the program, and to ensure there is a higher degree of consistency across the TA comments.

When students are interested in a topic area, they are motivated and engaged to participate in that module. Almost every single module had a comment “excellent, very interesting” as well as “boring module”. This shows that the content itself may not be the variable, but rather the students’ intrinsic motivation and desire to gain skills in that area. To harness this, the updated version of the internship programs will include an element of choice where students will be required to plan their own professional development journey.

Lessons Learned

During the pilot project, the most common negative feedback was that the questions were not applicable to their internship experience. It is challenging to develop a program which is flexible and applicable to 400+ students in 400+ different engineering internships. Although we succeeded in some respects, it is evident that the assignments require refinement. The assignment questions will need to be adjusted to be more adaptable and applicable to a wide variety of situations to encourage self-awareness and self-reflection in the students. Also, rather than requiring students to complete specific modules, we will introduce an element of choice so that students are required to plan and justify their own professional development journey. Both of these changes will also hopefully help to increase the students’ enjoyment of completing modules.

The next most common piece of feedback, particularly for INTE 513.02, was that the modules took too much time to complete. The goal of the course was to provide high value for low time commitment. It is evident that as students’ progress through their internship experience, their work responsibilities increase and they have less time to complete homework assignments. Therefore, we will be implementing a 6-5-4 model, where the number of modules required in each subsequent course decreases as the students’ work responsibilities increase.

Although the course is a Credit / No Credit course, students were given grades on their assignments. However, this meant that they read their feedback seeking to understand the reason for their grade, rather than reflecting on the comments provided by the TA. In the future iteration of this course, the grading procedures will be reevaluated to ensure they are valuable for the students. It will also be important to consider more consistent methods to mark qualitative assignments.

Next Steps

As already discussed, the next iteration of the INTE 513 program will include: 1) open-ended assignment questions that are adaptable to individual situations and encourage self-reflection; 2) an element of choice where students must plan and justify their own professional development journey; 3) reduction in course requirements for each subsequent course; and 4) improved consistency in the marking methods.

Additionally, we will seek feedback on the updated internship courses from industry representatives. During the pilot phase, industry was consulted and provided us with some initial input, however we will be setting up a formal industry committee in order to further develop and refine the content provided in the program.

Lastly, although Figure 1 illustrates continuity across the module topics both vertically (during a course) and horizontally (across courses), there is room for improvement. Specifically, the continuity across the modules vertically within a course was limited. Students felt after completing one module that there was no connection to the next module requirements. In order to improve this, we will be introducing an element of reflection on the previous topic at the beginning of each new topic.

CONCLUSIONS

The design and implementation of the internship pilot program has been a success so far. Students have expressed gratitude to the redevelopment of the program, and have provided suggested areas for improvement. It will be important to maintain a model of continuous improvement for this course as it is developed and refined.

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STUDIOS & SUSTAINABILITY: A CREATIVE CDIO APPROACH TO COMPUTER ENGINEERING EDUCATION

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ABSTRACT

As creativity and innovation become increasingly important in solving future electrical and computer engineering challenges, such as the end of Moore's Law, engineering education will need to incorporate creative and global problem-solving with technical course concepts. Creative skills and problem-solving lead to new and useful engineering processes, tools, technical and products, and development of these skills should begin early within an engineering program. Creativity within engineering encompasses a wide variety of definitions and aspects, including integration on a global scale and sustainability engineering development. Sustainability is an element of creative design that is often emphasized in other engineering disciplines while being overlooked in electrical and computer engineering. However, past research has shown that students do not view engineering as a creative career or one that allows them to make a sustainable impact on society. This paper will detail and explore the impact of a flipped classroom pilot for a required first year engineering computer programming course, and effects on its implementation on student perceptions of engineering. This initiative uses the CDIO method to integrate sustainability, design, creativity, arts and entrepreneurship through hands-on studio experience.

This course initiative requires students to build a creative and visual-based programming portfolio using the Processing programming language, working towards the development of a final coding product. The evolution of this final product requires students to apply the four CDIO stages to either a bio-inspired visualization project or a game creation project, while incorporating elements of sustainable engineering design. A final demonstration and peer assessment also introduces an element of entrepreneurship and business presentation.

This paper will describe the studio learning experience, the integration of the CDIO method with technical coding objectives, and preliminary results and observations from the fall semester offering. Overall, students have demonstrated more engagement and motivation due to the creative CDIO design techniques introduced in parallel with technical programming concepts. The developed curriculum may also be modified for a K-12 introduction to computer engineering and programming as computer literacy becomes more prevalent within schools.

KEYWORDS

Creativity, Sustainability, Programming, Flipped Classroom, Standards: 2, 3, 5, 6, 8, 11

COURSE OVERVIEW

Creativity is an important part of engineering graduate attributes across the world, including the attributes required by the Canadian Engineering Accreditation Board (CEAB, 2014, IEA, 2013). While there are varied theories and models of creativity (Taylor, 1975, Guilford, 1967, Torrance, 1974), this work uses the Taylor hierarchy of creativity (Taylor, 1975) to define creativity as consecutive stages of understanding and the development of creative thinking skills. In many engineering programs, students are expected to develop their innovation and creativity through open-ended introductory and senior design courses, while technical courses remain focus on domain knowledge. Students themselves are often focused on fulfilling assessment requirements necessary to achieve a high grade, sacrificing creative knowledge application in favour of a perceived correct answer. Despite an emphasis on creativity in industry hiring, related literature questions whether or not creative thinking is truly being taught in engineering postsecondary programs (Daly, 2014). Existing literature identifies a clear need for creativity to become a greater focus in engineering education so that graduating engineers are capable of meeting the innovation challenges of the future (Daly, 2014, Felder, 1987, Felder, 1988, Liu, 2004, Joseph). Previous CDIO initiatives (Arboelda, Jingdong, 2011, Shen, 2009, Chunfang, 2012) demonstrate work in the use of the CDIO framework for computer engineering education, while this research builds on the previous literature by combining the development of both creative and technical learning outcomes within a traditionally technical course, rather than a design course.

This work describes and details an initiative to redesign the mandatory first year engineering introductory programming course, required by nearly 800 students in a single semester, using the CDIO framework and syllabus attributes. This course was redesigned as a flipped classroom, where the instructional content was provided online through various mediums, while the instructor directed portion was delivered through exploratory, hands-on exercises. This paper will focus on the exploratory design portion of the course.

STUDIO EXPERIENCE

Like learning a second language, computer programming education requires not just the understanding of vocabulary and syntax structure, but the application of those concepts within problem-solving contexts as needed. In arts education, a studio environment is commonly used to allow students to collaborate with their peers in an open space, while still working individually on their creative product. Within studio sessions, students are often provided with creative prompts, giving them a starting place for creative design. The form of this prompt may vary depending on the medium. For example, a few written lines of dialogue may be given to start a creative writing piece, or a still-live model to start a sketch. Creative spaces are now being explored in engineering institutions as a way to the encourage teamwork and problem-solving required by national engineering graduate attributes (Zabudsky, 2015).

This initiative adapted arts education delivery approaches for encouraging peer cooperation and a deeper, hands-on understanding of technical concepts, allowing for development within CDIO attributes such as creative thinking, critical thinking, analysis, teamwork, and communication, alongside development of computer science and programming knowledge Engineering studio environments are proposed as an alternative to laboratory settings for collaborative peer technical practice, alongside project or assignment prompts that encourage students to start the creative thinking process.

Studio Workspace

Without the need for a traditional lecture hall, this scheduled portion of this course was run in the open workshop spaces usually reserved for the first year design course. Students were seated around tables in groups of 4, with an average of 32 students in each of the six available workshop rooms. To accommodate nearly 800 students, four separate studio session times were run. Each studio room was supervised and directed by a teaching assistant, under the supervision of a teaching assistant coordinator and the two course instructors. Students met in this studio space once a week for two hours to complete exploratory assignments and to work on their final design project.

Studio Activities

The studio activities and assignments allowed the students to reinforce their online learning while exploring the application of theoretical concepts. The assignments were designed to build in complexity and difficulty each week, resulting in a final coding portfolio that could be demonstrated to a future employer or internship opportunity. Each portfolio assignment consisted of an in-studio and post-studio component. The in-studio exercises were designed to be shorter and collaborative, allowing students to work together on a combination of written and coding problems. These exercises were also used as an attendance tool, as they were required to be submitted in-person before the end of the studio session. The post-studio exercises were due one week later, submitted online for further evaluation.

SUSTAINABILITY IN COMPUTER ENGINEERING

Sustainability is an important part of engineering design education, included in CDIO Syllabus 4.1.7 Sustainability and the Need for Sustainable Development, but is often not addressed in electrical and computer engineering projects. As this course was an introductory course for computer and software engineer concepts, sustainability was included as an integral part of the introductory education.

Sustainability Compass

The University of Calgary promotes the four primary categories of the Sustainability Compass, commonly used to identify different key issues and aspects of sustainability (University of Calgary, 2015). These categories and related concepts were integrated with the course curriculum to demonstrate the impact of technology on sustainability concerns.

Nature

The nature category includes any sustainability issue that may impact the natural systems on which all life depends. Students were educated on related ICT issues, including the environmental impact of e-waste disposal and the impact of technology on natural human and animal behaviours and habits.

Economy

The economy category includes issues relating to the sustainability of economic practices and standards that provide humanity with goods, services, and work. For example, the adoption of automation technology has both created and removed jobs in certain industry.

Software and digital developments, such as bitcoin, may also impact the sustainability of current economic practices.

Society

The society category examines the sustainability of social and cultural systems, from school communities to cultural communities. Students were given many examples regarding the balance between ethics and business practices, such as cybercrime and illegal hacking for purported moral reasons. Another relevant example provided was the use of telecommuting within industry, which requires balance between responsibility, time, effectiveness, and job scope creep.

Wellbeing

The wellbeing category involves aspects that impact individual health, happiness and quality of life. Students can relate most to the software-related examples in this category, which include issues such as online bullying, social media harassment, and catfishing. Students are also familiar with the positive elements of sustainable wellbeing practices, including donation campaigns and social media charity challenges.

CREATIVE DESIGN PROJECT

The final creative design project was developed using the CDIO framework to support the integration of technical knowledge, creative development, entrepreneurship and sustainability, pulling together elements from all four UNESCO pillars of education and the CDIO syllabus. Students worked in pairs to develop their choice of either a game or a bio-inspired data visualization project. Over 95% of the students chose to develop a game. The project requirements included some mandatory technical elements that had to be demonstrated, but otherwise students were given complete creative control over their final product. Students were required to demonstrate evidence of beta testing and documentation throughout the coding process, giving them the opportunity to integrate feedback from their peers and teaching assistants.

Creative Development

The project outline followed the CDIO design process, allowing the students to develop their ideas in an iterative and detailed manner. The design deliverables used brainstorming, visual mapping, creative storyboarding, and synthesis techniques to specifically develop the attributes found in CDIO Syllabus 2.4, especially 2.4.3 Creative Thinking.

Providing students with the chance to visualize their program and ideas allowed them to isolate any potential issues with user interaction, continuity, code layout, etc. Storyboarding is a technique used to map the intended stages of a storyline. This allows the creators to identify changes in character, dialogue, mood, scenery, and style. Each storyboard scene consists of a drawing or sketch, sometimes with a few lines of explanation or dialog written underneath, as shown in Figure 1. A storyboard should be divided into enough scenes to represent the entire process without missing any significant component. This technique allowed students to conceive each design stage and aided project management planning.

Sketch/diagram of game screenshot goes here.
This diagram should show what is happening on screen during a particular moment or scene in the game (i.e. Level 1 gameplay, or Level 2 score calculation, etc.)

Caption: One word summary of diagram content.

Explanation: Include a more detailed description of this particular moment or scene in the game, why is is important, and how it works.

Storyboards may include things such as:

- Each available level
- Menus
- Scoring
- Plot points/cinematic scenes

Use your storyboard to outline each interaction the user will have with your game. A multi-level game with a menu and rules screen will probably have more than six scenes in its storyboard.

Figure 1: A storyboard layout allows students to conceive and plan each stage of their design.

Integration of Sustainability

The project was designed to include a final report and documentation that required reflection and clear thought regarding the applicability of ICT sustainability issues. Students reported on various sustainability aspects, from physical ergonomic issues in gameplay to e-waste education, and from responsible program messaging to the accessibility requirements of disabled users.

Demonstration and Assessment

The final project culminated in an exhibition and demonstration day, where students were given the opportunity to test and experience the final products of their peers. This activity included a peer assessment assignment, where students were required to provide feedback and a rating for the other teams in their studio room. In their final reports, students were also required to reflect on their own experience within the project, including team dynamics and project management elements. This was designed to support the development of CDIO attribute 2.4.5 Self-Awareness, Metacognition and Knowledge Integration.

IMPLEMENTATION RESULTS

A preliminary analysis of the course implementation results has been successful, and will be used to further development the next iteration of the course curriculum. Feedback methods included team surveys and reflections, individual surveys before and after the final design project, and university required course ratings. All of this information has just recently become available following the completion of deferred examinations, and a further analysis of the information will be included in the final paper.

Overall, students reported the course to be similar in workload or slightly higher when compared to their other first year courses.

Creative Project Response

Students reflected on the creative design project with both qualitative and quantitative feedback. As shown in Table 1, the majority of students agreed that their understanding of technical concepts was increased through the creative design project, as well as their creative thinking. Over half of the students reported an increase in both their interest and enjoyment of programming as well. The majority of the students also reported learning additional concepts on their own time in order to the complete the project. When asked about this question, most of the students indicated that this was not due to a lack of understanding or lack of appropriate course content, but because their creative designs and desire to produce a particular idea required additional research of concepts outside the scope of the course.

Table 1: A summary of student response towards the creative design project.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My understanding of technical concepts increased	2.02%	5.26%	12.15%	52.63%	27.94%
My creative thinking was improved	1.62%	5.26%	18.22%	48.18%	26.72%
My interest in programming increased	9.31%	8.50%	17.41%	35.63%	29.15%
My enjoyment of programming increased	8.61%	8.61%	16.39%	37.70%	28.69%
I learned additional concepts on my own to complete the project	2.83%	2.43%	9.72%	46.96%	38.06%

Student Perceptions

Students were also asked about their perceptions of electrical, computer, and software engineering as a result of their participation in the course. 70% of the students agreed or strongly agreed that programming is an important skill for some engineers, but more importantly, only 25% disagreed that programming in an important skill of all engineers. With the increasing focus of computer literacy and programming knowledge, it is important that students recognize the impact that coding skills and problem-solving can have on engineering innovation and development.

Student Quote

“I believe that the game project allowed students to be creative and innovative. This project was very open ended which I believe was an advantage. Ultimately, I believe that this course was very well executed and organized. This course requires individuals to become better problem solvers, not just plug and chug.”

- ENGG 233 F15 Student

CONCLUSIONS

In summary, this work outlined the exploratory design elements of a course redesign initiative for an introductory engineering programming course. The creative design exercises and project were developed using the CDIO framework and syllabus for the effective teaching and learning of creative attributes alongside technical knowledge. Preliminary analysis of both qualitative and quantitative feedback has shown results supporting the desired outcomes of the course redesign, including increased creative thinking and understanding technical concepts. With the co-development of both creativity and technical knowledge, students will be equipped with the skills necessary for future innovation and design.

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William Rosehart is the current Dean of Engineering at the Schulich School of Engineering, University of Calgary. His research areas include engineering education, optimizing energy systems, controlling wind-based energy production, and studying the benefits of distributed generation. He has received a number of teaching awards and early career awards, including recognition as one of Calgary's 2007 Top 40 under 40.

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ENHANCING THE RDI COMPETENCE OF MASTER'S STUDENTS THROUGH DIVERSITY MANAGEMENT INTERVENTIONS

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ABSTRACT

In this paper, the RDI (Research-Develop- Innovate) competence of students is discussed in the context of Master's education at Finnish Universities of Applied Sciences, specifically when promoting diversity and inclusion in workplaces. Diversity can be seen as richness in an organization. It is a significant contributor to the creation of new knowledge. If properly designed and implemented, DM can bring about desirable improvements in workplaces.
We focus particularly on the application of a Diversity Management Measurement Tool (DiMa), Master's thesis projects, and the students' shared experiential learning developed in diversity management courses, that together produce a strong set of RDI competences.
We argue that the RDI competences students develop during their Master's programme can be applied in the workplace in multiple ways to the mutual benefit of student and their own (sponsor) organization.
These students are the key actors who design and implement an applied thesis project aimed at addressing a contemporary business challenge, and thereafter lead future challenging and complex development and change projects. Moreover, their professional personal development provides them with professional skills, competences and knowledge that enhances their career prospects and opportunities to make a meaning mark within the organization. For example, having enhanced their RDI capabilities students can actively challenge current opinion and ideas and promote understanding of diversity in workplaces and inclusive programs to achieve the benefits attached to this rising area of management.

KEYWORDS

Diversity, Diversity Management, Master's Education, Virtual Teams, RDI Competence, Standards: 5, 7, 8, 10

INTRODUCTION

In this paper, the RDI (Research-Develop- Innovate) competence of students is discussed in the context of Master's education at Finnish UAS's, specifically when promoting diversity and inclusion in workplaces. We argue that Master's students can promote understanding of diversity in workplaces and introduce and implement inclusive programs to achieve the benefits attached to this increasingly important area of management.

In describing the context and expected outcomes of undertaking a Master's degree at a Finnish UAS – in our case Helsinki Metropolia UAS (HMUAS) – firstly, we identify students' ability to Research-Develop- Innovate across a wide array of areas. Thereafter, by way of a more specific example, we illustrate RDI in the context of diversity management.

Higher education in Finland

Higher education in Finland is provided by universities and universities of applied sciences. The role of universities of applied sciences (UAS) is to give higher education qualification and practical professional skills (Ministry of Education and Culture). Master's level studies in UAS requires that the applicant has a bachelor's degree and at least three years of subsequent work experience in a relevant field (Ministry of Education and Culture). Helsinki Metropolia University of Applied Sciences offers 26 professional Master's degree programmes in the fields of Business, Culture, Technology, and Social Services and Health Care

These programmes are targeted at working life professionals aiming at certified degree for their professional career and foster personal development and life-long-learning. Studies are employer-friendly with flexible schedules allowing students to continue working and to apply their learnings to the employer's organizational context.

Master's degree students of HMUAS are often mature professionals with 10+ years of work experience.

Crucially, students are not just the recipients of teaching and learning, they also contribute to others. As we describe below, given their extensive work life experience, students are able to share these experiences that are contextual relevant to contemporary workplace challenges. We later illustrate this with particularly reference to understanding diversity and diversity management.

The studies develop practises, processes, and systems in collaboration with professionals, which supports personal growth in active learning environment (CDIO2.0 Standard 8). The final year project - Master's thesis work - is an integrated part of employer organization development.

Undertaking Master's studies

Although undertaking a master's degree clearly requires personal commitment, without the explicit support from one's workplace the undertaking would be doubly challenging. However, we view this a reciprocal arrangement; **to the mutual benefit of employer and employee.**

From the organization comes their investment by way of support for the student, which requires that their immediate supervisor explicitly provides backing in terms of allowing study time for a day-time programme.

From the student, first comes their research work. Uniquely, most students undertake a thesis project that is contextually placed within the organization; undertaking an applied solution to a current business challenge. In essence, this is frequently a change management project.

Some projects address 'hard' issues – for example …a new or improved process, measure, system or business model. Frequently this is bound up in concepts of continuous improvement, where the student's research leads the co-creation of the solution, for example, in the spirit of Action Research (e.g. Reason & Rowan, 1981). Solutions are proposed, validated, tested, implemented and evaluated – albeit that in some cases implementation and evaluation follow sometime after the thesis work has been completed. As typical examples, we might see an improved and integrated procurement process following a merger and acquisition, or the development of a new service-orientated customer value proposition.

On the other hand, some projects address what could be described as 'soft' issues – for example, relating directly to people in the workplace. Here, the same validation, testing, implementation and evaluation stages are also applicable. As an example, and in this case directly contextually relevant to workplace diversity, an approach to successfully form cross-cultural, global virtual teams. These types of projects also are implemented (or at least implementable sometime in the future) within the student's organization and therefore have to potential to make a real impact. Interestingly, both 'hard' and 'soft' business issues, are addressed by our students enrolled in Master's of Engineering programmes (and equally so in Master's of Business Administration studies).

Prior to the research project, the student first learns the research skills that provides them with the tools to engage in their thesis research. The intention is to provide the student with competences to engage in any robust, evidenced-based (e.g. Pfeffer & Sutton 2006) RDI project. Hence, the thesis project offers the organization a return on their 'investment' in permitting their employees to engage in a master's programme.

Continuing this line of thought, the second benefit of the Master's studies that the student can offer in this mutually beneficial relationship with their employer is the personal development and competences developed during the programme. In addition to knowledge acquired through study of subjects such as, Leadership, Strategy, and Finance and Accounting, additional transferable skills, for example, presentation, argumentation, evaluation, and teamwork contribute to the growing set of RDI competences (issues promoted in CDIO's vision statement).

DIVERSITY MANAGEMENT

Diversity can be seen as richness in an organization. It is a significant contributor to the creation of new knowledge. Diversity Management (DM) includes policies and actions which create an organizational culture where justice and productivity go hand in hand. Each member of the organization can feel included and respected as an employee, colleague, team member, or in another role. If properly designed and implemented, DM can bring about desirable improvements in workplaces. Some companies seek differentiation and competitive edge, some expect diversity and inclusion policies to result in higher ROI of human capital.

In the business /organizational context (and beyond) diversity is frequently perceived as a topic that relates to addressing injustice and inequality – making good injustice (sometimes relating to historical injustices but also currently inequalities). What immediately comes to mind are issues around race and ethnicity, gender, age, religion, disability and sexual orientation; all areas that over the last five decades have been the subject of legislation to redress inequality.

But another strand to diversity relates to those who, in simple terms, can be said to think and behave differently (so-called cognitive or behavioural diversity). Organizations tend to recruit and retain workers who 'fit'. The need to fit the job (person–job fit) is easy to understand; having the competences to undertake the work. The other aspect of fit is person–organization fit. While organizations rightly need to know that employees are aligned with the organization's vision, the danger here is that this results in the eradication of difference, resulting, for example in conformity and groupthink (Janis 1972). As researchers have frequently described, this leads to inertia and stifles innovation **(**Van de Ven, 1986**)**. As Meyerson and Scully (1995) have vividly articulated, organizations need to embrace difference, and permit employees to be critical of the status quo as these employees are a catalyst for change.

> *Tempered radicals, are individuals who identify with and are committed to their organizations and also to a cause, community or ideology that is fundamentally different from, and possibly at odds with, the dominant culture of their organization.* (Meyerson & Scully, 1995: 586)

By embracing diversity organizations are able to release (and exploit in the most positive sense) the talents of those who have been previously held back. As Christine Largarde, ("What If Women Ruled the World?" 2013) Managing Director of IMF, states:

> *Diversity is absolutely an asset. With diversity you bring different ways of looking at the world, different ways of analyzing issues, different ways of offering solutions. The sheer fact of diversity actually increases the horizon and enriches the thinking process, which is critical.*

INTRODUCING AND IMPLEMENTING DIVERSITY PROGRAMS

In the context of diversity and students' RDI competences developed in the course of their Masters programme, we focus particularly on the development and application of an diversity assessment tool, applied thesis research that focus on diversity-related topics addressing current challenges in the workplace, and on a Diversity Management course.

Diversity Management Assessment Tool (DiMa)

Combining Diversity Management content to relevant R&D methods and tools, students are equipped to act as change agents in bringing diversity to better use in work organizations. The Diversity Management Assessment Tool (DiMa) developed in a nationwide project in 2015 serves as an easy yet valid starting point: a current state analysis can be carried out using this tool. Later, upon completion of certain diversity and inclusion programs and activities, the outcome (change) can be measured using the same tool.

An extensive review of the DiMa tool development was authored by Matinheikki-Kokko (2015). DiMa is a quantitative measurement tool for assessing the strategic approach taken and the operational practices existing in an organization in relation to Diversity Management. The focus is on both assessment and analysis on the organizational level rather than the individual level. The DiMa tool can, however, also be used for the latter, if desired.

The aim of Diversity Management in the organizational level is to create a working environment, in which people can use their competences fully to achieve the goals of the work community and organization. In the assessment, we are interested in finding out how diversity is reflected in the organization's strategies, contents and approaches, and how the strategy is linked to the operative policies and practices. (Matinheikki-Kokko 2015, 57).

From the individual perspective, one's personal growth and development can be supported with Diversity Management. Do these individuals support diversity in their own work? Quite often, the management's view is different from the views and perceptions of the personnel.

The DiMa tool is able to capture these differences in opinions and presents an interesting point for further development, if so desired. (Matinheikki-Kokko 2015, 57).

The pilot phase of the DiMa tool development took place in the context of HEIs in 2015. The DiMa tool is currently being piloted in company environments and it will be brought to wider use in Master's education in autumn 2016.

Diversity & Inclusion Projects of Master's students

Research-based development, specifically action research, is a recommended approach for Master's Theses conducted in Master's degree programs at Finnish universities of applied sciences. The Master's Thesis is the most significant single part of studies, 30 ECTS, thus counting for a half or a third of the whole degree program.

As we earlier describe, the student's thesis is a meaningful research project that aims to address a contextually relevant business challenge within the student's workplace. For example, diversity management interventions are launched for developing, testing and piloting. Some lead to remarkable results as Master's Theses, while others pave the way for policies and programmes that need more time to show measurable impact. The strength of the research project is that it establishes a key set of RDI competences that both serve to explicitly address a real business challenge and future 'in house' or consultancy improvement projects. Students do not aim to improve or contribute to theory, but engage in applied research with the aim of developing contextually relevant solutions to the issue at hand.

In preparation for the research the student first acquires research skills; as we describe above, in their own right these are crucial DRI competences that can be utilized for any 'good' piece of internal project work that aims at change management or continuous improvement within the workplace.

In terms of process, having identified a general business challenge (usually in conjunction with their manager) most frequently a student engages in a current state analysis (CSA) in order to gain in-depth knowledge of the issue. Here, if appropriate, we might expect the DiMa tool to be employed as it can help in identifying the focus areas for DM development. From here they can then engage with relevant theory – or as we prefer to call it existing knowledge (capturing theory, contemporary ideas, and best practice) – which brought together offer a conceptual framework that serves to create the solution. This approach helps to ensure that the proposed solution has relevance to the specific issue within the firm rather than a generalizable solution that is more appropriate to theoretic explanation.

In case of Diversity Management topic area, Master's Thesis projects can also be conducted for partner organizations other than for students' own employers. The project may rely on development needs recognized by HR professionals or managers of a company.

"What can be achieved?" Changes in the way of thinking and in skills of perceiving diversity can most likely be seen. The potential ways of inclusion that are appropriate in the organization as a result of agile pilot projects in specified HR or other areas are expected to lead to rapid improvements. More profound changes in the operative level, let alone changes in the organizational culture - e.g. a proactive strategic approach - requires a longer time. This is where one of the benefits of this particular student group comes into play: Master's students who study alongside their work can keep on working and promoting Diversity Management also after they graduate! The impact of the RDI work done during the studies ideally continues and contributes to the goals of the organization also in the future. (Turunen 2015)

Developing Diversity & Inclusion Knowledge in Master's Students

Students enrolled on HMUAS Master's programmes come from diverse work organizations and are themselves internationally diverse. In addition to their core learning courses students may enrol on a Diversity Management course, and many chose this option in attaining their overall required ETCS credits.

An interesting facet of this course is that it recognises that the diverse group have much to 'bring to the table'. As Collins (2015) observes, "…*most of them are 'mature students' with considerable work and life experience – [they have] an opportunity not only to study the subject [….], but also to actively engage in the various topics and contribute by recounting their own experiences of working in Finnish and global organizations. Indeed, opening up their experience is crucial to the success of the course because it provides diverse real and relevant context*."

This means that not only do students receive traditional lecture-based learning of 'theory' – in other words, well-known key academic ideas/ concepts and recent research/ contemporary thinking – the course explicitly gives space for the life experience of students, that is, it hears the students' voices. Their experience and the real 'struggles' around diversity that they meet in their personal and work lives are more contextually relevant than teacher-selected case examples

Knowledge then emerges from co-created learning that blends theory, and the experiential learning (e.g. Kolb 1984) that students bring, reflect upon, and share with their cohort. It is in reflective practice (e.g. Schon 1983) that theory, context, and experience are drawn together, and which brings about learning that is relevant, practical and provides meaning to students and helps them make sense of issues of diversity in their workplace.

CONCLUSIONS

In this paper, we examine and discuss the RDI competence of students in the context of Master's education at Finnish UAS's. We first examine the issue in the general context of the Master's undertaking (at HMUAS) and then more specifically when promoting diversity and inclusion in workplaces. We describe how students develop a set of competences that enhance RDI which are not only at the heart of any successful change project in an organization but also central to the kind of personal development that has in impact on their organization. This provides them with a set of transferable skills that enhances their career opportunities and opportunities to make a meaning mark within the organization.

In this regard, we illustrate that students can promote understanding of diversity in workplaces through the introduction and implementation of diversity tools, diversity-directed applied research projects, and diversity learning programs to achieve the benefits attached to this increasingly important area of
management.

As Timonen and Turunen (2015) describe:

> *There is so much unused or unrecognized human potential which Diversity and Inclusion Management can bring to the surface. When understood, recognized, appreciated, and, finally, utilized for the benefit of an individual, a team, as well as the whole organization, a favourable flow of development can be seen.*

Nurminen et al., (2015) divide the innovation competence of a student into four parts: creative problem-solving; communication and networking across professional groups; multidisciplinary analysis, as well as goal-orientation. In projects where Master's students are key actors of Diversity Management, all of these competence areas are developed.

These competences nicely match three (of five) of the fundamental education objectives set out in the CDIO vision, namely:

- Rich with student design-build-test projects
- Integrating learning of professional skills such as teamwork and communication
- Featuring active and experiential learning

Moreover, they are aligned with CDIO's stated '*premise that engineering graduates should be able to: Conceive – Design — Implement — Operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products'*.

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EARLY INNOVATION PROJECTS: FIRST EXPERIENCES FROM THE ELECTRONIC ENGINEERING LADDER AT NTNU

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ABSTRACT

Ideas and experiences are shared on using project work for an external partner during the first two years of a study program in electronic system design and innovation. Challenges and possible solutions are discussed and a case is described in more detail. The initiative was started in 2014, so a full cycle of the approach has not yet been carried out. Experiences reported are thus somewhat preliminary, but indicate that students find working with real-world problems highly motivating. Important findings include that measures must be taken to counter variability of skills and interests among the involved students.

KEYWORDS

Electronics, project, innovation.

INTRODUCTION

It is generally agreed that some kind of project work should be included in an engineering education program (see e.g. Zhou, 2012). The amount of this mode of learning and at what stage it is introduced varies from institution to institution.

At the study program *Electronic System Design and Innovation (ELSYS)* at the Norwegian University of Science and Technology (NTNU) students are given a project early in the first semester that they will conclude in the fourth semester of their education. Moreover, the project is defined in cooperation with an external partner. A new partner with a new project is assigned for each class. We call it an *innovation project*, as it aims to solve a real-world problem for a specific problem owner. In the following we will discuss intended outcomes, challenges and solutions with this approach.

The approach is incorporated in *the Electronic Engineering Ladder* (Larsen & Lundheim, 2014, Lundheim & al. 2015), which is an integrated sequence of four courses during the first four semesters of the program. These courses are taught by a team consisting of 4-5 teachers accompanied by a number of teaching assistants. Presently, the team is identical to the authors of this paper. The first class of the program started in the autumn of 2014 and their innovation project will be fulfilled in spring 2016. The present paper is written before the finalization date, and reports experience gained so far.

MOTIVATION AND INTENDED OUTCOMES

One of the main motivations to introduce project based learning at an early stage, is better to motivate the students to learn the more theoretical fundamentals necessary to become a successful engineer. The motivational aspect is reinforced by choosing a real-world problem by an external partner. The stipulated outcome is that students will be well suited to adapt technical knowledge and skills to both technical and non-technical problem areas and customers.

CHALLENGES

We have identified three main challenges that have to be addressed in order to secure a positive outcome.

1. An obvious challenge with a first semester project is that most students are still technical novices at this stage. That is, focus has to be on how to formulate a project in such a way that the students can, based on their level of technical knowledge and skills, start studying possible solutions to the problem presented by the external partner.
2. How to ensure that the chosen problem allows and points towards solutions that support intended learning objectives of the study program? This includes how to ensure that the project based teaching builds up under the theoretical skills to be acquired. Especially, how to relate to the wide range of skills and personalities within a class, and how to properly compose functional groups where all members get activated and have a good learning experience.
3. How to fulfill the challenges above, and at the same time generate a project with an outcome that is useful for the external partner?

SOLUTIONS

To meet the challenge of putting novices to a real engineering problem, one important measure is to set up a progressive project organization. The teacher-team is responsible for that, and it has been addressed by dividing the project into two well-defined parts. The first stage is performed during the first semester, while the students are following courses in mathematics, circuit theory and computer science in parallel. The second stage is undertaken in the fourth semester, at which time skills and knowledge have been significantly improved enabling them to finalize the project for the external partner.

In the first stage, low-threshold problem solving technology is used to enable the students to realize their ideas. For this purpose we have chosen the Arduino Uno together with sensors, actuators and components that are easily interfaced with this platform. All student activity during this stage is concentrated on one full day each week. Students work in groups of six, and the day is structured with guest lectures and student presentations such that group work typically occur during two sessions of 2-3 hours each during the day. Using the Arduino is learned during the first weeks of the course by examples taken from a text book (Fizgerald & Shilo 2012). No formal teaching of programming is given in the course; it is assumed that the students should acquire sufficient skills from working out the problems in the text book and from the actual problems originating from the project work itself.

The challenge of obtaining well-functioning groups has been met in two different ways. For stage 1, we use a questionnaire surveying interests and previous experience among the students. Groups are then composed with the aim of securing diversity. During the first weeks, where activity is centered round learning the technology platform, students who finish assignments early, are encouraged to help the less skilled (peer instruction).

For stage 2 we use a matrix organization where each student is part of two different types of groups. Each student is given a predefined responsibility within a *group specific project*. Students with the same responsibility area form *expert groups*. An example of how this can be done is given in the case study below.

Finding good external partners and problems is a task that can only be solved by planning ahead. We start considering possible ideas at least a year before a class is started. Using our network, we discuss two or three different possibilities. Usually more than one alternative may be suited. Six month before start, we choose the one partner that seems most promising and continues the dialogue in order to find a problem formulation that is both relevant for the partner and likely to produce intended learning outcomes. It is important that the teaching staff involved is well acquainted with syllabus and skills that can be expected from the students during the project period.

A CASE

The first class of the Electronic Engineering Ladder was enrolled in 2014 and at the time of writing, the partner for the class starting in 2016 has recently been chosen. A summary of ongoing and future projects is given in Table 1.

Table 1 Innovation projects for the three first Elsys classes.

Project start	Project end	Partner	Topic
Autumn 2014	Spring 2016	Kystlaget Trondhjem (see below)	Vessel surveillance
Autumn 2015	Spring 2017	Vitensenteret i Trondheim (local Science Center)	Interactive exhibition models
Autumn 2016	Spring 2018	Adresseavisen (local newspaper)	New modes of interactive communication.

In the following we will describe in further detail the project for the first class, who is in the middle of the second stage of their project at the time of writing.

The partner for this group is *Kystlaget Trondhjem*, a society of owners of antique boats. The partner needs an inexpensive surveillance system for monitoring the state of a vessel and giving the owner an alarm on his mobile phone when a potential unwanted condition occurs. The owner can then open a web page to inspect a log of temperature, humidity, motion, etc. of his vessel.

Organization

During Stage 1, the students met with the boat owners. They inspected the vessels and got acquainted with peculiarities and special needs. They then started experimenting with various types of sensors connected to the Arduino platform. Realism was not given priority at this stage. Rather, the aim was for the students to get some experience with the technology and problems involved. The course was completed with a one-day conference where project results were presented in talks, posters and demonstrations.

Stage 2 takes place after the students have had several additional courses in circuits and systems, programming, computer architecture, mathematics and physics. Contact has been established with six different boat owners, who cooperate with the students in specifying and developing a solution for their vessel. The students are divided in six *boat groups,* each responsible for the successful development and installation of a surveillance system for a particular boat. Hence, there will be different requirements and solutions for each group.

In order to secure sufficient competence in each boat group, and to stimulate involvement from all group members, seven *expert groups* have been defined as listed in Table 2.

Table 2 Expert groups

Expert group	Responsibility
E1: Sensor system	Sensor solutions dependent on specific needs for various vessels.
E2: Detection system	Algorithms and parameters for sampling and processing of sensor signals for detecting anomalies and giving alarms
E3: Communication system	Securing communication between vessel installation, server and boat owner.
E4: System integration and project management	Overall responsibility for a functioning system at the end of the semester.
E5: Physical integration and installation	Power supply, encapsulations, PCB, cabling and installation on vessel.
E6: Implementation platform on vessel	Microcontroller platform and programming.
E7: Data base and user interface	SW on server and application software at user.

Each boat group will have at least one member in each expert group. Meetings are held alternately in boat groups and expert groups according to the following scheme:

1. Boat groups meet and discuss problems and solutions.
2. Open problems are taken to the respective expert groups.
3. Problems are brought up in the expert groups and solutions are compared and discussed.
4. Shared experiences and solutions are brought back to the boat groups.
5. The sequence is repeated.

For each expert group an advisor is appointed. This is one of the teacher team or a member of the Department's technical staff.

The weekly schedule for the course is organized with two for hour sessions. Some weeks these sessions are used for group work without interruption. In other weeks, in particular at the beginning of the semester, plenary meetings in auditoriums are held. During the first weeks the following plan was used:

Tuesdays
0815: All meet in an auditorium. Information is given and plans are discussed. This session is led by a teacher.
0900: Work in boat groups
1200: End of session

Wednesdays
1215: Students meet in expert groups. As these meetings finish, boat groups continue project work.
1515: All meet in an auditorium. Results are presented and discussed. This session is led by students (Expert group 4).

Documentation

Written communication skills are an important part of any engineering education. In the innovation project we emphasize that all written communication should serve a purpose and the documentation style should reflect this purpose.

Three types of documentations are required.

1. In order to make each boat group able to find a good solution for their vessel, it is important that they have the best possible knowledge of available technology and methods. Ideas discovered by one group will often be relevant for others. To obtain this, each expert group maintains a Wiki page containing relevant information within their field of expertise.
2. In order to aid future modifications and repair, the installed system should be documented by a technical report. Each boat group is responsible for preparing this report.
3. An easy-to-read user guide must be written for each installation must be provided. This document should be readable to persons with no technical background.

Assessment

Each student is given a pass/no pass mark. To pass the course, three requirements must be met.

1. The student must attend and actively participate in his/her boat and expert group.
2. The Wiki page of the expert group in which the student participates must be approved.
3. The technical report and user guide written by the student's boat group must be approved.

The students are actively engaged in the assessment. Monitoring of attendance is taken care of by each group. If a student fails to fulfill his/her responsibility, the teacher team is contacted by the group. A warning may be given to the student in question. Moreover, the expert groups' Wiki pages are assessed by the boat groups.

The teacher team gives feedback to drafts of technical reports and collects comments from boat owners on the user guides before final assessment of these documents are given.

EXPERIENCES

As a complete cycle of an innovation project is not yet completed, in the following we will mainly concentrate on experiences from the first stage, i.e. from the autumn semesters of 2014 and 2015. The discussion is based on personal experiences of the staff, formal and informal meetings with students and a student questionnaire given at the end of the semester.

The main feedback from the students is that working with the Arduino platform is *fun*. In particular, they seem to appreciate the hands-on experience this gives as a supplement to the circuit theory course they have in parallel. The extent to which students actually gain command of solving problems by programming the platform varies considerably across the class. An unintended outcome of this is that during the project work, much of the actual design and coding is left to the most skilled students, and some group members become passive. The use of expert groups in the second phase of the project seems to have reduced the problem of passive students considerably.

Working with a real-world problem for an external partner seems to be very motivating. Asked whether they rather would have a (safer?) school-defined project, none of the respondents answered affirmatively. 18% said it did not matter, while 82% said working for an external partner was important.

An important experience is that in both classes so far, all groups have actually been able to present *some* solutions to the given problems at the end of the first semester. Assigning the presentations of these solutions to an open conference is motivating, and positive feedback from audience has been encouraging for the students.

In this first stage, the students sometime show a slight frustration over not being able to realize all their ideas. This is not a bad thing, as rightly addressed it motivates them for learning those skills in the following courses.

Ending each project day with presentations from selected groups has been quite fruitful. Aside of training students to address an audience, it serves as a means of exchanging ideas and getting feedback from peers.

As mentioned, it is early to sum up experiences for the second stage of the innovation project for the first class. At the time of writing (February 2016), all boat groups are engaged in design and preliminary test of subsystems. The matrix structure seems to have made the activity level more uniform among the group members.

FURHTER PLANS

An important issue to be addressed is the variable involvement within some of the groups due to different levels of skills among the students, in particular with respect to programming. Measures that are under discussion are

- Extending the introductory first weeks to secure better familiarity with programming.

- Using a more diversified approach during the first stage where special attention can be given to students who need it.
- Supplement learning from examples with more formally organized teaching of programming.
- Better organizing of peer instruction.
- Organize the project work in such a way that non-technical tasks become more explicit and appreciated. Thus, students with a lower technical command can both be activated and experience that their effort is important.

The composition of functional groups is a challenge both for the first and second stage of the innovation project. Using personality tests may be a useful tools (Sæbø, Almøy and Brovold, 2015). Some initial trials of this has been done in composing the boat groups in the case described above, and this work will be further developed based on experiences gained during spring 2016.

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FLIPPED MATH, LESSONS LEARNED FROM A PILOT AT MECHANICAL ENGINEERING

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ABSTRACT

At the University of Twente, all bachelor programme curricula are organised as thematic modules with a project and several courses. The courses offer students knowledge and skills that can be integrated and applied to design a solution for the problem presented to them in the project. A 'just-too-late' teaching model is applied, meaning that knowledge is offered to students a while after they encounter challenges and problems in the project, so they will first try to come up with their own solutions. For most courses this model is working well. For the math courses this is somewhat more difficult, partly because it is a general course offered to all engineering and science programmes at the same time.

To create more flexibility in the timing of the math courses and to get students to engage in the subject matter earlier and more actively, a flipped classroom setting was designed including diagnostic tests and repair sessions. A pilot is conducted to test this setting in which 102 students participated.

The pilot was evaluated by classroom observations, interviews, surveys at different moments during the course, analysis of Blackboard log files and a panel discussion. After the first weeks, participation during lectures and diagnostic tests dropped dramatically. The pass rate of the course was 66%, compared to 80% in previous years. Evaluation results showed that a substantial part of the students was not actively involved in the self-study activities from the beginning of the course and that active class participation dropped further during the module. Also some positive effects were reported by students engaging more actively with the subject matter and gaining better insight.

A set of recommendations was made for improvement of the flipped classroom setup focussing on stimulating and retaining active involvement of students.

KEYWORDS

Flipped classroom, Math Education, Active Learning, Student Engagement, Standards 2, 3, 8 and 10.

INTRODUCTION

The University of Twente is research intensive university with approximately 9.500 students and 3000 staff members (support and academic). While the university is known as a technical university and a member of the 3TU federation (http://www.3tu.nl), non- technical programmes like communication science and business administration are also part of the university's offer. Between 2010 and 2015 the three technical universities in The Netherlands have engaged in a major bachelor innovation (Gommer, Klaassen & Brans, 2015). The University of Twente chose to implement a new educational concept bearing a large resemblance to the CDIO concept; the Twente Educational Model (TEM, 2016). Following the educational model of the engineering programmes, where thematic project education has been the leading educational model for many years, all programmes were divided into thematic modules of 15 ECTS (1 quartile). The core of every module is a design or research project where students work in groups to solve a complex problem. Theoretical courses as well as practical workshops are offered to students to provide them with the knowledge and skills needed to approach the problem. A 'just-too-late' teaching model is applied, meaning that knowledge is offered to students after they encounter challenges and problems in the project, so they will first try to come up with their own solutions.

The aim is to make all modules 'Student Driven', meaning that the focus is on active learning methods and on enabling the student to be responsible for his or her own learning process by offering choices in content as well as working methods and stimulating active study behaviour. At mechanical engineering explicit attention is paid in the first two modules on study skills and reflection to support students in their development towards self-directed learners.

For most courses this thematic approach with 'just too late teaching' works quite well. The theory is integrated into the project stimulating the students to actively engage in the course content when it's needed to contribute to the design or the research project.

For the math courses this is somewhat more difficult. One reason is that math is a general subject offering students the basic skills for design as well as research, but the direct application to the project is not always clear. Also, in the TEM educational model, math education is included as a general learning theme with courses offered to all engineering and science programmes at the same time. However this being very efficient, the result is that there is not always a match between the project and the math topics covered in the same module. In some cases the math content offered differs from the math that is needed to complete the project. In other cases there is a match between content and project, but there is a mismatch in timing (e.g. topics are offered in the math course when the project-phase in which they are needed has already ended).

At the mechanical engineering programme, the problems of non-matching content and timing were experienced in several modules. In some cases extra math explanation was needed for students to complete the project. Also, a tendency exists to postpone studying math content until right before the exam because there is no stimulant coming from the project to dive into the material earlier.

To create more flexibility in the timing of the math courses and to get students to engage in the subject matter earlier and more actively, a flipped classroom setting (De Boer and Winnips, 2015) was designed including diagnostic tests and repair sessions. The question we aim to answer in this paper is:

Does this flipped classroom set-up help students to engage in the subject more actively and obtain a better understanding of the math subject?

The method section describes the flipped classroom set-up as well as the methods and instruments used to evaluate the pilot. In the results section student and teacher experiences and pass rates are reported.
In the final section, a conclusion is formulated, supplemented with recommendations for improvement of the flipped math set-up.

METHOD

Set-up of the pilot

The pilot took place during the math course in the fourth quartile of the first year mechanical engineering programme. The thought behind this was that if successful, the flipped classroom approach could be more broadly implemented with the new students starting the programme in September.

In its original set-up, the math course has a duration of 6 weeks with one lecture a week for all science and engineering students and a weekly tutorial at programme level. Students are assessed by means of two exams, one half-way through and one at the end of the course. Both exams deal with different topics. A digital learning environment (Blackboard) is used to provide students with the necessary information. ‘MyLabsPlus’ (from Pearson publishers) can be used by students to practice with the course content.

In the new set-up (see figure 1), students do not attend math lectures, but instead work at home, orienting on this week’s topics, supported by learning materials placed on Blackboard. Every week, the lecturer places a structured document on Blackboard for every topic that is covered during that particular week. This document contains an explanation of the topic, practice assignments and (where possible) references to the math book and to short instructional videos on YouTube where topics are explained in more detail or from a different angle.

By following the instructions in the self-study document, students could prepare for the different topics independently. Any questions the student might have on the topic could be taken to the question hour on Wednesday morning. The aim of this meeting was to give students an active role and give them the opportunity to learn from each other and from the questions and explanations from fellow students.

The question hour was followed by a tutorial where students work on assignments in the book with supervision of a lecturer from the math department.

Instead of the summative in-between tests in the original version, a diagnostic test is scheduled on Thursday’s. By participating, students would receive feedback on their progress and understanding of the subject matter and also get acquainted with the way of working towards the solution of the math problems. Right afterwards, the diagnostic test was discussed by the lecturer in dialogue with the students. The week was concluded with a so called ‘repair tutorial’ where students could work on the topics that they didn’t do well on during the diagnostic test and receive some extra explanation from the lecturer.

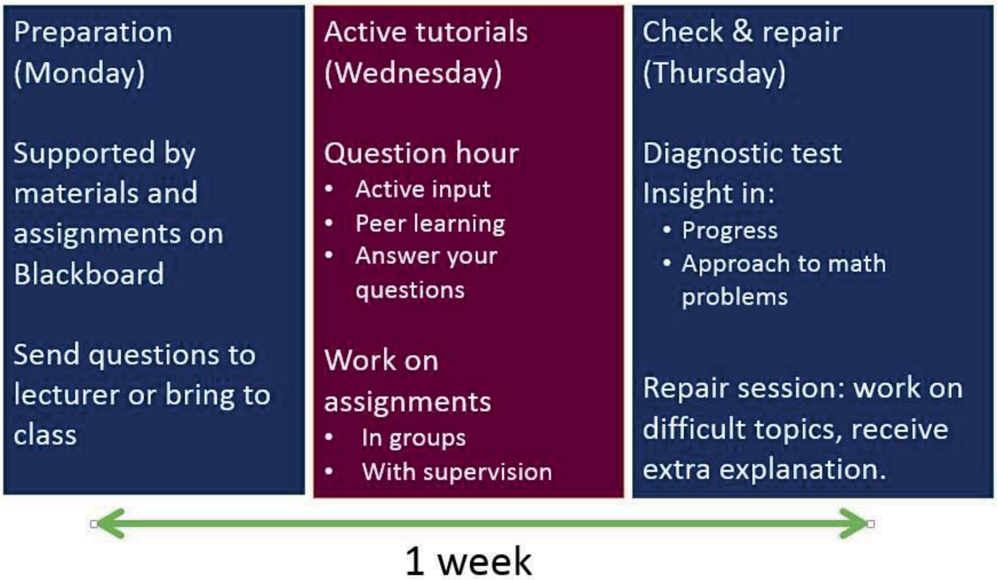

Figure 1. Weekly structure as presented to students

Evaluation of the pilot

102 students participated in the pilot setting. The pilot was evaluated in different ways. First of all, an educational advisor from the centre of expertise in learning and teaching attended several different meetings of the math course to observe attendance and active participation of students, the amount of interaction in the classroom and teacher behaviour. Information from lecturers was collected through evaluative discussion and email to determine their experiences with the flipped-classroom set-up and students' reactions to it.

At three times during the course, a survey was conducted with students; at the beginning of the module during the first meeting, half way and at the end of the course. The survey contained both open ended as well as closed questions about attendance to and appreciation of different components of the flipped classroom setup, expectations about the course and the degree of difficulty, etc.

In Blackboard, log files were kept of the frequency and timing of student access to the materials for preparation of the topics. These log files were compared to students' test results.
After the course a panel evaluation was held with four students to elaborate on the survey results and discuss their experiences with the flipped classroom setup.

RESULTS

Observations and attendance

What was noticed during the first question hour is, that response from students was low, even though it was clearly announced that the lecture would be given based on questions coming from the students. After putting in some effort, the lecturer managed to attain some interaction with students and to get some students to demonstrate solving a problem in front of the classroom, but this remained difficult, also during later question hours.

Attendance during the question hour and tutorials was 65% during the first three weeks, dropping to 30% during the last week. Attendance at the diagnostic test was low from the beginning (approximately 35% during the first three weeks). Halfway the course the diagnostic test was moved to the end of the week (after the repair tutorial) because students indicated that they needed more time to prepare for the test and practice with the subject matter. Despite this switch attendance continued to drop to only 3 students attending the last test.

Students indicated that exams from parallel courses and exam resits from the previous period interfered with the math course, a possible cause for the attendance-drop during the last three weeks.

Blackboard log files

The decline in attendance was not reflected in the amount of activity on the Blackboard page of the Math course. When looking at the amount of 'views' of the relevant Blackboard pages, students who are active on Blackboard remain active during the second half of the course with an increase of activity during the last week before the math exam. What is not visible however, is if students are still working according to schedule or if they are falling behind. Also, it is not visible if the nature of the activities changes. Are students still working on the practice assignments or do they just read through the document?

When the amount of activity on blackboard is compared to the final course grade, a positive correlation is found of 0.23, sig < 0.05 (Figure 2). The average number of views of the math folder on Blackboard of students with an insufficient final grade (≤ 5.4) is 99. The average number of hits of students with a sufficient grade (≥ 5.5) is 169.

Figure 2. Number of views of the main folder on Blackboard compared to final grade

Evaluation

During the course, three surveys were conducted at the start, halfway and at the end of the math course. The number of respondents declined from 64 filling in the first survey to 30 filling in the third one (parallel to the decline of attendance during the lectures).

Start survey

65% of the student population participated in the start survey. The basic attitude towards math and the confidence in their math skills is on average high: 80% of the students say they

generally are good in math. 67% say they like doing math. Expectations on how much fun the course will be are not very high. Average score (on a scale from one to 10) is a 5.9.
When asked what they expect not to like about the course, 16% comments on the expected workload and time investment the new setup will ask for. 13% comments on the flipped classroom setup in general.

On average students expect to obtain a 6.6 as a final grade for the course. Only 4 students expect an insufficient grade.

Midterm survey

Fifty percent of the students participated in the survey halfway the course. Looking at attendance, the tutorial on Wednesday had the highest attendance rate. 63% of the respondents indicate that they have attended all three tutorials. The diagnostic test on Thursday had the lowest attendance. Only 25% of the respondents indicated that they participated in all three tests.

The majority (74%) of the respondents indicated that they did work on the self-study assignments; 39% of the respondents made all assignments, 35% did part of the assignments. Students that did not do the assignments indicated that they preferred the assignments at the tutorials or that they did not need the self-study assignments to understand the subject matter. Most students (63%) did not use the instructional videos. The main reason was that students did not need the videos to understand the subject matter.

Some statements were presented to students about the usefulness of the different components of the new setup and about the flipped classroom concept as a whole.

Table 1. Statements on usefulness of the flipped classroom concept

Statement	**Negative (%)**	**Neutral (%)**	**Positive (%)**
The text in the self-study documents were clear	17	20	63
The assignments helped me to understand the subject matter	20	13	67
The videos helped me to understand the subject matter	25	45	30
The question hour on Wednesday was useful	13	25	62
The tutorial on Wednesday was useful	4	11	85
The diagnostic test gives me a good insight in the subject matter	15	25	60
The discussion of the d-test is useful	11	23	66
The repair tutorial is useful	25	30	45
I like the flipped classroom setup	45	22	33
The new setup help me more than the traditional setup	40	33	27
I would like to have more math courses offered in this setup	42	27	31
I would like to follow other courses besides math in this setup too	56	31	13

Noticeable is that most students are positive about the separate components of the new setup (with the exception of the videos), but that the flipped classroom setup as a whole is appreciated much less. What also stands out is that two third of the students is positive about the usefulness of the diagnostic test and the discussion while this was the component with the lowest attendance (25% attending all three tests).

Students were asked what they liked about the new math course setup. Most mentioned answers were:
- Being more actively engaged in the subject matter (24%)
- Gaining more insight in the subject matter (20%)
- Working independently / freedom to work at your own pace (20%)

These correspond with the aims of the pilot as described in the introduction paragraph.
What students did not like about the new setup was:
- Having to do / find out too much by yourself (24%)
- Workload, pressure to keep up with the pace (17%)
- Absence of lectures (14%)

During the oral discussion after the evaluation students added that they did not like to have the diagnostic test before the second tutorial because this gave them too little time to work on and master the subject matter. After the midterm evaluation this was altered.

End survey

Thirty students participated in the survey at the end of the course (before the exam). As an answer to the question what was learned during the course, most students (76%) give a math content-related answer, 24% of the students say they have learned something about planning and working independently.

When students are asked what they like about the course, 36% give a content-related answer. Half of the respondents mentioned the new setup or an element from the new setup.
As an answer to what they did not like, 43% of the students mentioned the new setup, 26% specifically mentioned the absence of summative in-between tests.

The expectation regarding the grade that will be obtained has remained the same (6.6 average). Only two students expect to obtain an insufficient mark. This strongly disagrees with the actual pass rate.

Pass rates

In week 4 a test exam was offered to students, covering the first part of the course content. 56 students participated in this test. Only 9 students obtained a sufficient mark. The lecturers indicated that students did not seem worried about these results when they were announced in class. Their impression was that students did not take the test exam very seriously and that many students were not on schedule studying the subject matter.

After the math course, the summative exam took place, covering all course content. At the first attempt 48 mechanical engineering students obtained a sufficient grade (≥ 5.5). This sets the pass rate to 47%. At other programmes, the pass rate was considerably higher (60%) while usually mechanical engineering students have comparable to slightly higher math scores than students from other programmes. After the resit, the pass rate rose to 66%, compared to a pass rate of 80% last year.

Panel discussion

A discussion was organized with four students. Final grades of these students varied from 4.5 to 6.8 on a 10-point scale. Two students attended all types of lectures, two only attended the tutorials. Two students indicated that they made all practice assignments on Blackboard. One student only looked at the documents but didn't make the assignments. One student tried to make the practice assignments but did not always succeed in finishing them before the tutorial. About the question hour students indicated having low expectations of the amount of input and interaction that would come from fellow students and therefore they questioned its usefulness. Suggestions for improvement are: smaller groups (30 – 40 students), give students a more active role, less open setup to help students to start up, look at the pdf's together.

The video materials were not used a lot because the subject matter was clear to these students. What students liked about the new setup was the independence, the weekly documents on blackboard that made them dig deeper into the subject matter and the diagnostic tests.

The main point for improvement mentioned was that there was too little time to finish the weekly practice assignments. The documents on Blackboard were appreciated but cost a lot of time to work through. Less subjects in the weekly documents would appeal more to students.
About the low attendance at the diagnostic tests the panel students think this is caused by the exams from other courses on Friday and students feeling it's not useful to do the diagnostic test when they are behind on studying the subject matter.

When asked about the low percentage of students wanting this setup for other courses, the panel students indicate that they have a hard time imagining how other courses besides math could be carried out in a flipped classroom setting.

Finally, students reported to be surprised about the final grades. They did not attend the last diagnostic tests but had a good feeling about their mastery of the subject matter and expected a higher grade.

CONCLUSION AND RECOMMENDATIONS

Conclusion and discussion

Looking at the pass rates of the course we can safely conclude that the desired end result was nog yet attained. What was aimed at was, that the with the new flipped classroom approach students would engage in the subject matter more actively and dig deeper into the different topics to gain more insight in the subject matter.

Final grades show us that this is not the case. Pass rated are fourteen percent lower than prior years. Other programmes that followed the traditional setup with the same exam do not show this decline.

However, it also seems too early to write off this approach as a complete failure. Certainly during the first half of the course some of the students reported the effect that we hoped to see with all students. Students opened their books, searched actively for answers and indicated a better understanding of the subject matter.
What was disappointing was the lack of active participation during the question hours and the declining attendance during the tutorials and the diagnostic tests. Partly, this could be

attributed to students not being used to this independent approach to learning and weren't able to make the turn during the fourth quartile. The fourth quartile is typically a quartile in which motivation and student effort somewhat sinks in. This new approach based on self-responsibility was not taken up very well.

Noticeable was that attendance at the tutorials and the diagnostic tests dropped dramatically during the second half of the course, at the same moment the other courses in the module started their formal tests. A possible explanation is that a large part of the students stayed away because these assessments were prioritized over the diagnostic tests from the math course. Once fallen behind on the sturdy pace of the math course, it is hard to catch up again. Overestimation of oneself also seems to play a role here. Even after the very bad results of the first test exam, attendance at lectures and diagnostic tests did not improve as might be expected, but instead further declined.

Looking at literature, this effect is seen more often when flipped classroom settings are implemented (De Boer and Winnips, 2015). Students that do participate actively seem to benefit from the new approach, but the real challenge is to get (and to keep) students on board without imposing all kinds of regulations on students contradicting the self-responsible approach to learning we hope to evoke.

Recommendations for improvement

To improve participation in this flipped classroom setting without introducing measures like obligatory attendance or summative assessment or classroom preparation, several things can be done.

Integrated approach

In this pilot, the math course was given in a new setup with only diagnostic in-between testing. Other courses within the same module however, did not abandon their in-between summative tests causing unfair competition for the math course. Especially on Thursdays, students tended to stay away, because most summative tests were scheduled on Fridays. An integrated approach where all courses running parallel within the same period follow the same approach with regard to self-responsibility and in-between assessments will prevent courses from 'competing' with each other for student effort.

Ideally, an educational approach asking from students to work independently and take up responsibility for their own learning should not be part of just one or two courses but part of the programme's culture. By being clear to students about expectations regarding independent and active study behaviour and integrate this approach into all parts of the programme this will become the normal daily routine within the programme. To realize this, it's important that the concept is supported by all staff members.

Explaining the flipped classroom approach

At the start of the fourth period a short introduction was given to students about the flipped classroom concept. Evaluation results show that students are still insecure about what is expected from them in this new setting, causing some resistance to the new approach while separate components of this approach are appreciated. A better and more thorough explanation about why the flipped classroom approach works and how it works can take away some if these insecurities (De Boer and Winnips, 2015).

Smaller groups

A lot of students, especially during their first year at the university, find it hard to interact in a large group. Students hesitate to ask a question or share their ideas in fear of looking ‘dumb’ in front of their peers. Interaction often is limited to students sitting on the first two rows. Having a question hour in smaller groups (e.g. 30 students) could lower the threshold to interact.

Spreading study load

In the survey and the panel discussion students reported that the weekly schedule for the math course was quite full and that the workload was not equally spread over the weeks, making it hard to finish all the preparation assignments, especially during the first weeks. Once fallen behind, it’s hard to catch up and participation to lectures and diagnostic tests seems less useful when not all subjects have been studied yet. Relieving the workload a little could give students the possibility to catch up.

Development of instructional videos

Some students report to have a need for a (short) oral explanation of the theory before starting to work on the assignments. The videos found are not perceived as a satisfying substitute. Sometimes the quality of the video is insufficient. Also students like to see and hear someone from their own university, referring to specific pages in their math book, etc. What could meet their needs is to develop short instructional videos where the math lecturer provides students with an oral explanation on each topic.

Methods and tools supporting active preparation

Finally, several things could be done to encourage student preparation and participation in the existing set-up. Students could for example work in groups discussing a specific topic or assignment during the first part of the lecture. Then, during the second part of the lecture groups can be asked to give a short explanation to fellow students on ‘their’ topic or demonstrate the solution of a particular assignment on the chalkboard. Also online tools exist that support students in (collaboratively) preparing their classes or reading materials at home. The role of the lecturer as a stimulator of active learning and peer learning is essential here.

Flipped math 2.0

Based on these recommendations, several changes were made in the first year curriculum and the setup of the math course.

Exams and resits from other courses were moved to the math-free week in the middle and also towards the end of the module (after the math course) to reduce competition from other courses. Elements of the flipped classroom setup were introduced in math courses in the preceding quartiles. The effects and importance of active and self-responsible learning were explained and emphasized during the entire first year.

With regard to the math course itself, the group was split in two subgroups to lower the threshold for students to ask questions and stimulate interaction. The workload was spread more evenly over the weeks and the amount of self-study assignments was slightly reduced. Also, the diagnostic test was moved to Monday morning to give students more time to practice and process the weekly subject matter. During the question hour, active participation will be stimulated by placing students in small groups (3 to 4 participants) and presenting them with mathematical problems to solve together.

The course will run in the modified setup in the fourth quartile of this academic year (April - June 2016) en will be evaluated in the exact same way to allow for comparison of the results.

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3 Engineering Education Research

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INTEGRATING INNOVATION PEDAGOGY AND THE CDIO APPROACH – TOWARDS BETTER ENGINEERING EDUCATION

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ABSTRACT

The relationship between innovation pedagogy and CDIO (Conceive – Design – Implement – Operate) raises many questions. Are there common elements, or do these approaches conflict, or can they be integrated somehow? In this paper we discuss similarities and differences between innovation pedagogy and CDIO and how these approaches are interconnected. The objective of innovation pedagogy, developed at Turku University of Applied Sciences (TUAS), is to provide the students with innovation competences in order to enable them to participate in innovation processes in their future working places and develop them. In working life, different types of knowledge is needed in innovation creation and innovative solutions are created through collaboration of people with different backgrounds. Both CDIO and innovation pedagogy are developed and implemented in close co-operation with businesses and industries in order to answer to this challenge. At TUAS, the integration of the innovation pedagogy approach and the CDIO approach aims to provide diverse social and multidisciplinary learning environments and thus enhance the development of innovation competences. The research on integration opportunities of innovation pedagogy and the CDIO approach is described through CDIO standards in order to explore the similarities and differences in both initiatives.

The outcome of our discussion is that the CDIO approach and the innovation pedagogy approach can be integrated. They face similar challenges and share very parallel goals and objectives, and thus their integration can help engineering education to develop to the needed direction. The findings and the value of this paper extend the concept of knowledge in the learning context to support the development of innovation competences by integrating the CDIO approach and the innovation pedagogical approach.

KEYWORDS

Innovation pedagogy, engineering education, learning outcomes, innovation competences, integration, Standards: 1–12

INTRODUCTION

Clark (1998) writes that enterprising universities are those that actively seek to move away from close governmental regulation and sector standardization. An entrepreneurial university seeks to innovate how it operates and functions in its business (Clark 1998). Both the CDIO (Conceive – Design – Implement – Operate) approach and Innovation Pedagogy provide tools and framework to make that shift and differentiate in the higher education markets. In addition, successful universities will always seek to improve their performance in teaching and research (Shattock 2010). This continuous improvement is one of the key points both in CDIO and Innovation Pedagogy too.

The report of the Confederation of Finnish Industries (2011) emphasizes the transformation of society towards an information society where the capacity to work for new and improved solutions becomes crucial. Education has to promote creativity and adopt methods from working life: experimenting with others without the fear of making a mistake will be encouraged. Future education has to focus on skills in addition to knowledge and working in groups. Furthermore, versatile learning methods prepare students for the changing working life. The CDIO approach and Innovation Pedagogy both focus on these relevant and important issues in education. Since certain similarities exist it is interesting to discuss how these approaches or frameworks can be integrated. In our earlier research, it has been discussed from the pedagogical viewpoint (Penttilä & al. 2013) and from the communicational viewpoint (Penttilä & Kontio 2014) how the CDIO approach is interconnected with innovation pedagogy. The aim of this paper is to ensure wider understanding of the implementation, opportunities and challenges of the integration of these approaches for engineering education.

INNOVATION PEDAGOGY – THEORETICAL FOUNDATIONS

The core idea of innovation pedagogy is to bridge the gap between the educational context and working life. Learning and teaching processes are to be developed so that they provide improved competences for the students and enable personal and professional growth. Learning is deeper when previously gained knowledge is continuously applied to practical contexts. Creating new services, products and organizational or social innovations – new added value – requires both knowledge and skills, which are applied to an innovation process. (Kairisto-Mertanen et al. 2012; Gibbons et al. 1994; Kairisto-Mertanen, Penttilä & Putkonen 2010; Nonaka & Takeuchi 1995; Nowothy & Gibbons 2001; Nowothy & Gibbons 2003.) The approach can also be extremely useful when rethinking learning environments, which according to innovation pedagogy are social and multidisciplinary (Kairisto-Mertanen, Penttilä & Putkonen 2011). A learning environment is most frequently understood as the physical or virtual surroundings meant and built for learning purposes. In innovation pedagogy the social aspects of working and learning are emphasized and group processes where learning happens in multidisciplinary teams form an essential part of the whole process of learning. A social learning environment is formed by people with different talents and competences and by the interaction enabling collaborative learning. Equally, also the tasks in working life often require knowledge and skills which do not belong to the scope of a single discipline. (Penttilä & Kairisto-Mertanen 2011; Watts et al. 2012; Penttilä & Putkonen 2013.)

The core of innovation pedagogy lies in emphasizing interactive dialogue between the educational organization and students as well as the surrounding working life and society. Accordingly, its conceptual core can be divided, as Figure 1 describes, into three different spheres in parallel to the three major actor groups benefiting from innovation pedagogy (Penttilä et al. 2011):

• final learning outcomes, creation of innovations and produced capability to participate in diverse innovation processes – having primarily to do with students, who are expected to create innovations while affiliating with working life

• learning of innovation competences alongside with study programme specific knowledge, skills and attitudes – being mostly connected with working life, which provides students with ideal surroundings to acquire the competences needed in innovation processes and in future working life in general
• meta-innovations – referring to the necessary cornerstones needed for learning according to innovation pedagogy; the elements enabling innovation pedagogy to be applied, including methods of learning and teaching utilized in the learning processes by the faculty members together with the students, enhancing both the creation of innovations and innovation competences.

Metainnovations are essential requirements for innovation pedagogy to succeed, as they enable the emergence of the so-called cornerstones of innovation pedagogy in any learning environment. These cornerstones include innovative learning and teaching methods, cross-disciplinary learning environment/boundary crossing, integrated and extensive research and development activities, flexible curricula, versatile and development-oriented assessment and concentration of acknowledging the importance of entrepreneurship and service production as well as internationalization in the level of research, development and student engagement. Metainnovations contribute especially to the development of students' interpersonal and networking competences.

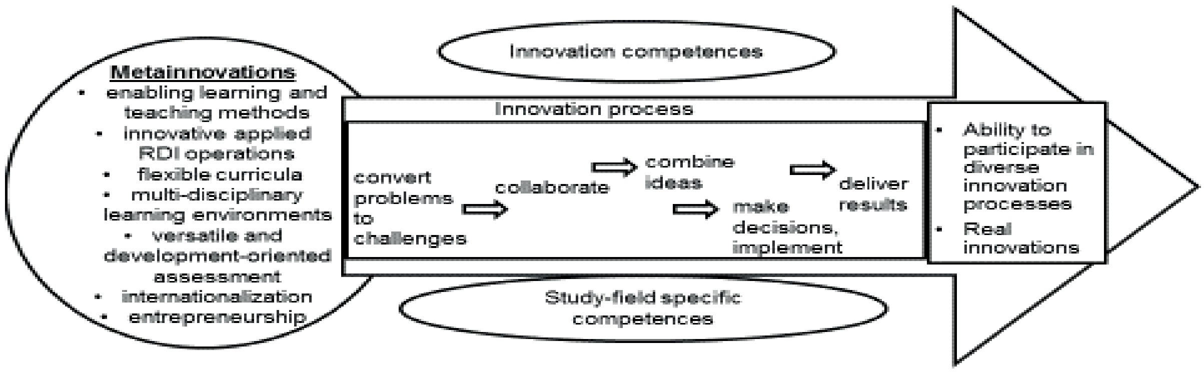

Figure 1. Methods, objectives and learning outcomes according to innovation pedagogy

Innovation competences are learning outcomes that refer to knowledge, skills and attitudes needed for the innovation activities to be successful. The innovation competences drawn up at TUAS follow the European Qualifications Framework and comprise three levels: individual, interpersonal and networking innovation competences. The individual level includes creative problem solving, goal orientation, and systems thinking; the interpersonal level focuses on the abilities to work and co-operate in teams, and the networking level covers the abilities to create, maintain and develop networks in a multidisciplinary and multicultural environment as well as to communicate and interact in an international environment. Innovation competences are learned gradually as new information is added to our knowledge structures. Innovation competences are developed together with study-field specific competences in such a learning environment which is as close to an innovation process; students work with authentic problems in multidisciplinary teams, combine ideas, make decisions, implement, evaluate and deliver results. (Räsänen 2014; Kairisto-Mertanen, Penttilä & Lappalainen 2012; Kairisto-Mertanen, Penttilä & Nuotio 2011; Kairisto-Mertanen et al. 2012)

CDIO APPROACH – KEY ELEMENTS

The CDIO approach is a worldwide collaborative network of developing engineering education. The CDIO collaboration network is based on a commonly shared premise that engineering graduates should be able to Conceive – Design – Implement – Operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products (Crawley et al. 2014). The CDIO approach has three goals:

- Educate students to master a deeper working knowledge of the technical fundamentals
- Educate engineers to lead in the creation and operation of new products and systems
- Educate future researchers to understand the importance and strategic value of their work.

The CDIO approach provides a numbers of resources that individual programmes can adapt and implement to meet these goals. The two key elements of the CDIO approach are: CDIO standards and CDIO Syllabus. The CDIO standards describe 12 principles to effective education and practice. The basic principle is that the authentic context of engineering education is the conceiving-designing-implementing-operating of products, processes and systems. Knowledge and skills are learned in a cultural surrounding and environment that contributes to understanding (Crawley et al. 2011). The CDIO Standards define the distinguishing features of a CDIO programme. They guide and support educational programme reform and evaluation, and provide a framework for continuous improvement. The standards aim at improved learning results, students learning more and students having a better experience at their HEIs. (Brodeur 2010)

The other key element and effective practice of the CDIO approach – the CDIO syllabus – answers to the challenge that a programme should have set “Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders”. The general objective of the CDIO Syllabus is to describe a set of knowledge, skills and attitudes desired in a future generation of young engineers. It offers rational, complete, universal and generalizable goals for undergraduate engineering education. The syllabus organizes learning outcomes in four high-level categories:

- technical knowledge and reasoning,
- personal and professional skills and attributes,
- interpersonal skills: teamwork and communication
- conceiving, designing, implementing and operating systems in the enterprise, societal and environmental context.

The CDIO syllabus reflects the requirements of modern working life and is constantly under observation. The latest additions based on the working life expectations have been dealing with engineering leadership and entrepreneurship. An extension of the CDIO Syllabus for Leadership and Entrepreneurship has been added, providing competence areas such as innovation, managing a project, business plan development and the innovation systems.

The CDIO approach is not a quality assurance toolkit, but it certainly provides procedures to support quality enhancement (Georsson, Bennedsen, Kontio, 2015). Based on the CDIO standard 12 CDIO programmes should evaluate their performance against all 12 standards and identify their development needs and areas of education that need to be focused on (Kontio et al. 2012). This procedure is called CDIO self-evaluation and for continuous improvement purposes, the self-evaluation should be repeated on regular basis. For example, at Turku University of Applied Sciences there are programmes that have used CDIO self-evaluation several times over the years (Kontio, 2012).

Finally, the fundamental principle of CDIO is that it is adaptable to all engineering schools. Actually, the basic ideas of the CDIO approach could offer a starting point for a definition of a new approach in other fields of education too, presuming that the most engineering specific parts are adapted to the field in question. Anyway, most of the CDIO standards are quite adaptable in any field of education as such.

RESEARCH DESIGN AND FINDINGS

Turku University of Applied Sciences (TUAS) was reconstructed in 2004 so that multidisciplinary faculties were established. The aim of the new structure was to facilitate cooperation between different disciplines. The new faculties provided natural working environments with several possibilities for crossing borders and this way supporting innovative initials among students and faculty members equally. The empirical evidence of applying innovation pedagogy and the CDIO approach has been collected during the last ten years at TUAS, and especially in its two largest faculties, the Faculty of Technology, Environment and Business (TEB) and the Faculty of Business, ICT and Chemical Engineering, both multidisciplinary, having engineering education as their biggest field of study (Stenroos-Vuorio 2012). When examining the results of the multidisciplinary organizational structure it can be seen that the volume of research, development and innovations has increased. The empirical evidence from TUAS supports that the creation of knowledge-intensive, multidisciplinary organizations in the universities boosts innovation activities. Knowledge sharing prevents the formulation of closed knowledge pools and especially supports innovation creation. (Kettunen 2009)

The research on integration opportunities of innovation pedagogy and the CDIO approach is carried out so that innovation pedagogy is described through the CDIO standards in order to explore the similarities and differences in both initiatives. The shared language provides opportunities for deeper integration in educational development.

Standard 1. Innovation pedagogy as context
Innovation pedagogy is considered the *context* for all education in that it is the cultural framework, or environment, in which knowledge, skills and attitudes are taught, practiced and learned. The principle is *adopted* by the education when there is explicit agreement of the university or the faculty to initiate innovation pedagogy, a plan to transition to it, and support from the management to sustain reform initiatives.

Standard 2. Innovation pedagogy syllabus outcomes
The knowledge, skills, and attitudes intended as a result of education, *i.e.,* the *learning outcomes*, also called learning objectives, detail what students should know and be able to do at the conclusion of their studies. In addition to learning outcomes for study field specific (e.g. technical disciplinary in engineering studies) competences, innovation pedagogy specifies learning outcomes as innovation competences, divided in individual, interpersonal, and networking competences. The *individual level* includes independent thinking and decision-

making, target-oriented and tenacious actions, creative problem-solving and development of working methods as well as self-assessment and development of one's own skills and learning methods. The *interpersonal level* focuses on the abilities to co-operate in a diversified team or working community, to take the initiative and to work responsibly according to the targets of the community, to work in research and development projects by applying and combining knowledge and methods of different fields, to work along the principles of ethics and social responsibility as well as to work in interactive communication situations. Finally, the *networking level* covers the abilities to create and maintain working connections, to work in networks, to co-operate in a multidisciplinary and multicultural environment as well as to communicate and interact in an international environment. They are consistent with educational objectives' goals and validated by stakeholders, i.e. primarily working life.

Standard 3. Integrated and flexible curriculum
A curriculum according to innovation pedagogy is *integrated and flexible*. An integrated curriculum includes learning experiences that lead to the acquisition of individual, interpersonal, and networking competences (Standard 2), integrated with the learning of study-field specific competences. An explicit plan identifies in CDIO the ways in which the integration of CDIO skills and multidisciplinary connections are to be made; in innovation pedagogy the competences are also integrated, i.e. innovation competences are mapped to study field competences and co-curricular activities that make up the curriculum (e.g. tutoring and personal study plans). However, a very explicit and detailed curriculum is not an objective, because the curriculum has to flexible, providing the students with more opportunities to tailor their own professional paths, and answering better to the needs of the constantly changing working life.

Standard 4. Introduction to innovation pedagogy
The 4th CDIO standard emphasizes the need for an introduction to engineering course providing a framework for the practice of engineering. The course includes personal and interpersonal knowledge, skills, and attitudes and prepares students for more advanced product and system building experiences. In innovation pedagogy, a specific introductory course is not typical, but all studies, from the very beginning, aim to provide the students with a broad understanding of needs and expectations of the current and future working life, emphasizing the development of innovation competences in the context of all studies. Therefore the first study units often aim to enhance e.g. team-working in multidisciplinary teams, an entrepreneurial attitude and project working skills, interconnected also with study field specific competences.

Standard 5. Constructivist approach to studies
The 5th CDIO standard denotes a range of central engineering activities considered basic or advanced in terms of their scope, complexity, and sequence. Innovation pedagogy, being targeted for all educational areas and aiming to develop students' generic innovation competences in every study field, diverges from CDIO approach here, not focusing on one study field such as engineering, business or design. However, learning experiences are also considered as basic or advanced in innovation pedagogy in terms of their scope, complexity, and sequence in the studies. For example, simpler tasks and learning experiences are included earlier in the studies, while more complex applications appear in later studies designed to help students integrate knowledge and skills acquired in preceding study units and learning activities.

Standard 6. Innovative learning environments

The CDIO standards highlight the physical learning environment in order to support the learning of disciplinary knowledge, and in addition practical hands-on learning is emphasized in physical workspaces. The physical learning environment is crucial in innovation pedagogy as well, making active learning methods possible by providing opportunities for practical applications and real problem-solving in authentic environments. The CDIO approach mentions also *social learning*, that is, settings where students can learn from each other and interact with several groups. This is emphasized in innovation pedagogy even further; the social learning environment forms the essential element for all learning.

In businesses and organizations, the way of working includes that problems are solved and innovations are created in groups and networks, and there usually are people from many different fields and disciplines who are expected to work effectively together. Equally also the tasks at work often require knowledge and skills which do not belong to the scope of one discipline only. Innovative solutions are created through social learning in diverse surroundings and therefore the social learning environment and boundary crossing/ multidisciplinarity play a key role in workspace solutions according to innovation pedagogy (Penttilä & Kairisto-Mertanen 2012).

Standard 7. Integrated learning experiences

Learning experiences in innovation pedagogy are equally integrated. The curriculum and learning outcomes can be realized only if there are corresponding pedagogical approaches that make dual use of students' learning time. With integrated learning experiences, the students are better prepared to meet the demands of their future profession.

Standard 8. Active learning

Both innovation pedagogy and the CDIO approach emphasize active learning methods, which engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas. Active learning is considered *experiential* when students take on roles that simulate professional practice, for example, projects, simulations, and case studies. Innovation pedagogy goes some steps further, including also tacit knowledge and intuition as important in contexts relating to a concrete innovation process (Penttilä & Putkonen 2013). In addition, active learning according to innovation pedagogy includes also the earlier mentioned collaborative learning, where different actors are able to work together in dialogue, in such a manner that their own expertise can be efficiently shared and combined in novel ways, resulting in something more than the sum of its parts.

Standard 9 and 10. Enhancement of faculty competence

The CDIO approach supports the faculty members to improve their own competence in the personal, interpersonal, and product and system building skills, as well as their teaching skills. Innovation pedagogy was originally developed for universities of applied sciences, where it is a prerequisite that the teaching staff has, in addition to the university degree on the teaching field, also a university degree from the field of education (= teacher's education), and third, at least three years' work experience from the teaching field. Thus, deep understanding of teaching and learning has always been the basis for innovation pedagogy. As CDIO, innovation pedagogy encourages the teaching staff for continuous improvement of their own competence. According to innovation pedagogy, learning is a shared process; it's not only the students who learn, but also their teachers and tutors as well as other stakeholders such as businesses and other organizations participating in the learning processes.

Standard 11. Assessment according to innovation pedagogy

The CDIO approach and innovation pedagogy share a parallel goal in assessment; effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address not only study field specific competences but innovation competences as well. In innovation pedagogy there are special challenges for assessment; in the assessment of innovation competencies, the emphasis is more on performance-oriented competences and lies on interpersonal and networking innovation competencies. This sets special demands especially on the number and timing of assessment, assessment criteria and assessment methods. For this purpose, the INCODE barometer, which can be used in self, peer and tutor assessment of behaviour and its development, has been developed in the co-operation between European partner universities (e.g. Watts et al. 2013).

Standard 12. Evaluation of innovation pedagogy
Both in CDIO and innovation pedagogy, the feedback forms the basis of decisions about the programme and its plans for continuous improvement. A key function of evaluation is to determine the effectiveness and efficiency in reaching the intended goals. Evidence collected during the evaluation process also serves as the basis of continuous programme improvement. Moreover, many external evaluators and accreditation bodies require regular and consistent evaluation.

Above, we have described innovation pedagogy through the CDIO standards in order to show the similarities and differences in both initiatives. Our conclusion is that innovation pedagogy can be easily be described using the ‘same language’ by using the CDIO standards. The findings can be summed up and presented in a similar format as the CDIO standards (Figure 2).

Innovation Pedagogy Standards – Best practices

1. Innovation Pedagogy as Context
Adoption of the principle that Innovation pedagogy is considered the context for all education

2. Innovation Pedagogy Syllabus Outcomes
In addition to learning outcomes for study field specific competences, innovation pedagogy specifies learning outcomes as innovation competences, divided in individual, interpersonal, and networking competences. They are consistent with educational objectives' goals and validated by working life

3. Integrated and Flexible Curriculum
Curriculum that leads to the acquisition of innovation competences integrated with the learning of study-field specific competences, in a flexible way to allow the student to formulate his/her own professional path according to dynamic working life needs.

4. Introduction to Innovation Pedagogy
that provides the students with broad understanding of needs and expectations of the current and future working life

5. Constructivist approach to studies
The learning experiences are considered as basic or advanced in innovation pedagogy in terms of their scope, complexity, and sequence in the studies'; learners are guided to utilize and process their previous experiences while helping them cumulate new ones via diverse learning environments

6. Innovative Learning Environments Innovative solutions are created through social learning in diverse surroundings and therefore the social learning environment and boundary crossing/ multidisciplinarity play a key role in workspace solutions according to innovation pedagogy.

7. Integrated Learning Experiences
The curriculum and learning outcomes can be realized only if there are corresponding pedagogical approaches that make dual use of students' learning time.

8. Active Learning
Teaching and learning based on active and often experiential learning methods

9.-10. Enhancement of Faculty Competences
Actions that enhance university staff competences in study field specific competences as well as in teaching and learning competences providing integrated learning experiences

11. Assessment according to Innovation Pedagogy
Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address not only study field specific competences but innovation competences as well.

12. Evaluation of Innovation Pedagogy
The feedback forms the basis of for continuous improvement; a system that provides feedback to students, university, and other stakeholders including working life, for the purposes of continuous improvement

Figure 2. Innovation pedagogy standards

CONCLUSIONS AND FINAL REMARKS

In all, both innovation pedagogy and the CDIO approach face very similar challenges and share parallel goals and objectives. Our conclusion is that innovation pedagogy and the CDIO approach can easily be integrated. Innovation pedagogy is a strategic approach, representing a philosophy that permeates through the entire organization, and is visible in all activities. Innovation pedagogy offers a name to the development of students' competences, enabling them to participate in the processes of creating innovations.

The CDIO approach has a clear focus on engineering education whereas innovation pedagogy tries to bear in mind the broader needs of the entire economy and focuses on producing valid competencies for the future society where special emphasis is put on innovation creation. Innovation pedagogy can be applied to all the disciplines and to all education be it in the university at any programme, but also to other levels of education e.g. to secondary education where the basis for the students' understanding of learning is created. The CDIO syllabus goes to a deep level of detail while defining the necessary competences, but it is good to remember that the CDIO syllabus is also a reference list and all of the features are not meant to be followed in detail. Innovation pedagogy focuses on providing the methods and tools to provide the three categories of innovation competencies: individual, interpersonal and networking innovation competences. Innovation pedagogy states that certain cornerstones or "metainnovations" are needed to succeed in this task, for example such as entrepreneurship and internationalization, which also are included in the CDIO syllabus in various parts. Internationalization is mentioned as communication skills in foreign languages, developing a global perspective and working in international organizations. Entrepreneurship is named in the enterprise and business context as well as in the new syllabus addition, engineering entrepreneurship. In all, innovation pedagogy can form an extensive pedagogical strategy for any educational institution providing both objectives and methods and tools in order to reach the desired learning outcomes leading to innovation creation. The integration of the CDIO approach and innovation pedagogy can provide the students with innovation competences in order enable them to participate in the innovation processes in their future working places and develop them. Innovative solutions are created through social learning (~collaborative learning) in diverse surroundings and emphasize the significance of boundary crossing in higher education and its ability to provide the different types of knowledge needed in innovation creation.

Additionally, our conclusion is that innovation pedagogy can be easily described using the 'same language' by using the CDIO standards. The shared language provides better opportunities for deeper integration in educational development. To sum up, on a practical level innovation pedagogy integrated with the CDIO approach means applying existing learning and teaching methods in a creative, value-increasing way. Simultaneously, new methods are developed and put into practice while ensuring that students take responsibility for their learning and that they actively pursue their learning objectives. As a result, graduating students have professional skills and qualifications that are both innovative and development-oriented. The findings of this paper suggest that integrating the CDIO approach and innovation pedagogical approach support the development of students' innovation competences. Innovation pedagogy strengthened with the CDIO approach moves further from traditional theoretical learning to the application of learned skills to practical development challenges. This aims to ensure improved learning processes and learning outcomes in addition to development actions in engineering education and higher education in general.

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BIOGRAPHICAL INFORMATION

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Dr. Taru Penttilä, (Ph.D. /Soc. Sc., Lic. Sc./Econ.& Bus. Adm.) is one of the pioneers of the development of innovation pedagogy, and she has published numerous scientific articles and other research reports and publications about the topic. She is responsible for the pedagogical development of the Faculty of Technology, Environment and Business and leads the research group in innovation pedagogy, acting also as one of the key consultants and experts of the topic. Her research focus in her doctoral studies was curriculum development. She also has a long experience in working as a principal lecturer in marketing and international business, project manager and researcher.

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ANALYZING THE MEANING OF INTERDISCIPLINARY IN THE CDIO CONTEXT

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ABSTRACT

Companies search for potential recruits with interdisciplinary skills. Consequently, to meet this requirement, universities and teaching institutions develop and offer interdisciplinary courses and programs. However, the meaning of interdisciplinarity varies between different actors. In order to be able to compare, monitor and evaluate concepts, it is important to ensure that the concept have the same meaning and content for all actors. Hence, the purpose of this paper is to describe the term interdisciplinarity and its application in higher education with specific focus on CDIO related literature. Moreover, dimensions of interdisciplinarity will be illustrated in an ongoing master program.

This paper consists of two parts. The first part is a theoretical study conducted in order to describe the concept and illustrate the width of applications of interdisciplinarity in the CDIO context. For this purpose, the content of the CDIO knowledge library was surveyed using the following key words: inter*, cross*, trans*, interdisciplinary*, crossdisciplinary*, and transdisciplinary*. The second part is empirical in nature and describes an on-going interdisciplinary master program named “Innovation through Business, Engineering and Design” offered at the Linnaeus University, Sweden, as well as its dimensions of interdisciplinary.

The CDIO approach advocates integrated learning experiences and the use of disciplinary competencies for solving interdisciplinary problems. This is reflected in the body of knowledge represented by the CDIO library: most of the articles reviewed in this study are describing interdisciplinary or transdisciplinary activities. The interaction could be between subjects, skills and courses within the discipline, i.e. in a cross-disciplinary or multidisciplinary mode, or between students representing different disciplines in multidisciplinary, interdisciplinary or transdisciplinary mode. Faculty staff acts as designers and enablers of these activities, both in terms of curriculum development on strategic level and activity creation and activity execution on the operational level. The practical example given in the paper illustrates the importance of an effective administration for succeeding with interdisciplinary activities.

KEYWORDS
Interdisciplinarity, Literature survey, Master program in innovation, Standards: 3, 5, 7, 8

INTRODUCTION

Interdisciplinary studies will prepare the students to meet the complex behavior they will face in their future working life (Newell, 2012). Most modern companies are looking to hire graduates with interdisciplinary skills, so it is important for universities and teaching institutions to encourage interdisciplinary programs (Vanstone et al., 2013). Consequently several universities and teaching institutions have developed interdisciplinary courses to meet the need from future employers, see for instance Augsburg (2003) and Duffield et al. (2012). Interdisciplinarity has multiple faces and the contents vary among involved actors, Nikitina (2006). Supplementary, it is difficult to identify indicators of interdisciplinarity (Porter & Chubin, 1985). Davies and Devlin (2007) define interdiscplinarity as the integration of two or more disciplines in the education. A more elaborated definition is found in Pharo et al. (2012, p. 498): "…the integration of disciplinary perspectives to produce insights that are more than the summing of disciplinary knowledge".

Meeth (1978) describe levels of interdisciplinarity: intradisciplinar, cross-disciplinar, multidisciplinar, interdisciplinar and transdisciplinar. Intradisciplinar studies are studies within one discipline. In cross-disciplinar studies one discipline is viewed from the perspective of another discipline. Multidisciplinarity occurs when multiple, discrete disciplines are applied for solving a common problem. Each discipline suggest solutions to the problem, no knowledge transfer exists though. Interdisciplinary studies also apply different disciplines, but in a more active way for solving the problem. The problem itself thus requires multiple disciplines for being solved. Transdisciplinary goes beyond the disciplines. While interdisciplinary studies start with the discipline, transdisciplinary studies starts with the issue or problem to solve. Davies and Devlin (2010) claim that there are a number of variants of interdisciplinarity and propose three new terms: relational, exchange and modification interdisciplinarity. Relational interdisciplinarity is when a common subject is discussed using related disciplines. These related disciplines are used rather as perspectives on the common subject, and the aim is not integration of disciplines. Relational interdisciplinarity thus resembles the term multidisciplinarity. Exchange interdisciplinarity maintains the disciplinary integrity, but uses other disciplines for a critical exchange of perspectives.

The need for students with interdisciplinary knowledge cannot be mistaken, however interdisciplinary knowledge and skills have many faces and expressions and hence the question arises; How can the concept of interdisciplinary be applied in higher education? Hence the purpose of this paper is to define interdisciplinary and its application in higher education with a specific focus on CDIO related literature and illustrate dimensions of interdisciplinarity in an ongoing master program.

APPLICATION OF INTERDISCIPLINARITY IN THE CDIO CONTEXT

Study description

Our research is based on a literature review focusing on interdisciplinary articles and the meaning of interdisciplinarity. The literature review has been based on articles presented and published in former CDIO conferences and its accompanying papers. The content of the CDIO knowledge library was surveyed using following key words: inter*, cross*, trans*, interdisciplinary*, crossdisciplinary*and transdisciplinary*. The survey resulted in 47 hits representing 43 unique articles. Of these 8 were not within the topic, 6 tangent the topic but were outside the actual investigation area and 29 were relevant, see table 1. The activities described in the CDIO literature were categorized and analyzed with respect to two aspects: type of activity and type of interaction. The summarized results of the study are found in appendix 1. In the following, the main findings are presented.

Interdisciplinary defined in the CDIO context

Few publications include a definition of interdisciplinarity. Nordal and Busk Kofoed (2012) use the definition by Meeth (1978) that describes levels of interdisciplinarity. They also discuss the T-shaped student, i.e. a student with both disciplinary and interdisciplinary skills. The theory of T-shaped people is also used as a theoretical foundation in Elmquist and Johansson (2011). Kans et al. (2014) discuss variations of cooperation, including interdisciplinary cooperation, and use definitions by Davies and Devlin (2007) and Pharo et al. (2012) that address the characteristics as well as variations of interdisciplinarity, and Waterman et al. (2011) that discusses interdisciplinary cooperation. Spooner (2011) argues for the transdisciplinary approach to product and process design. They declare that transdisciplinarity puts focus not only on the problem solution but also on the problem choice. Moreover, they propose the cooperation between faculty staff: “to achieve a virtually seamless product experience, design staff must constantly cross disciplinary boundaries.” Jørgensen et al. (2011) propose an own multidisciplinary approach for design engineering consisting of "creative, synthesis oriented competences", "innovative, socio-technical competences" and "reflective technological engineering competences".

Table 1. Results by key word

Key word	Hits	Relevant*	Related	Not relevant
Cross	8	6	0	2
Inter	3	3	0	0
Trans	0	0	0	0
Crossdisciplinary	6	4	3	0
Interdisciplinary	27	17	3	6
Transdisciplinary	3	3	0	0
Total	**47**	**33**	**6**	**8**

* The number of unique articles was 29

The most commonly used term for describing the interdisciplinary activity is “interdisciplinary”. 13 out of 29 articles use this term. The terms “multidisciplinary” and “cross-disciplinary” is used in 6 articles each. ”Transdisciplinary” is used in 3 articles while 2 articles did not use any explicit term for describing the activity. Interdisciplinary activities are found in all kinds of subject areas and the articles represent all types of engineering education. The level of education is both undergraduate, mainly Bachelor of Engineering, and graduate, i.e. masters level. Main part of the articles describes activities on undergraduate level, with one interesting exception: For articles using the term “multidisciplinary” the activities are evenly distributed between levels. Some articles described activities on both undergraduate and graduate level.

Interdisciplinary activities in the CDIO context

The type of activities spanned from modules in a course, such as an examination form, an exercise or a workshop, to full programs. The activity could thus be a module, a project, a course, several courses or a full program. In addition, one article describes an interdisciplinary mechatronics platform used for several types of interdisciplinary activities (Habash et al., 2010). The most common types of activities are projects and courses. Examples of interdisciplinary courses are found in seven of the articles. Some courses are given within one program, thus mainly promoting the students to use different disciplines to solve a task or study a concept, such as the obligatory introductory engineering project courses described in Wetterö et al. (2006) and Ingeman-Nielsen and Christensen (2011). The latter course trains teamwork and project management skills, communication and writing skills as well as critical thinking, while applying disciplinary knowledge. The Materials Project Laboratory course at MIT integrates material science, business economics and communication in a project-based setup (Tarkanian and Caulfield, 2013). Courses and projects that in an interdisciplinary mode collaborates with other courses given during the semester are found in several programs at DTU, see for instance Jørgensen et al. (2011), Clement et al. (2011) and Birk et al. (2014). This is the result of a university wide adaptation of CDIO in 2008.

Most of the interdisciplinary activities are obligatory for students enrolled in certain programs, but other initiatives are voluntary, such as those described in Al-Atabi (2013) and Törnqvist (2015).Some courses are cross-disciplinary and engage students from two or more programs and/or disciplines, such as the course taken by Architectural Engineering and Civil Engineering students (Karlshøj and Dederichs, 2011). The multidisciplinary capstone course described in Seidel et al. (2011) is run in collaboration with several faculties (Engineering, Business, Creative arts). Spooner et al. (2011) reports on transdisciplinary product design projects engaging engineering, industrial design and business students. In Kans et al. (2014) four project-based courses which mix students from different programs and/or universities are described. An approach to restructure two master's programs for allowing more cross-disciplinary collaboration is found in Elmquist and Johansson (2011). A new introductory course, a joint second semester course and more collaboration in the final degree project were suggested.

Course modules are described in three articles. Sunnerhagen et al. (2006) describe an examination form with an interdisciplinary context, in which chemical biology students presents research plans for medical doctors. Being experts in the discipline but not in research methods the medical doctors ask questions to the students, and the ability to describe, explain and reason around the subject is graded by the teachers. A company based workshop in product design which forms a part of an interdisciplinary course is described in Elmquist et al. (2014). The course is a joint course for students enrolled in three different master programs and the workshop was developed by faculty representing these disciplines. Palm and Törnqvist (2015) describe a course module which includes the subject specific as well as soft sides of technical projects, such as group processes and ethics. The paper addresses the possibilities to integrate ethical aspects in a technical project course by real-life resembling scenario cases.

Two articles address interdisciplinary educational programs. Nordahl and Busk Kofoed (2012) describe interdisciplinary programs in Medialogy, which is defined by the authors as an interdisciplinary science. Helenius (2010) describe a multidisciplinary master program with cross-disciplinar intake of students. The program recruits students from computer science, software engineering, information systems, telecom or digital media. In addition, several cross-program initiatives are described. An institution wide adaptation of more than 30 programs to the CDIO approach assisted by a cross-disciplinary faculty team described in Leong-Wee and Pee (2007) resulted in a revised syllabus, a new engineering introduction course and improvement in the third year project course. Lourenço Jr and Veraldo Jr (2015) also report on a school wide reforming of the syllabus, affecting six engineering programs. The paper describes interdisciplinary projects each semester covering at least two disciplines and covering both soft and hard skills. In the multidisciplinary engineering design course described in Tien and Hajibeigy (2014) two students from each discipline form teams and apply mainly their disciplinary knowledge to create functioning artifacts.

An approach to link academy and industry is described in de Roza (2010). Amongst the various activities and platforms the paper mentions multi-disciplinary industrial projects which involve students and staff from different disciplines. The curriculum is flexible and schedules are designed to enable and support student participation in industrial projects. The opposite problem occurred in Rudd et al. (2011), i.e. obstacles to succeed with interdisciplinary projects due to tight and fixed schedules. Rudd et al. report on four System Engineering projects within the involving sixteen students from four different majors and three departments. The interdisciplinary teams developed functioning prototypes for various needs, and amongst the lessons learned was that teams working in a web-based mode due to conflicting schedules affected the outcome negatively.

Interdisciplinary interactions in the CDIO context

The type of interdisciplinarity was categorized with respect to the entities which interact. Subject interdisciplinarity is when different subjects are combined and/or required for the activity. Student interdisciplinarity requires students from different disciplines to interact. Staff interdisciplinarity describes activities where faculty staff representing different disciplines interacts. In addition, we also noted if the activity address interaction with industry. The majority of the papers describe activities in which different subjects interact, see Appendix 1. Such descriptions can be found in almost half of the papers. The common characteristic of subject interactivity is that it exists within the same study program. The activity, often in project form, requires or uses previous knowledge or skills gained in the course or in previous courses for solving a problem or investigating a phenomenon. Some of the programs are interdisciplinary in their nature and would naturally train students in an interdisciplinary mode, see Nordahl and Busk Kofoed (2012) and Helenius (2010).

The interaction between students from different disciplines and programs is described in twelve of the papers. In most cases the interaction happens between different engineering students while other initiatives are school or university wide, see previous descriptions above. Several of the activities are focusing on solving industry or societal problems. Six papers describe interaction with industry. In addition, interaction between students and professionals is found in Sunnerhagen et al. (2006), see above for a description of the activity. Faculty staff interaction is addressed in eight of the papers. Staff often interacts in teams for developing curricula, courses or modules and for running different activities, but de Roza (2010) also give examples of staff and student interaction in industrial projects. An example of an interdisciplinary program at Linnaeus University is given in the following section.

APPLICATION IN HIGHER EDUCATION EXAMPLE: INNOVATION THROUGH BUSINESS, ENGINEERING AND DESIGN

The master program Innovation through Business, Engineering and Design was developed in line with the Linnaeus University vision (Linnaeus University, 2015):

“a creative and international knowledge environment promoting curiosity, creativity, companionship and utility”

The program is a two-year Master's program that aims to develop the students' ability to work in interdisciplinary groups as well as to deepen their subject knowledge. The program trains students in project and innovation management, process and product development, business and system development, and social entrepreneurship.

This program reveals several dimensions of interdisciplinarity:

- **Student groups**

In order to create interdisciplinary learning for the students enrolled in this program, the students work together in groups with students from other faculties/disciplines (the involved faculties are Business Administration, Engineering and Design). Each group consists of equal number of students from engineering, design, and business administration. The students will work in the assigned interdisciplinary groups throughout the semester. The groups are rearranged, with regard to its members, to the coming semester.

- **Problem/task for the student groups**

Focus in the fall semester is local innovation and innovation in local companies and in the spring semester are multinational companies, non-governmental organizations, and other organizations. In the student’s work are of interdisciplinary nature; the innovation should be able to balance the different process parts with respect to function, design, durability, production conditions, and business administration. This requires knowledge of, and interaction between, different disciplines where different perspectives and approaches are utilized. The student groups receive a project, (in form of briefs) from the problem owners (industry or society), that is supposed to be solved within these groups. The students act as problem solvers weighing and balancing each subject and the final solution, proposed by the students, consists of a wide-ranging solution taking the involved subjects into consideration.

- **Faculty members, curriculum, and administrative task**

While the students carry out their interdisciplinary project, the students are enabled and facilitated by the university in different ways; faculty members, curriculum, and administrative staff. While the students are carrying out their projects, faculty members hold lectures and provide tutoring both individually, and in groups of faculty members coming from different disciplines. At several occasions aligned with the different development phases of the project, an interdisciplinary team of faculty members within different subjects provide tutoring for the student groups. The program curriculum states that the students should be able to demonstrate an understanding of the increase in value of interdisciplinary collaboration. This is further developed in the course syllabus where it is stated, for instance, that the students should plan and carry out an interdisciplinary process and project and discuss the connections between the contributions of different fields of competence in an interdisciplinary project. As the students belong to different faculties, it is necessary that the administrative staff are working together in order to solve the practical problems that appear, and to prevent future problems. There are several different administration functions, such as grade reporting and schedule arrangements, involved and the functions ensure that all students have the same conditions.

RESULTS AND CONCLUSIONS

The CDIO approach advocates integrated learning experiences and the use of disciplinary competencies for solving interdisciplinary problems. This is reflected in the body of knowledge represented by the CDIO library: most of the articles reviewed in this study are describing interdisciplinary or transdisciplinary activities, as defined in Meeth. Terminology confusion seems to exist though; interdisciplinary activities are referred to as cross-disciplinary, multidisciplinary as well as interdisciplinary, and few articles include a definition of interdisciplinarity. This indicates a need for better understanding of the interdisciplinary concept in the CDIO community.

Most activities identified in the articles, whether in course, project, or course module form, are curricular activities. This implies that in order to successfully implement interdisciplinary activities, these should be regulated in the curriculum. The interaction could be between subjects, skills and courses within the discipline, i.e. in a cross-disciplinary or multidisciplinary mode, or between students representing different disciplines in multidisciplinary, interdisciplinary or transdisciplinary mode. Faculty staff acts as designers and enablers of these activities, both in terms of curriculum development on strategic level and activity creation and activity execution on the operational level. The practical example given above illustrates the importance of an effective administration for succeeding with interdisciplinary activities. This implies that faculty members, both administrators and teachers, have to work in interdisciplinary teams. Industry interaction is found especially in activities that are interdisciplinary and transdisciplinary, and which involves students from several programs and faculties. Industry related problems are by nature more complex which requires higher levels of interdisciplinarity.

This article is based on the meaning and contents of interdisciplinarity. However, developing interdisciplinary programs implies breaking the traditional university structure in which ordinary ways of developing programs are outdated. Hence additional research needs to be conducted on how to realize an interdiciplinary program as well as for identifying resources needed and success factors. Another interesting aspect for further studies is the students' learning with regards to interdisciplinarity and how it is possible to measure that the students attain interdisciplinary knowledge.

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BIOGRAPHICAL INFORMATION

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APPENDIX 1. SUMMARY OF LITERATURE REVIEW RESULTS

Author	Subject and level	Type of learning activity*	Type of interdisciplinarity*
Sunnerhagen et al. (2006)	Chemical biology. Master.	Examination form.	***Interdisciplinary*** context: students and examiners from different disciplines.
Wetterö et al. (2006)	Engineering biology. First year in a masters programme.	Full course "Engineering Project for Engineering Biology" with an ***interdisciplinary*** task.	Between subjects.
Leong-Wee and Pee (2007)	Engineering programmes. B eng.	Final year project.	***Cross-disciplinary*** staff team. (In the final year project combinations of different subjects/disciplines.)
de Roza (2010)	Engineering programmes. All levels.	***Multidisciplinary*** industry projects.	Staff and students cooperate with industry in projects.
Habash et al. (2010)	Mechatronics for all types of engineering students. B eng.	A mechatronics platform that is utilised for interdisciplinary teaching.	Using an ***interdisciplinary*** platform for integrating students. Between subjects. Students interact as well.
Haeck (2010)	Engineering programmes.	The whole university.	Academic staff should cooperate in creating ***transdisciplinary*** programmes.
Helenius (2010)	Service design and engineering (students from computer science, software engineering, information systems, telecom or digital media). Master.	Full ***multidisciplinary*** programme with ***cross-disciplinar*** intake of students.	Between students in the programme, also industry application. Between faculty members in the design of the programme.
Clement et al. (2011)	Biochemical engineering. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.
Elmquist and Johansson (2011)	Product development, production management. Master.	Joint courses and joint degree project.	Between students representing different disciplines. ***No explicit use of terms multi, inter, cross or transdisciplinarity.***
Ingeman-Nielsen and Christensen (2011)	Arctic Technology. B prof.	***Interdisciplinary*** course "Site investigations".	Between subjects.
Jørgensen et al. (2011)	Design and innovation. Bachelor (master).	Thematic semesters with integrated ***multidisciplinary*** projects.	Between subjects and in curriculum.
Karlshøj and Dederichs (2011)	Architectural Engineering and Civil Engineering. Master.	A ***multidisciplinary*** course in "Advanced building design".	Multidisciplinary team of professors, between students.
Kjærgaard et al. (2011)	Electronics. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.
Krogsbøll et al. (2011)	Civil engineering. B eng.	***Cross-disciplinary*** projects in semester 1-4. Two are design-build projects.	Between subjects and courses.

Rudd et al. (2011)	Officers' education, subject systems engineering. Undergrad.	***Interdisciplinary*** capstone projects outside the normal curricula.	Project level. Students made teams but mainly used their disciplinary knowledge.
Seidel et al. (2011)	Several faculties; Engineering, Business, Creative arts. B eng.	A ***multidisciplinary*** capstone course "Advanced innovation and new product development".	Between faculty staff. Students from five different faculties in the same course working with industry.
Spooner et al. (2011)	Engineering, industrial design and business students work on product design. B eng.	***Transdisciplinary*** projects.	Between students working with industry.
Nordahl and Busk Kofoed (2012)	Medialogy, which is an ***interdisciplinary*** science. Bachelor and master.	Full programme and projects that are ***interdisciplinary*** and ***transdisciplinary***.	Between subjects.
Al-Atabi (2013)	Chemical, electrical, electronic and mechanical engineering. B eng.	Voluntary programme consisting of several courses.	Seems like the students work in ***interdisciplinary*** teams.
Tarkanian and Caulfield (2013)	Material science. B eng.	Specific ***interdisciplinary*** project course. Mandatory for material science majors.	Between subjects.
Birk et al. (2014)	Food science B eng.	***Interdisciplinary*** course "Food microbiology".	Between subjects.
Elmquist et al. (2014)	Product development, Product development and materials engineering and Industrial design. Master.	Company based workshop, in an ***interdisciplinary*** course" Materials and design".	Between staff and between students solving an industry problem.
Kans et al. (2014)	Mechanical engineering. B eng, bachelor.	Different courses including ***interdisciplinary*** cooperation.	Between staff and between students.
Rebrin et al. (2014)	Metallurgy. B eng.	***Interdisciplinary*** project course spanning 5 semesters.	Between subjects.
Tien and Hajibeigy (2014)	Engineering; in the paper mechanical engineering and electrical engineering. B eng.	***Multidisciplinary*** project in the course "Multidisciplinary Engineering Design".	Between students representing different disciplines.
Lourenço Jr and Veraldo Jr (2015)	Engineering programmes. B eng.	***Interdisciplinary*** projects every semester.	Between subjects.
Nyborg et al. (2015)	Software technology, IT and Economics, IT Electronics. B eng.	***Interdisciplinary*** project courses, both within and across programmes.	Between students and subjects.
Palm and Törnqvist (2015)	Information technology. B eng.	Course module.	Between subjects and skills. ***No explicit use of terms multi, inter, cross or transdisciplinarity.***
Törnqvist (2015)	Various subjects at the faculties of Arts and science, the Institute of technology and the Faculty of health sciences. Later part of bachelor and master.	Full course "***Cross Disciplinary*** Projects".	Between students representing different disciplines aiming at solving an industrial/societal problem.

* The terms marked in bold italic is the term used by the authors of the original article

AIMS OF ENGINEERING EDUCATION RESEARCH – THE ROLE OF THE CDIO INITIATIVE

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ABSTRACT

The CDIO Initiative is first and foremost an endeavour for engineering education development, but in the 12th International CDIO Conference in 2016, a special track is opened for engineering education research (EER). This paper aims to clarify a tension within the emerging EER field regarding the aims of research: is it seeking new knowledge to improve educational practice, or for its own sake? While usefulness and scholarliness are not mutually exclusive characteristics, it is a matter of priorities when selecting and formulating problems, and defining the quality of research. Considering this tension is not merely an abstract exercise of ideas and ideals, because definitions of quality also come with assumptions of who can be a legitimate judge. There are implications for legitimacy and power, with real consequences for the people within engineering education and its stakeholder groups. The EER community needs to understand the tension and create a working and productive relationship between scholarliness and usefulness. There is a need for quality mechanisms to stake out borders and standards for EER, at least weeding out such work that is neither scholarly nor useful. Success means creating legitimacy for the research that is simultaneously credible and useful, so it actually can contribute to the improvement of engineering education and create conditions for sustainable careers in academia. In the light of this discussion, an argument is made for how CDIO can contribute to shaping the EER field, and how EER can strengthen CDIO.

KEYWORDS

The CDIO Initiative, the International CDIO Conference, engineering education research, engineering education development, research aims, discipline, usefulness.

INTRODUCTION

The work within the CDIO Initiative (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014) has continuously been documented and openly shared, in books, reports, conference proceedings, and not seldom as peer-reviewed papers in international journals. Despite this long list of publications, the development of engineering programs has always been the priority (Edström & Kolmos, 2014). When the CDIO Initiative opens a new conference track for engineering education research (EER), it is worth considering the purpose of EER, as well as the nature of research that can be relevant for the CDIO Initiative.

This paper starts with a background of the emerging field of engineering education research in the United States and Europe, highlighting somewhat different traditions. The next section explores more deeply the fundamental inherent tension regarding the aims of research, contrasting research with a *consideration for use* and research to further a *discipline*. In the light of this tension, a suggestion is made for the rationale for adding an EER track in CDIO.

ENGINEERING EDUCATION RESEARCH – AN EMERGING FIELD

The study of engineering education was historically scattered across different disciplines as individual scholars found it an interesting *object of study*. Now a more coherent international academic field is evolving; this time the initiative comes from within the engineering community itself. The growth of academic infrastructures for the EER field includes conferences, peer-reviewed journals, and research centres with professorships and PhD programs. Below, some of the development in the United States and in Europe is sketched.

EER in the United States

The development is most visible in the United States, where a well-organised movement is working to establish EER as a discipline. Their efforts are documented in the Journal of Engineering Education (JEE), published by the American Society for Engineering Education (ASEE). It signalled a transition in 2003 from a "scholarly professional journal" into "an archival record of scholarly research in engineering education" (Jack R Lohmann, 2003). In 2005, JEE added the bold subtitle "the research journal" (Jack R Lohmann, 2005). The goal was to be a "world-class journal globally advancing rigorous scholarship" and forming a global community for "advancing engineering education through education research". Using "rigorous" eight times in two pages, a five-year strategic plan (JEE, 2005) called EER "an emerging discipline". The National Science Foundation (NSF) was calling for fundamental research (Gabriele, 2005), enabling careers for specialised researchers, and large research centres, most notably departments with PhD programs. When Haghighi (2005) announced the PhD program at Purdue University, he called it the "birth of a new discipline… in the domain of serious science". Since then, several other institutions have started PhD programs.

The role of NSF funding is crucial for the EER movement. Wankat, Williams, and Neto (2014) noted that in a 2003 issue of JEE the US-based authors of almost one third of the papers acknowledge NSF grants – but ten years later this is true for *all* papers. Editor Lohmann (2011) acknowledged that the development of the journal reflected the rapid growth of educational research in the engineering education community. More specifically, it reflects the volume of NSF funding for US-based researchers specialising in EER. It should be noted that JEE authorship does not reflect the espoused global ambitions. For instance, 88% of its authors in the first issues of 2013 were US-based (Wankat et al., 2014).

It is clear that both *rigorous* and *discipline* were important buzzwords in the EER movement ten years ago (see also Adams et al., 2006; Borrego, 2007b; Streveler & Smith, 2006). This signalled an ambition to achieve recognition equal to (any other) engineering science. EER is represented more as an offspring of engineering than of educational research. For instance, Felder, Sheppard, and Smith (2005) call for research "subjected to the same rigorous assessment and evaluation that characterize first-rate disciplinary research". However, both rigorous and discipline turned out to be contentious concepts. Jesiek, Newswander, and Borrego (2009) identified stakeholder ambivalence toward a discipline, with better consensus for calling it a *field*. The next strategic plan (JEE, 2011) uses neither rigorous nor discipline –

but *scholarly research*. If the first plan emphasised “advancing rigorous scholarship” per se, the intention of impact was now brought to the foreground: “scholarly research that leads to timely and significant improvements in engineering education worldwide”.

EER in Europe

The development of European EER is far more diverse. In the absence of a strong funding agency, the researchers who can dedicate their careers to studying engineering education are few and far between. Hence, there is less capacity for a concerted EER movement. To support and strengthen the fledgling community, the European Society for Engineering Education (SEFI) started a working group for EER in 2008, aiming to “create a European community of engineering education researchers in order to contribute with research evidence to the advancement of engineering education” (Kolmos, 2008). At the annual SEFI conference, the EER track is the largest sub-theme since 2011 (de Graaff, 2014).

The European Journal of Engineering Education (EJEE) is published by SEFI. Like JEE, its character has gradually become more scholarly (Osorio & Osorio, 2004), but it is deliberately positioning itself as more inclusive. The editorial policy talks of a forum for “dialogue between researchers and specialists”, inviting a wide array of stakeholders to “share accounts of good practice”. Editor de Graaff (2014) notes that EJEE articles in 2012 were cited 0,139 times on average (while JEE had 2,7 citations per paper). de Graaff suggests that readers are engineering educators looking for inspiration, rather than researchers looking for references. In stark contrast to the academic ambitions of JEE, de Graaff declares that EJEE will stay on this course and consider usefulness to practitioners to be its real impact. Another difference is that EJEE authorship is highly international, far beyond what is expected due to the diversity of Europe itself, as a considerable share are non-European.

To some extent, the emerging EER community in Europe can be seen as response to the movement in the US, formed around the work and the people with the closest match to a more clearly defined identity offered from across the Atlantic. The exchange among the communities is intense, with several US-led efforts to establish bonds and shape the field (see for instance Finelli, Borrego, & Rasoulifar, 2015; Jesiek, Borrego, & Beddoes, 2010). In addition to cross-participation in each other’s conferences (SEFI and ASEE), the global Research in Engineering Education Network (REEN) organises a biannual symposium.

An Inherent Tension

Already this brief history demonstrated how the different ambitions for the EER field reflect various stakeholders’ interests and actions, and also significant diversity in how EER is conceptualised. Simply put, the battle cry on one side of the Atlantic was *scholarliness* and on the other it was *usefulness*. To investigate some of the possibilities and trade-offs in staking out the field we will now consider the *aims* of doing EER. It is not so much a geographic issue, but a far more fundamental one. As will be seen, it is a highly value-laden issue, everyone who sets out to study engineering education will experience the same inherent tension, and it will always be discussed. We must learn to understand and deal with it, positioning our work and positioning ourselves.

The fundamental defining question for EER regards: is the aim of research to improve educational practice, or is it to seek new knowledge for its own sake? These are not mutually exclusive categories, but different priorities will be set in the definitions of quality depending on what aim is in the foreground and what is in the background.

Simply put, if the aim is to produce new knowledge, it is a task of *proving* something and the main criterion is *truth*. On the other hand, if the aim is to have implications for practice, the consideration for *usefulness* will be most important. This affects how quality is judged. Borrego and Bernhard (2011) cite Alan J. Bishop's distinction between two research traditions. In a *method-led* tradition, quality comes from proper use of methodology, making conclusions credible. In fact, the term 'rigorous' is used precisely because it is assumed that rigorous methods ensure truth. In a *problem-led* tradition, quality lies in selecting questions that are interesting and significant for real-world problems, and generating meaningful insights relevant for these problems.

Any definition of quality is always intricately intertwined with the question of who can be the legitimate judge of it. Considering the balance and relationship of the two aims is therefore not merely philosophical exercise. The priorities are followed by implications for legitimacy and power, with real consequences for the people within engineering education and its stakeholder groups. The tension is also relevant for the researcher's personal motivation to do EER. The identity as a researcher with a development agenda is quite different from that of a 'disinterested' researcher whose identity is often tied to a disciplinary belonging. This is, of course, a classic discussion for all research, and the debate has been lively within higher education and in society at large, not least with the expansion of research and higher education in recent decades. In the following, some useful ideas from these debates will be presented, first discussing discipline-led and then practice-led research.

DISCIPLINE-LED RESEARCH

Disciplinary autonomy and quality control

In academia, seeking knowledge for its own sake is, in practice, often the same as furthering a discipline. This is because the judgement of quality belongs with one's disciplinary peers, whose approval is the basis for dispensing all resources under academic control. The academic capital comes in hard currency such as publication, dissertation, funding, appointment, tenure, promotion, awards and prizes, etc. Borrego (2007b) defines a "rigorous engineering education researcher" as one who attracts funding and publishes in journals such as JEE, because, she explains, in both cases rigorous standards are enforced through peer review. The peer review instrument functions as a "powerful selection mechanism of problems, methods, people and results" (Gibbons et al., 1994), and the result is discipline in every sense of the word. The dictionary lists several meanings of discipline: a system of *rules of conduct* or *methods of practice*, the possession of *self-control*, and the act of *punishing* – all of which are also applicable to academic discipline. As Harvey Brooks (1967) points out: "Although scientists like to emphasize that fundamental research is 'free', it is actually, in another sense, a highly disciplined activity. The discipline is provided by the scientific community, to which the researcher is related. His choice of problem and direction is heavily conditioned by the social sanctions of this community, the requirements of originality, and scrupulous reference to related and contributing work of others." In the end, those individuals whose work is not judged to be up to the mark will inevitably be weakened and marginalized by a lack of resources and recognition – and this is exactly how the quality mechanism works. The weeding and pruning of its practitioners is the responsibility of the discipline; it is the quality control that legitimises academic freedom.

Thus the effort to establish EER as a discipline aims ultimately to achieve this autonomy, without which the researchers will struggle to achieve status and recognition in the academic landscape. As long as the researchers work in the academic environment the disciplinary logic will still fundamentally define their careers. In academia, disciplines are the "homes to which scientists must return for recognition or rewards" (Gibbons et al., 1994). Academic homelessness is a highly relevant issue for EER: "[Most] people in the community are living on the fringes. They are staff on soft money with no reward structure. The only way to give them a home to gain recognition is to have a home as a discipline." (Jesiek et al., 2009). In reality, stakeholder approval is also important for any discipline that depends on external funding. If legitimacy is lost, e.g. if it is perceived as an irrelevant ivory tower of "disinterested" researchers, there is a risk for discontinuation of resources (de Graaff, 2014). But as Gibbons et al. (1994, p. 23) point out: "Scientists have long appreciated that there is no intrinsic reason why the funding strategies of governments, firms, or foundations should conform to the current internal, cognitive structure of their discipline. Over the years, they have exercised great ingenuity in translating their own research interests into the language appropriate to other agendas."

What Defines a Discipline?

In a highly interesting account, Fensham describes the evolution of science education research (Fensham, 2004), which can be seen as a parallel to EER. He identified a number of maturity indicators for the disciplinary development of the research field (see Table 1).

Table 1. Fensham's disciplinary criteria for science education (Fensham, 2004).

Structural Criteria	**Research criteria**	**Outcome Criteria**
▪ Academic recognition ▪ Research journals ▪ Professional associations ▪ Research conferences ▪ Research centres ▪ Research training	▪ Scientific knowledge ▪ Asking questions ▪ Conceptual and theoretical development ▪ Research methodologies ▪ Progression ▪ Model publications ▪ Seminal publications	▪ Implications for practice

Applying these criteria to EER, Jesiek et al. (2009) noted that the structural criteria, i.e. the academic infrastructures of the field, are beginning to match. However, the research criteria, e.g. common research questions, conceptual and theoretical development, methodologies, and progression, imply a more coherent endeavour than is presently seen. Of Fensham's criteria, the *implications for practice* (outcome criteria) have hardly begun to be discussed and will need a deeper analysis.

So far, much debate on quality in EER has focused on methods, indicating a method-led approach (Borrego & Bernhard, 2011), and consistent with discipline formation. Borrego, Douglas, and Amelink (2009) state that to develop a scientific field, "appropriate methods, convincing evidence, and standards for evaluating the quality of research studies are just as important" as identifying important research areas. Clearly, claiming quality definitions is key to staking out disciplinary territory.

The focus on methods could also reflect certain assumptions about EER. An understanding of qualitative methods is seen as the missing element for engineering faculty who set out to do educational research (Borrego, 2007a; Case & Light, 2011; Koro-Ljungberg & Douglas, 2008). At one stage, EER was conceptualised as measurement, or 'assessment', of effectiveness of teaching methods (Olds, Moskal, & Miller, 2005). It was thought of as the first step for faculty who want to demonstrate that a (their) teaching intervention “works”, making methodological soundness crucial. However, this was identified as a limited view already by Streveler and Smith (2006) who argued that EER has the wider purpose “to answer fundamental questions about how students learn engineering”. And as de Graaff and Kolmos put it, “the aim of a scientific study is to understand the causes of the success or failure, not just to assess it” (Johri & Olds, 2014). They further note that the measurement paradigm conveys a false ideal of context-free knowledge, as “demonstrating that a specific method is successful in one classroom does not necessarily mean it will also be successful in another school with different conditions and with different teachers” (ibid). To deepen the discussion on methods, Baillie and Douglas (2014) argue that quality must start with the epistemology – the ways of knowing – and the ideal is a coherent alignment of theory, methodology, and methods.

So far, quality discussions focus little on the aims of research. In particular, the potential for improving education is seldom mentioned as a quality dimension. To take usefulness seriously, we need sophisticated understandings of what kind of research would be useful. Compared to well-established methodological aspects, it is more challenging to operationalize criteria related to usefulness. The problem-led research tradition emphasises values such as relevance to practitioners and meaningfulness of insights. Bernhard and Baillie (2013) propose criteria for the quality of the study *in general* (e.g. informed by theory, research question and literature, internal consistency), the quality of the *results* (e.g. richness in meaning, contribution) and the *validity* of the results (e.g. heuristic value, empirical anchorage, pragmatic criterion). As these dimensions can accommodate both scholarliness and usefulness, such criteria can lead the quality discussion, and the field, forward.

RESEARCH WITH A CONSIDERATION FOR USE

Mode 1 and Mode 2

Gibbons et al. (1994) provide useful concepts for understanding the interests on each side of the argument. ‘Mode 1’ is their term for the ideal model of traditional science, organised according to a discipline-led logic, where “problems are set and solved in a context governed by the, largely academic, interests of a specific community”. Thus, success can be described as “excellence defined by disciplinary peers”. Here, the relationship between research and practice is seen as linear: “discovery must precede application”. The other (newer) ideal with a problem-led logic is labelled ‘Mode 2’. Here, knowledge production and application are integrated: “When knowledge is actually produced in the context of application, it is not applied science, because discovery and applications cannot be separated, the relevant science being produced in the very course of providing solutions to the problems defined in the context of application” (p. 33). Such problem-led research challenges the disciplinary structure, because the cognitive logic follows the problems at hand: “…because the solution comprises both empirical and theoretical components it is undeniably a contribution to knowledge, though not necessarily disciplinary knowledge. Though it has emerged from a particular context of application, transdisciplinary knowledge develops its own distinct theoretical structures, research methods and modes of practice, though they may not be located on the prevailing disciplinary map” (p. 4).

The point is that both forms of knowledge production coexist and will continue to do so. Mode 2 challenges the hegemony of disciplines, with implications for what counts as interesting and valid problems to study, for the methods and participants of knowledge production, and for the evaluation of process and results. Quality is determined not only by the truth criterion but also by relevance and usefulness.

Usefulness is a Stakeholder Perspective

'Usefulness' implies someone beyond the researchers themselves who can benefit from the research, and this opens up for other interests and perspectives. Research agendas can be formulated in wider dialogues, and quality control may involve also other stakeholders. It is perhaps understandable if researchers hesitate to share the ownership of the research enterprise; it is a different order than the traditional academic one. It is perhaps telling when Jesiek et al. (2009) label the two aims "research" (in itself) and "practice and other 'external projects'". It remains to be seen if the EER community can sustain legitimacy if improving educational practice is seen as *external*. Research with a consideration for use may require a mind-set where research and development are more integrated, and rather than linear progression, we should create many kinds of interplay. If we are to understand how solutions and interventions could work, research problems cannot be reduced and context-free. Thus, the cognitive structure follows the logic of problems and the problems are set in a context. The boundary between research and development must be blurred and permeable, in a spiral of discovery, integration and application. Plenty of boundary work is needed and must be recognised, and so should boundary people.

COMBINING USEFULNESS AND SCHOLARLINESS

Pasteur's Quadrant

The balance and relationship between scholarliness and usefulness is both a philosophical and practical question, on the individual and collective level. For the field, there are implications for peer review, for upholding borders and forming relationships between research and development, or between researchers and developers. For individual researchers the tension is at the heart of every inquiry: do I consider 'what can be useful' or 'what can be known'? Or (how) can my work be *simultaneously useful and credible*?

Harvey Brooks (1967) helpfully pointed out that "the terms basic and applied are not opposites. Work directed toward applied goals can be highly fundamental in character in that it has an important impact on the conceptual structure or outlook of a field. Moreover, the fact that research is of such nature that it can be applied does not mean that it is not also basic." He mentions how Pasteur's work on practical problems was also conceptually ground-breaking, founding a whole new branch of science.

Elaborating Brooks' argument, Stokes (1997) put the label *Pasteur's Quadrant* on the intersection of consideration for use and quest for fundamental understanding (figure 1). In Edison's quadrant, focus is mainly on solving a specific problem, and Stokes points out "how strictly Edison kept his co-workers from pursuing the deeper scientific implications of what they were discovering in their rush toward commercially profitable electric lighting". Also Soderberg (1967) mentions how Edison, as well as Ford, were characterised by "a core of anti-intellectualism along with impatience toward scientific sophistication".
Bohr's quadrant is the basic science, seeking fundamental understanding. This is knowledge for its own sake, and the ideal is a disinterested researcher. Here, the premise is that *someone else* should figure out *later* if and how the new knowledge can be used. This is the

linear model of innovation starting with basic research, followed by applied research and development, and then with production and diffusion. The linear model has been largely refuted empirically but remains strong in arguments for funding basic science (Godin, 2006).

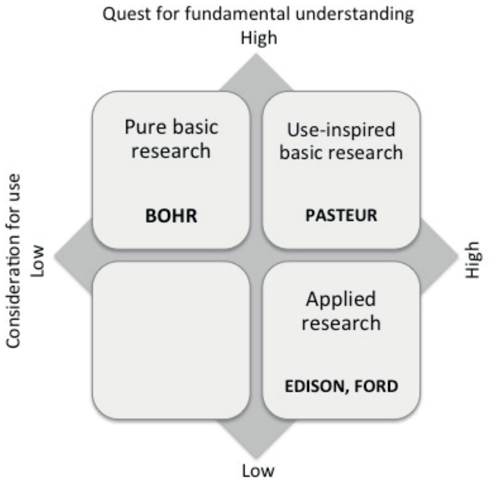

Figure 1. Pasteur's Quadrant (based on Brooks, 1967; Soderberg, 1967; Stokes, 1997).

Defending Both Sets of Values

Since success depends on internal recognition as well as external legitimacy, the demands of scholarliness and usefulness will always apply simultaneously. This does not mean that the tension can be glossed over. Values on *both* sides of the balance must be safeguarded and we must be able to see through hollow claims. For instance, disciplines have an interest in claiming usefulness to legitimate their resources. Likewise, there is an interest in labelling as research also what is really development, to improve status and opportunities for career and funding.

EER is facing the dilemma of any new community. To grow the field, thresholds to enter must be reasonable – but to enable progression and create recognition, standards must be raised and specialisation encouraged. The diversity has been seen to cause friction. Established researchers have rolled their eyes at newcomers' descriptive papers stating that "we tried it and liked it and so did the students" (Felder et al., 2005). Practice-oriented scholars have critiqued rigid definitions of rigour (Felder & Hadgraft, 2013) and worried that "high publication standards exclude practitioners" (Borrego et al., 2009). The field needs both specialists devoting their career to EER, often crossing over from other backgrounds, as well as part-timers, e.g. engineering faculty taking key roles in dissemination and implementation.

The conclusion is that the field needs a culture that can handle the diversity, and structures for productive dialogue. Nevertheless, EER needs quality mechanisms to stake out some borders and standards, at least to weed out such work that is neither scholarly nor useful. The EER community must understand the tension between the two aims and take on the important task to create a working and productive relationship between them. This is not going to be a simple task, but it must be done. Otherwise we risk landing in different camps, weakening the community in an eternal trench war. Success means creating legitimacy for the research that is simultaneously credible and useful, so it actually can contribute to the improvement of engineering education *and* create conditions for sustainable careers in academia.

THE ROLE OF CDIO IN EER

Criteria for review

When the CDIO Initiative opens a track for EER papers, the ambition is to make a contribution in the handling of this tension, by combining usefulness and relevance for improving engineering education with demands for scholarliness, while supporting the goals of the CDIO initiative.

Inspired by Bernhard and Baillie (2013), the first draft of review criteria for the 2016 International CDIO Conference were formulated with the aim to balance the aspects related to scholarliness and usefulness. See Table 2. The guiding questions avoid superficial compliance with technicalities. For instance, instead of asking about a methodology section, they ask for an adequate explanation how the problem is approached and the argument built. Instead of asking for research questions, they ask for a clear aim or problem statement.

Table 2. Review criteria for the EER track in the 12th International CDIO Conference, in Turku, Finland, June 12-16, 2016 (Edström, 2015).

Overall relevance	▪ Is the topic relevant, significant, interesting and timely for the engineering education community, and in particular for the CDIO Initiative?
Literature	▪ Is the paper informed by relevant theory and other literature? ▪ Is it put into good use here?
Aim or problem	▪ Is it clear what the paper is trying to achieve, what problem it addresses? ▪ Does this have significant implications for the audience?
Research approach	▪ Does the paper adequately explain how the problem is approached and how the argument is built? ▪ Are limitations critically discussed?
Conclusions	▪ Do conclusions address the stated problem or aim? ▪ Are the claims credibly supported? ▪ Does the paper deliver a take-away message for the community?
Coherence and clarity	▪ Is the paper clearly and logically structured? ▪ Do the parts contribute to the whole? ▪ Can the reasoning be followed through the paper? ▪ Is the paper readable and language appropriate for the audience?

How CDIO can Strengthen EER, and Vice Versa

Creating a connection between the CDIO Initiative and the EER community has potential advantages for both sides. CDIO brings to the table a dynamic international community with many experienced people, a diversity of institutions, and the CDIO approach as a joint frame of reference. The International CDIO Conference attracts a wide international audience of experienced and critical practitioners; it is an arena for developing a bold agenda for useful research.

In the CDIO community, the educational reform was always first and foremost a practical endeavour. However, although it was never a purely intellectual pursuit we always approached the educational development work with considerable curiosity and willingness to learn from the experiences. Our ideal for research on engineering education should be

Pasteur's quadrant (Figure 1), where practical usefulness intersects with new understandings. Even when our approach to educational development is highly result-oriented, i.e. when we are in Edison's quadrant, we recognise the potential for experiential learning. Not least, we have tried and failed, and tried again, enough times to result in interesting lessons learned.

The CDIO community has always been an arena for jointly analysing these experiences and validating empirical knowledge. The annual conference proceedings have became our most formal mechanism for archival and dissemination. The ultimate aim of adding a conference track for EER is to further sharpen our tools for educational development, and to increase our available toolbox by adding new perspectives. It will encourage us to practice even more of the good intellectual habits from research, e.g. building on previous work, making room for more systematic reflection, and raising the ambition in documenting our work and communicating it. This may support us in producing more, and more credible, evidence to increase legitimacy and support dissemination. The move to include EER can stimulate individuals to keep developing within the community over a longer term, when the work they produce is better aligned with incentive systems in academia. We can hope to attract some new friends who might bring new interesting perspectives and ways of knowing and working.

However, taking the step to add EER to our repertoire does not mean that we value engineering education development any less. The hierarchical and linear thinking, which places research before and above development, should always be rejected. We are not co-opted into research; we do it to strengthen our important mission.

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BIOGRAPHICAL INFORMATION

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CDIO AS A CROSS-DISCIPLINE ACADEMIC MODEL

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ABSTRACT

The purpose of this paper is to examine the broader applicability of the Conceive Design Implement Operate (CDIO) curricular model (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) across academic disciplines adjacent to and outside of engineering.

To study this, we examined a sample of five selected undergraduate degree programs developed at Sheridan College Institute of Technology and Advanced Learning as case studies. Housed in four different academic Faculties, each program has varying proximity to technology education. We used one additional CDIO-based program, Bachelor of Engineering – Mechanical, in the Faculty of Applied Science and Technology (Mechanical), as the control group to assess how an engineering program might appear in our findings.

To test our questions, using a series of matrices, we mapped discipline-specific program learning outcomes (PLOs) and characteristics onto the CDIO framework and UNESCO framework (Delors, et al., 2013), assessing compatibility / incompatibility.

We discovered that we were able to successfully map non-engineering discipline curricula to the CDIO model when terminology was modified to be discipline-specific. Non-engineering programs mapped closely at the first level (X) where the CDIO model merges with UNESCO standards, and at the CDIO Standards level, where all studied programs rated highly. Some discipline-specific modifications were required to achieve a mapping to the second level (X.X) of CDIO Syllabus. Additionally, our observations of the mapping to the second level of CDIO Syllabus revealed significant variation in curricular emphasis by program.

KEYWORDS

Universal model, Non-engineering disciplines, Mapping, UNESCO, CDIO Syllabus, CDIO Standards: 1 - 12

INTRODUCTION

The purpose of this paper is to examine the broader applicability of the Conceive Design Implement Operate (CDIO) curricular model (Crawley E. F., Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) across academic disciplines adjacent to and outside of engineering. Our inspiration to undertake this investigation is rooted in the dynamic growth of our home institution, Sheridan College Institute of Technology and Advanced Learning (Sheridan). As such, a brief institutional history is provided as background context for undertaking this research.

Sheridan is a post-secondary institution on three campuses in adjacent cities of the Greater Toronto Area, in Ontario, Canada. Sheridan serves approximately 20,000 full-time students and 35,000 continuation education students. Founded in 1967 as a College of Applied Arts and Technology, it initially offered 1-year (certificate), 2-year (diploma) and 3-year (advanced diploma) credentials. In 2003, Sheridan changed designation along with 4 other regional institutions, and became an Institute of Technology and Advanced Learning (ITAL), analogous to becoming a polytechnic. This provided the institution with access to develop and offer 4-year undergraduate degrees. Since then, Sheridan has experienced a dynamic curriculum growth, developing and offering 20 new 4-year undergraduate degrees, with a number of additional degrees in various stages of development and application. In 2012, president Dr. Jeff Zabudsky announced the “Sheridan Journey,” with the vision, “to become Sheridan University, celebrated as a global leader in undergraduate professional education” (Sheridan). While established as a prolific research institution among Canadian large colleges – ranked first in formal research projects completed, 2015 (Research Infosource Inc., 2015) – focus remains on educating students, with a strategic goal to, “inspire creative, innovative teaching and learning” (Sheridan, 2013).

One such degree in the development and application process is the Bachelor of Engineering – Mechanical. The authors of this program, lead by Dr. Farzad Rayegani, selected the CDIO curriculum model along with Canadian Engineering Accreditation Board (CEAB) requirements to drive curriculum development. They appreciated the CDIO philosophy of positioning graduates to be successful in their discipline by combining theory and practice in a way unique in engineering education. To summarize, the initiative was developed to ensure engineering students receive a rational, complete and generalizable universal education that prepares them to be leaders and in some cases entrepreneurs (Crawley E. , Malmqvist, Lucas, & Brodeur).

During development there was an engaged discussion about the CDIO curriculum model across disciplines and Faculties at Sheridan, especially as CDIO’s emphasis on creativity and experiential learning aligns well with our institutional values. These conversations included one of the authors of this paper, Dave Wackerlin, who at the time was co-authoring a Bachelor of Architectural Studies degree development. The cross-institutional prolific development of new degree programs, that extended conversation, and this author’s reflection upon how CDIO might inform development of Architectural Studies curricula, inspired this research paper.

The current CDIO initiative is geared specifically to engineering, but given its success, the topic this paper investigates is CDIO’s broader applicability across disciplines. **Can the CDIO philosophy be generalized to create a more universal model that includes other academic disciplines?** Our literature review indicates that no academic institution has adopted this model for programs outside of engineering and engineering related sciences (such as Engineering Technology and programs of Applied Science), which is intuitive, considering the engineering directed terminology used in the model. However, our own personal experience with the CDIO model suggests that it resonates outside the focused disciplines of engineering. To explore this topic, we asked three sets of questions.

First, **could we effectively map other discipline specific curriculum onto the CDIO Standards and Syllabus structure by varying the engineering specific terminology?** If so, **would that create at an effective curricular variant that preserves the CDIO values and strengths?** Preliminary findings with a technology-related program suggested so, and we elected to broaden the investigation to other programs to find if there is a boundary of effective mapping as disciplines become less technical in nature.

Our second research question is, **how does mapping each program to the CDIO model inform future iterations of syllabus revision undertaken by that program?** Each of the five programs studied is mandated to undertake comprehensive program review at maximum span of 7-year intervals. Observations from our research could potentially identify opportunities the program might explore for implementation in their curriculum.

Our last research question informs CDIO curriculum and those who implement CDIO curricula at their institutions. **How can the study of the mapping of non-engineering disciplines to CDIO, and in particular how portions of the syllabus are emphasized differently by non-engineering disciplines, inform future iterations of the CDIO syllabus and particulars of its implementation?**

METHOD

Participants

To study our questions, we used a sample of selected undergraduate degree programs developed at Sheridan College as case studies. Housed in four different academic Faculties, each program has varying proximity to technology education. The programs and Faculties studied are:

- Bachelor of Applied Information Sciences – Information Systems Security in the Faculty of Applied Science and Technology (Computing),
- Bachelor of Health Sciences – Kinesiology and Health Promotion in the Faculty of Applied Health & Community Studies (Health Sciences),
- Bachelor of Architectural Studies in the Faculty of Applied Science and Technology (Architecture),
- Bachelor of Illustration in the Faculty of Animation, Arts & Design (Illustration),
- Bachelor of Business Administration – Accounting in the Pilon School of Business (Accounting).

Additionally, we used a CDIO-based program, Bachelor of Engineering – Mechanical in the Faculty of Applied Science and Technology (Mechanical), as control group to asses how an engineering program might appear in our findings.

Design

To test our questions, we mapped discipline specific program learning outcomes (PLOs) and characteristics onto the CDIO framework and UNESCO (Delors, et al., 2013) framework, assessing compatibility / incompatibility.

Our data sources were formal degree application / renewal documents that had been submitted to our provincial government, provided by each of the individual programs. These documents were:

- Computing; Application for Ministerial Renewal 2012 (Sheridan, 2012)
- Health Sciences; Program Review 2012 (Sheridan, 2012)
- Architecture; Application for Ministerial Consent 2014 (Sheridan, 2014)
- Illustration; Application for Ministerial Renewal 2012 (Sheridan, 2012)
- Accounting; Application for Ministerial Consent 2012 (Sheridan, 2012)
- Mechanical; Application for Ministerial Consent 2014 (Sheridan, 2014)

To ensure that our comparator curricula was sufficiently robust for this study, we established that all of the programs participating met benchmarks for quality through a review of the degree application / renewal documents. We found that all five degree programs:

- Were developed or renewed within the last 4 years of this study, suggesting modern curriculum theory and practice had been implemented,
- Were designed internally by professional academics who as a team possessed expertise in their fields, industrial experience, and teaching / learning expertise,
- Were designed following an institutionally mandated internal process and receiving multi-stage approvals to ensure quality,
- Where applicable, were designed in alignment with established professional standards
- Employed Program Advisory Councils (PACs) in both development and delivery upon operation.

Our review of these quality assurance measures validated that the programs studied use curricula of quality sufficient to study.

We also performed a review of the CDIO model to confirm its suitability for consideration in this study. Notable literature included the works of Crawley et al, (Crawley E. F., Malmqvist, Ostlund, Brodeur, & Edstrom, 2014) (Crawley E. , Malmqvist, Lucas, & Brodeur) which detail the CDIO model, and review of the UNESCO Know – Do – Live – Be pedagogical model (Delors, et al., 2013). One author also attended the 2014 10th annual CDIO conference in Barcelona, Spain, and observed paper presentations by CDIO participant institutions. Our review validated that CDIO curriculum is suitable for study as curricular exemplar.

When comparing these programs to the CDIO model, we separated our observations into three categories. We considered the top level (X) of the CDIO syllabus, which Crawley identifies as mapping to the UNESCO Know – Do – Live – Be model, (Delors, et al., 2013), the second level (X.X) of the CDIO Syllabus with more detailed description, and the CDIO Standards.

Setting and Procedure

Stage 1 – Study of the “detailed program map” for each program.

Each detailed program map was reviewed and studied in detail. Containing a compressed version of course outlines, complete with course description, critical performance statements, course learning outcomes and evaluation plans, detailed program maps revealed the details of courses that made up the curriculum, in addition to specific detailed administrative information such as delivery method and credit hours, etc.

Stage 2 – Study of “PLO’s and the “PLO matrix” for each program.

Each of the PLO’s were reviewed to understand the topics and level of learning that the program was delivering. The outcomes had been assembled in a matrix by program authors to illustrate the correlation between them and the individual courses that make up the programs. Authors of this study reviewed those matrices to understand depth and breadth of individual PLO integration into the curriculum.

Stage 3 – Development of UNESCO and CDIO Mapping Matrices.

Applying Stage 1 and 2 findings, three mapping matrices were developed to assess the data.

Matrix 1: UNESCO / Program Comparison. Using the four pillars of learning (know – do - live - be) defined by UNESCO as categories, we compared the UNESCO model to the PLOs of each program. In addition, a fifth category, titled “Additional” was introduced with the purpose to harmonize the UNESCO and CDIO models (see Table 1). Findings were established based on a literature review of the detailed program map and learning outcomes, and verified by each author for consistency. The matrix was designed with the x-axis representing the 4+1 categories of UNESCO / Additional and the y-axis representing each of the six programs. A numeric rating scale from 1 to 5 was used to assess the correlation, with 1 being least correlated and 5 being most correlated.

Matrix 2 – CDIO Syllabus / PLO Comparison. Using the five categories of the CDIO Syllabus level 1 (X) and level 2 (X.X), a matrix was developed to compare the CDIO syllabus to each of the PLO’s for the six programs studied. The matrix was designed with the CDIO Syllabus categories on the x-axis and the PLO’s on the y-axis. Using a colour coding technique each of the cells were highlighted according to the PLO’s proximal relationship to CDIO Syllabus item. To express this relationship three categories were established; engineering application relationship to CDIO (white); non-engineering application relationship to CDIO (grey); and no relationship (black).

Findings from our analysis comparing PLO’s to CDIO Syllabus Level 2 (X.X) are organized into three categories to answer each of our study questions; observations, impact for program, and impact for CDIO. ‘Patterns’, which are groupings of the colour coded cells read vertically in the matrix and identified by an outline in the figures, are described in the observations associated to that program.

Matrix 3 – CDIO Standards / Program Comparison. Using the 12 Standards outlined in the CDIO Standards, a matrix was developed to compare with each of the six programs studied.

The matrix was designed with the 12 Standards on the x-axis, and the each of the six programs on the y-axis. We applied the rubric criteria defined by the CDIO, from 0 to 5. Each of the cells were rated based on their relationship to the CDIO Standards.

Stage 4 – Collaboration with Program Specific Experts. Throughout the mapping of the data, discussions were had with each Associate Dean representing the six programs to clarify or provide additional information required. Following matrices development, we met with the Associate Dean from each program to discuss our research methodology and findings. Their intimate knowledge of each program aided in achieving valid and reliable findings. There were a few instances where changes were suggested. When this occurred, a thorough explanation was given to ensure changes were accurately made and to ensure everyone was informed. Interviewing experts from each of the programs also reduced potential bias as it equalized our depth of knowledge of individual programs used to examine results.

Addressing Potential Sources of Bias

This study relies on coding of documents and interpretation of language to establish findings. As such, there are several potential sources of bias that we have addressed.

A potential source of bias, that PLO's were not written with CDIO in mind, and therefore direct interpretation to CDIO can be discretionary, was addressed by thorough review of course outlines, course learning outcomes, and collaborative interviews with program leaders to ensure accurate mapping.

Another source of bias we considered was observer bias in the form of interpretative differentiation between coders (the authors) in assigning colour coding to the cells. The two authors addressed this by each author validating all matrices drafted by the other, and through collaborative interviews with program leaders.

We discovered that reading the matrices horizontally versus vertically when colour coding had some influence on results. To address this, we double coded each matrix (both horizontally and vertically), and validated each other authors coding.

REPORT/FINDINGS (RESULTS)

Matrix 1 - UNESCO / Program Comparison

As illustrated in Table 1 below, despite some variation in emphasis between the curricula examined, it is evident there is a strong correlation between all six of the programs and UNESCO Standards. While there is some variation in total scores of individual programs, we did not find evidence suggesting that this is indicative of quality difference between the curricula. Rather, it suggests their proximal relationship to UNESCO, which is close in all cases. This analysis revealed a stronger relationship between the 6 programs and UNESCO than to the CDIO Syllabus at level 2 (X.X). We attribute this to several factors. First, UNESCO is multi-disciplinary curriculum design model, and therefore was designed with a multi-disciplinary lens, where the CDIO Syllabus was designed with a focus on the disciplines of engineering. Secondly, it can be expected that all programs in our study have a strong emphasis on the ‘know’ and ‘do’ categories as this aligns with Sheridan’s core value of preparing industry ready graduates. Lastly, the UNESCO standards are higher level and less detailed than CDIO Syllabus Level 2, so there are fewer and less defined categories to compare to. More varying responses are found in categories ‘live’, ‘be’, and ‘additional’. We consider that this variation is indicative of variation between discipline foci rather than quality of curriculum. For example, Accounting is the only program to achieve a 5 in the ‘Additional’ category, which could be anticipated given the business focus of the program.

Table 1. Matrix 1: UNESCO / Program Comparison

UNESCO Mapping					
Scale 1 - 5	**Know**	**Do**	**Live**	**Be**	**Additional**
	DISCIPLINARY KNOWLEDGE AND REASONING	PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	THE INNOVATION PROCESS	LEADERSHIP AND ENTREPRENEURSHIP
Bachelor of Engineering - Mechanical	5	4	3	5	4
Bachelor of Applied Info Sciences – Info Systems Security	5	5	3	4	3
Bachelor of Health Sciences	5	5	4	3	4
Bachelor of Architectural Studies	5	5	4	4	4
Bachelor of Illustration	5	4	4	4	3
Bachelor of Business Administration - Accounting	5	4	4	4	5

Matrices 2 – CDIO Syllabus / PLO Comparison

This study surfaced a number of interesting observations regarding individual programs, which are detailed below. There are also some findings that are generalizable across all of the programs; there was a high degree of non-engineering (grey) mapping, and certain terms that might commonly be considering engineering related (math, science, design, experiment, implement, operate) were found regularly throughout the non-engineering PLO’s. Our findings supported our primary research question, as we were able to map all programs to the CDIO standard successfully. Pattern comments identify areas of interest in observations, but do not attempt to address all features of the matrix. Further research could have increased detailed observations for individual programs and follow-up on pattern observations.

Bachelor of Engineering – Mechanical

Table 2. Bachelor of Engineering – Mechanical: CDIO Syllabus / PLO

Bachelor of Engineering - Mechanical	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 DESIGNING	4.5 IMPLEMENTING	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
Degree Program Level Learning Outcomes																			
1 Create sustainable engineering solutions through applications of mathematical, scientific and fundamental engineering concepts, methods and techniques.																			
2 Create sustainable engineering solutions that are based on feasibility, technology, environmental impact, and economic assessments.																			
3 Validate conclusions through investigations of complex engineering problems that include relevant experimentation, data collection, analysis, interpretation and synthesis.																			
4 Design a system, component, or process that meets regulatory and industry standards and considers, health and safety risks, economic, environmental, cultural and social impacts																			
5 Demonstrate proficiency in the techniques, skills, and tools necessary for mechanical engineering practice with an understanding of the associated limitations.																			
6 Perform as an effective team member and leader in collaborative, multidisciplinary settings.																			
7 Communicate technical concepts and issues effectively with both technical and non-technical audiences.																			
8 Explain the roles and responsibilities of the professional engineer in society.																			
9 Analyze the impact of engineering solutions in a global, economic, societal and environmental context.																			
10 Demonstrate ethical conduct, accountability and equity consistent with the requirement of the profession.																			
11 Incorporate business practices, including project management tools & techniques, into practices of engineering.																			
12 Develop self-leadership strategies to enhance personal and professional effectiveness that is responsive to a rapidly changing world.																			
Pattern #	1										2	3						4	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 - An even distribution of learning in disciplinary knowledge and reasoning that is emphasized in a large number of the learning outcomes. The correlation represents a direct relationship to the CDIO Syllabus, which we expected because it is an engineering discipline.

Pattern #2 – No foreign languages PLO. Several of the studied programs, including Mechanical, did not emphasize foreign language.

- Impact for Program; Opportunity to explore ways of integrating foreign language in the existing curriculum and provide pathway to global employment.
- Impact for CDIO; Opportunity to further focus on the importance of foreign languages and provide recommendations on how it can be successfully integrated into curriculum.

Pattern #3 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns and is a positive example of CDIO implementation intent.

- Impact for Degree; This aligns with the industry standard according to the CDIO mandate and prepares graduates of the program to be industry ready.

Pattern #4 – Low relationship between 'entrepreneurship' and the course learning outcomes.

- Impact on Program; Existing engineering programs at Sheridan have extensive industry partnerships that is not reflected in this list, opportunity to formalize in PLO's.
- Impact on CDIO: Opportunity to Incorporate intrapreneurship overtly into syllabus.

Pattern #5 - Program learning outcomes were written with intent to align to CDIO, which created an observable learning outcome mapping 1:1 relationship emphasis. They were also all engineering aligned. The map views as ‘less dense’, which we interpret as a reflection of this CDIO oriented design compared to the other study participants, whose program addressed CDIO Syllabus in a less targeted, broader (more cells, less engineering) manner.

Bachelor of Applied Information Sciences – Information Systems Security

Table 3. Information Systems Security: CDIO Syllabus / PLO

Bachelor of Applied Information Sciences – (Information Systems Security),	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 DESIGNING	4.5 IMPLEMENTING	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
Degree Program Level Learning Outcomes																			
1 Analyze, **design,** program, **implement**, secure and maintain network applications																			
2 **Design, implement,** test and document object-oriented software systems																			
3 Install, configure, build, troubleshoot, secure, modify and maintain computer system architectures and networks to meet user requirements																			
4 Initiate and undertake critical analysis of security issues to develop and **implement** security policies and to solve problems																			
5 **Design, implement,** program, secure, troubleshoot and administer databases																			
6 Communicate clearly, concisely, and correctly in written, spoken, and visual form that fulfills the purpose and meets the needs of diverse audiences																			
7 Reframe information, ideas, and concepts using the narrative, visual, numerical, and symbolic representations which demonstrate understanding																			
8 Interact with others in groups or teams in ways that contribute to effective working relationships and the achievements of goals																			
9 Identify, evaluate, report on and, understand when, how and where to refer security issues																			
10 Identify and **implement** investigative techniques adhering to legal processes and case law																			
11 Analyze, **design,** and **implement,** security and threat auditing procedures																			
12 Identify, **design,** and **implement** processes and vulnerability assessments to counter corporate, state, and politically sanctioned losses																			
Pattern #				1							2			3				4	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – Analytical reasoning and problem solving is a ‘core value’ in the program, and shows as strong mapping on the matrix.

Pattern #2 – Currently there is no learning outcome that addresses communication in foreign languages. See: Bachelor of Engineering - Mechanical.

Pattern #3 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns with the intent of the design of this degree program. Aligns closely with Bachelor of Engineering – Mechanical.

Pattern #4 – Low relationship between ‘entrepreneurship’ and the course learning outcomes. See: Bachelor of Engineering - Mechanical

Bachelor of Health Sciences – Kinesiology and Health Promotion

Table 4. Kinesiology and Health Promotion: CDIO Syllabus / PLO

	Bachelor of Health Sciences – Kinesiology and Health Promotion	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
		1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 DESIGNING	4.5 IMPLEMENTING	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
	Degree Program Level Learning Outcomes																			
1	Develop scientficially based, goal directed physical activiy and lifestyle plans specific to individual and/or group needs and abilities																			
2	Provide leadership in the **implementation** of fitness and wellness promotion programs specifically developed for special populations that consider the variables associated with intergenerational programming and cultural diversity																			
3	Integrate research for the purpose of making informed planning decisions on health, fitness and performance-related outcomes in diverse populations																			
4	**Design** health promotion programs, establishing valid and appropriate approaches through application of the scientific method																			
5	Provide leadership in the intergration of health wellness and safety programming into corporte environments																			
6	Establish best treatment practices for populations with special needs within an inter-professional healthcare team environment																			
7	Guide individuals or groups to assist them in reaching their physical health and lifestyle goals																			
8	Manage the financial, legal and human resources necessary to operate a small business or work effectively within a larger corporate business																			
9	Recruit and train volunteers for a variety of health promotion and fitness initiatives in both the corporate and not-for-profit sectors.																			
10	Work in a manner consistent with professional ethics and pratice, and within legal and organization requirements																			
11	Communicate effectively in written, spoken and visual forms.																			
		1	2				3			4					5				6	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – This program has an emphasis on descriptive sciences, such as anatomy. It also has a focus on social / behavioural science applications of those sciences.

Pattern #2 – A strong emphasis on application of discipline specific knowledge.

Pattern #3 – Emphasis is placed on system thinking throughout the curriculum. This prepares students for the duties they will be required to do in the working field; such as designing health promotion programs for clients, advising clients of best treatment practices, ensuring clients reach fitness goals, etc.

Pattern #4 – Teamwork is a 'core value' of the curriculum and Health industry. Many of the graduates will be integrated with a team of professionals and with clients through services such as personal training.

Pattern #5 – There is an equal distribution of conceiving, designing, implementing and operating spread throughout the learning outcomes. This aligns with CDIO philosophy.

Pattern #6 – Emphasis is placed on leadership and entrepreneurship. Many students will graduate and work independently as entrepreneurs in the health and wellness industry.

Overall – Program matrix reveals an equitable distribution across PLO's and CDIO syllabus.

Bachelor of Architectural Studies

Table 5. Bachelor of Architectural Studies: CDIO Syllabus / PLO

	Bachelor of Architectural Studies	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
	Degree Program Level Learning Outcomes	1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 DESIGNING	4.5 IMPLEMENTING	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
1	Recommend **design** choices based on a critical understanding of the relationship between human behaviour, the natural environment and the design of the built environment.																			
2	Analyze information pertaining to the programming, **design** and presentation processes involved in the architectural project. (The steps to conveying an architectural project to a prospective client include the programming of spaces in order to determine usages and adjacencies, the **implementation** of a coherent design that speaks to a concept, and the preparation of a presentation that will include drawings, models, photographs, studies, precedents, etc.)																			
3	Apply organizational, spatial, structural and constructional principles within the process of the conception and development of sites, spaces, building elements and tectonic components that will be used by individuals of varying physical and cognitive abilities.																			
4	Identify the diverse needs, values, behavioural norms and social/spatial patterns that characterize different cultures and individuals, and the implications of this diversity on the societal role and responsibilities of those working in the architectural profession.																			
5	Depict the diverse global and local traditions in architecture, landscape and urban **design**, as well as the factors that have shaped them.																			
6	Incorporate the principles that inform the **design** and selection of life-safety systems into buildings and their subsystems including legislation, building codes, and standards applicable to a given site and building design project.																			
7	Create a comprehensive program for an architectural project that accounts for client and user needs, appropriate precedents, space and equipment requirements, the relevant laws and standards, site selection, context and condition, and **design** assessment criteria, based upon an architectural idea.																			
8	Communicate through appropriate representational media the essential formal elements at each stage of the programming and design process, including technically precise description and documentation of a proposed **design**, for purposes of review and construction.																			
9	Respect the principles of sustainable **design** to produce projects that conserve natural and built resources, provide healthy environments for occupants/users, and reduce the impacts of building construction and operations on future generations.																			
10	Select appropriate combinations of building materials, components and assemblies for **design** details.																			
11	Formulate projects that fully integrate structural systems, environmental systems, life-safety systems, building envelopes and building service systems into building **design**.																			
12	Contribute to the **design** and/or **implementation** of applied research projects within a collaborative context.																			
13	Interpret information related to financing, building economics, construction cost control, life-cycle cost accounting and elements of project delivery that pertain to cost outcomes.																			
14	Describe the different methods of project delivery, the corresponding forms of service contracts, and the types of documentation required to render competent, ethical and responsible professional service.																			
15	Outline the techniques and skills for architects to work collaboratively with allied disciplines, clients, consultants, builders and the public in the building **design** and construction process, and to advocate on environmental, social and aesthetic issues in their communities.																			
16	Describe the profession's responsibility to the client and the public under the laws, codes, regulations and contracts common to the practice of architecture.																			
17	Explain the basic principles and practices applied in an architectural organization, including financial management, business planning, marketing, negotiation, project management and risk mitigation.																			
18	Apply the basic principles utilized in the appropriate selection of construction materials, products, components and assemblies, based on their inherent characteristics and performance.																			
	Pattern #	**1**		**2**								**3**			**4**				**5**	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – There is less math and science than engineering programs, but direct engineering connection. The engineering connection is a direct translation to the understanding of how buildings are assembled through a series of structural courses.

Pattern #2 – Advanced engineering skills, analytical reasoning, investigating and system thinking are all 'core values' in the realm of architectural thinking. This is the foundation of understanding architecture.

Pattern #3 – There is no direct teaching of foreign languages, but several PLO's identify their importance.

- Impact for Degree: Given the degree program has a travel semester integrated into the curriculum, there is opportunity to broaden the focus on communication in foreign languages. This would also strengthen the understanding of cultural traditions in the field of design.

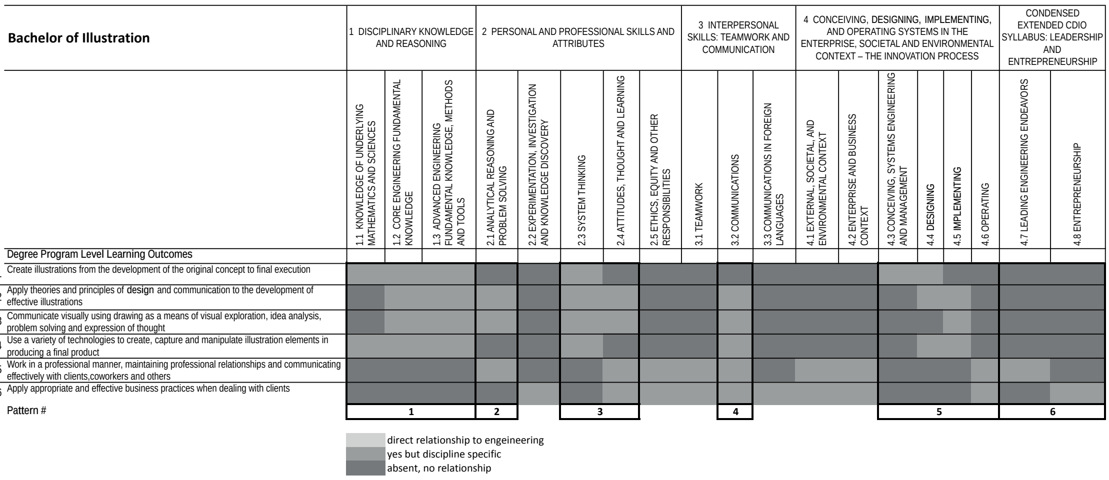
Pattern #4 – PLO's address conceiving, designing, and implementing. It is difficult to teach students through the making of full scale buildings. Strategies to overcome this are achieved through the making of scaled models.

- Impact for Degree: Find ways to have students work on full scale projects, such as the collaboration with Habitat for Humanity.

Pattern #5 – Learning outcomes emphasize leadership as Architectural practitioners are commonly 'prime consultants' who organize and lead the numerous consultants involved in construction projects. Learning outcomes emphasize entrepreneurship as consultants or partners in small businesses, a common growth outcome for graduates.

Bachelor of Illustration

Table 6. Bachelor of Illustration: CDIO Syllabus / PLO



Observations

Pattern #1 – Fundamentals of math and science are addressed but not emphasized. We observe the curriculum emphasizes discovery characteristics across the matrix.

Pattern #2 – Analytical and problem solving is a core value and emphasis of the program. These are the fundamental skills in teaching students how to logically understand and solve a problem.

Pattern #3 and 5 – In the creative field of design (illustration) students are taught to be visual artist and use their imagination to understand problems and derive a solution. This systems thinking approach follows the methodology in place by CDIO as conceiving, designing, implementing and operating, one of the core values.

Pattern #4 – Communication is important in expressing attitudes visually and is also a core value.

- Impact on CDIO: Explore emphasis on different types of communication.

Pattern #5 – Emphasis on Design and Implement, which reflects discipline orientation, and the lack of requirement to 'operate' illustration installations.

Pattern #6 – In the field of design illustration we expect a significant number of artists become entrepreneurs.

- Impact for Degree: Opportunity to examine if additional entrepreneurship emphasis is appropriate.

Bachelor of Business Administration – Accounting

Table 7. Accounting: CDIO Syllabus / PLO

	Bachelor of Business Administration - Accounting	1 DISCIPLINARY KNOWLEDGE AND REASONING			2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES					3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION			4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS						CONDENSED EXTENDED CDIO SYLLABUS: LEADERSHIP AND ENTREPRENEURSHIP	
		1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS	2.1 ANALYTICAL REASONING AND PROBLEM SOLVING	2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY	2.3 SYSTEM THINKING	2.4 ATTITUDES, THOUGHT AND LEARNING	2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	3.1 TEAMWORK	3.2 COMMUNICATIONS	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT	4.2 ENTERPRISE AND BUSINESS CONTEXT	4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT	4.4 DESIGNING	4.5 IMPLEMENTING	4.6 OPERATING	4.7 LEADING ENGINEERING ENDEAVORS	4.8 ENTREPRENEURSHIP
	Degree Program Level Learning Outcomes																			
1	Create relevant, complete and accurate financial statements and information reports using the appropriate accounting principles to provide information to measure the entity's performance.																			
2	Interpret financial statement and organizational results to enhance the entity's decision making performance.																			
3	Assess the measurable objectives of an entity's strategic plan using appropriate quantitative and qualitative analyses.																			
4	Use appropriate technological tools and information systems necessary to provide the required financial information for effective decision making.																			
5	Evaluate strategic opportunities that add value and are consistent with operational goals, policies and procedures.																			
6	Contribute to the development of investment plans, business plans and financial proposals to assist in converting the entities financial strategies into specific financial objectives.																			
7	Evaluate internal controls and audit requirements in accordance with generally accepted auditing standards.																			
8	Prepare regulatory filings in accordance with legal requirements.																			
9	Analyze the implications of an entity's tax-planning strategies.																			
10	Apply legal concepts within the domestic and international business environment identifying the need for professional legal guidance.																			
11	Communicate effectively in a variety of organizational settings.																			
12	Evaluate complex qualitative and quantitative data to support strategic and operational decisions.																			
13	Develop comprehensive strategic and tactical plans for an organization.																			
14	Work independently and collaboratively in inter and/or multi-disciplinary and diverse environments.																			
15	Use creative, critical and reflective thinking to address organizational opportunities and challenges.																			
16	Apply problem solving and decision making frameworks that propose defensible solutions to organizational opportunities, challenges, change and risk.																			
17	Demonstrate ethical and socially responsible behaviour.																			
18	Integrate appropriate technologies in developing solutions to business opportunities and challenges.																			
19	Build effective internal and external relationships using influencing, communication and consultative skills.																			
20	Evaluate the dynamic of the global business environment from a competitive and economic perspective.																			
21	Develop self leadership strategies to enhance personal and professional effectiveness.																			
22	Assess business processes relative to organizational goals.																			
23	Perform robust research through the application of accepted applied research methodologies.																			
	Pattern #		1			2						3				4			5	

direct relationship to engeineering
yes but discipline specific
absent, no relationship

Pattern #1 – One of the fundamental skills (core value) of the accounting field is math. We observe a strong relationship to that specific stream in the CDIO Syllabus.

Pattern #2 – Problem solving, knowledge discovery, and system thinking are all 'core values' in the realm of accounting. Students will be working on a range of project types throughout their career that will address these core values; such as, developing strategic and tactile plans for organizations, use critical and creative thinking skills to address organizational opportunities and challenges, evaluating quantitative data and contextualizing it, etc.

Pattern #3 – As our economy and business industries continue to globalize, it is predictable that this program has a strong relationship to that portion of the CDIO syllabus. Globalization is a core value of the business cluster of degree programs.

Pattern #4 – There is an emphasis on conceiving and operating. This is emphasis is predictable as the industry follows the external accounting regulations and practices.

Pattern #5 – Though the field of business has a high rate of entrepreneurs, there is no direct entrepreneurship connection to the CDIO. In follow-up meeting we found that integration and definition of entrepreneurship differs from CDIO.

- Impact for CDIO: Opportunity to consider the ways Accounting defines and integrates entrepreneurship into their curriculum.

Matrix 3 – CDIO Standards / Program Comparison

As illustrated in Table 8 below, all programs studied are valid, strong curricula and are fully compliant to CDIO Standards, resulting in scores of 5/5. We found this result surprising at first examination. However, upon close review of the supporting documentation, we confirmed the reliability of these findings. As explanation, we consider that strong centralized program oversight, both internally within our institution through review processes, and externally by provincially mandated program renewal processes, cause programs to create and maintain robust quality assurance recording mechanisms. All programs are reviewed and revised within a 7-year timeframe to meet ministry standards, with renewal of ability to offer the program contingent upon successful renewal. Programs are often revised to ensure they align with the institutional vision and mission and are up-to-date with industry standards, and with professional advisory committees.

Note that each program was evaluated based on their discipline, not on engineering, which would have much lower applicability in learning outcomes. Where the word “Engineering” was used in Standard 4 and 6, it was replaced to reflect the specific disciple. For example, “Introduction to Engineering” was replaced with “Introduction to Accounting” to reflect the Bachelor of Business Administration program). Similarly, we reviewed documentation to ensure that appropriate discipline specific workspaces were provided in assessing compliance with Standard 6.

Table 8. Matrix 3 – CDIO Standards / Program Comparison

CDIO STANDARDS/RUBRIC	Standard 1 – The Context	Standard 2 – Learning Outcomes	Standard 3 -- Integrated Curriculum	Standard 4 -- Introduction to Engineering	Standard 5 -- Design-Implement Experiences	Standard 6 -- Engineering Workspaces	Standard 7 -- Integrated Learning Experiences	Standard 8 -- Active Learning	Standard 9 -- Enhancement of Faculty Competence	Standard 10 -- Enhancement of Faculty Teaching Competence	Standard 11 -- Learning Assessment	Standard 12 -- Program Evaluation
SHERIDAN DEGREE PROGRAMS												
Bachelor of Engineering - Mechanical	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Applied Info Sciences – Info Systems Security	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Health Sciences	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Architectural Studies	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Illustration	5	5	5	5	5	5	5	5	5	5	5	5
Bachelor of Business Administration - Accounting	5	5	5	5	5	5	5	5	5	5	5	5

CONCLUSIONS AND FURTHER RESEARCH

We successfully mapped non-engineering discipline curricula to the CDIO model when terminology was modified to be discipline specific. Non-engineering programs mapped closely at the first level (X) where the CDIO model merges with UNESCO standards, and at the CDIO Standards level, where all studied programs rated highly. Some discipline specific modifications were required to achieve a mapping to the second level (X.X) of CDIO Syllabus. Additionally, our observation of the mapping to the second level of CDIO Syllabus revealed significant variation in curricular emphasis by programs. Sources of these variations include characteristics inherent to the disciplines that vary their applicability to CDIO. For instance, the Illustration degree emphasized communication (3.2) heavily, while the Accounting degree emphasized mathematics (1.1), which makes inductive sense when considering the type of professions graduates enter. Second level variation could also include external influencers, such as professional governing bodies. For example, the Architectural Studies program was designed to align with Canadian Architectural Certification Board (CACB) standards. There was an even distribution of programs that adhered to external professional standards versus those with no such requirement, and we did not observe a general pattern of whether these programs varied more or less from CDIO. Rather, we observed that external governing bodies exert curricular design pressure on programs that may influence them independently (either towards or away from CDIO). Applying the current CDIO curricular model to non-engineering disciplines can inform curriculum development in important ways, but should not be interpreted as a checklist to be implemented without considering the disciplinary context.

Mapping each program to the CDIO Syllabus can inform future iterations of Syllabus revision undertaken by that program. For example, several of the programs studied might examine integrating foreign languages as a pathway towards accessing global employment for graduates.

Mapping these non-engineering programs to the CDIO model can inform future iterations of the CDIO model. For example, study of the Accounting program suggests an alternative way to consider entrepreneurship.

This research provides possibilities further research. Most importantly, there is an opportunity to convene a cross-disciplinary research team to examine the CDIO Syllabus at second level (X.X), develop a generalizable version of the third level (X.X.X), and design an implementation plan to assist curriculum designers. Another interesting direction of further research could be to analyse program and CDIO learning outcomes to Bloom's taxonomy in an effort to assess relative learning levels. While our research used degree renewal and application documents with 'Degree Level' sections to ensure that studied programs meet degree level outcomes, analysing both programs and the CDIO outcomes to Bloom's may have interesting results.

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TEACHING-RESEARCH NEXUS IN ENGINEERING EDUCATION

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ABSTRACT

The aim of this paper is to study the teaching-research nexus in a research intensive technical university. The research questions are (i) How are the links between research and teaching perceived by faculty?, and (ii) How are the links performed in practice? We use a mixed methods design including a survey, interviews with top management, case studies, and documentary studies of policy documents. The results show that faculty believe in the occurrence of a teaching-research nexus, primarily based on the idea that all faculty members do both research and teaching. Some informants in the study address the need for flexibility in terms of division of tasks. The results also show that faculty learn themselves as a result of teaching. For some, it is more challenging to include research on bachelor level, while some present examples of how it can be done. All informants agree that the teaching-research links are obvious on master level. The low value given in academia to the nexus is identified as one of the preventing factors. Regarding how the links are performed in practice, the results show that beside traditional courses and master theses, other options include project courses, some in cooperation with industry. There seem to be few courses on research methodology, while integrating learning of research processes in other courses seem to be more common. Generally, the research included comes from the department or from the faculty member's own research. In this study, there are no indications of an academic drift in which engineering education lose the connections to industry; on the contrary, the results indicate reciprocity between links to research and to industry.

KEYWORDS

Teaching-research nexus, Engineering education, Teaching and learning activities, Links to industry, Standards: 3, 5, 7, 8.

INTRODUCTION

In academia, there is a widespread belief that there is a symbiotic link between research and teaching of mutual benefit (Neumann, 1992; Robertson, 2007). This link involves a number of aspects, as for instance promotion structures and incentives in academia (Kasten, 1984) and the division of labour among different categories of staff (Geschwind & Broström, 2014). Other facets relate to how research is integrated into teaching activities as whether there are tangible or less obvious aspects of research that are included (Neumann, 1992) and, additionally, whether there are the results or the processes of the research that are integrated into teaching and learning activities (Healey, 2005). Divergently, it has been argued that there is no reinforcing relationship between research and teaching, at least not in terms of research productivity and teaching effectiveness (Hattie & Marsh, 1996; Marsh & Hattie, 2002; Ramsden & Moses, 1992).

Efforts have been made to improve the teaching-research link, on institutional, disciplinary and departmental level (Commission, 2008; Jenkins & Healey, 2005; Jenkins, Healey, & Zetter, 2007). However, there are studies that raise concerns about this process, thus indicating that the process of moving towards more theoretical and academic values have caused an academisation (Kyvik, 2009) or an academic drift in engineering education (Christensen & Erno-Kjolhede, 2011; Harwood, 2010). Harwood defines academic drift as "the process whereby knowledge which is intended to be useful gradually loses close ties to practice while becoming more tightly integrated with one or other body of scientific knowledge" (Harwood, 2010). This process of engineering education becoming more science-based influenced the evolvement of the CDIO initiative (Crawley, Malmqvist, Ostlund, & Brodeur, 2007), aiming to educate engineers with deep knowledge in technical fundamentals *and* the skills required in engineering practice.

Hence, there are tensions involved in the teaching-research nexus including, on the one hand, efforts made to improve the link and, on the other hand, concerns raised regarding the risk of losing connections to engineering practice. This leads us to question how the link between teaching and research is realised in a research intensive technical university which also is member and co-founder of the CDIO initiative. In this study, we focus on attitudes and activities in relation to the nexus, synergies between research-teaching and teaching-research, and additionally, synergies in relation to connections to industry. The research questions we pose in this study are: (i) How are the links between research and teaching perceived by faculty?, and (ii) How are the links performed in practice?

THE TEACHING-RESEARCH NEXUS

There are several frameworks and models describing the nexus from somewhat different perspectives (Griffiths, 2004; Healey, 2005; Neumann, 1992; Robertson, 2007). In order to study the links between research and teaching, we chose two of them as our theoretical framework, i.e., the ideas developed by Neumann (1992) and Healey (2005) respectively. Their work focuses on different types of teaching activities, but also on other more comprehensive aspects of the nexus.

In the framework by Neumann, there are three types of links between research and teaching: (i) *the tangible connection*; (ii) *the intangible connection*; and (iii) *the global connection* (Neumann, 1992, p. 162). The first type, the tangible nexus, relates to the researchers' knowledge, based on their own research but also on knowledge obtained in their field of research, which they include in their teaching. The second, the intangible nexus, relates to several aspects as the approaches and attitudes one has towards knowledge including having a critical view and being positive towards learning. Additionally, this type of nexus includes what Neumann denotes "the broadening effect" since preparing for teaching means that you have to review and reflect upon your own subject or discipline, and "the youthful contact" that relates to the positive influence that interaction with students can offer (Neumann, 1992). The third type, the global nexus, entails a perspective on all the research conducted at a department and all the teaching offered, thus this third type describes how the educational programmes and curricula are influenced by the research at departmental level.

In the other framework we use in this paper, Healey (2005) presents a model illustrating different ways of including research in teaching activities, a model based on the work by Griffiths (2004). The model, presented in Figure 1, describes how either research content/results or research processes and problems are in focus. Additionally, the model shows how students can be regarded as either participants or audience. The two axes in the model lead to four different types of teaching activities: *research-tutored, research-based, research-led* and *research-oriented* (Healey, 2005).

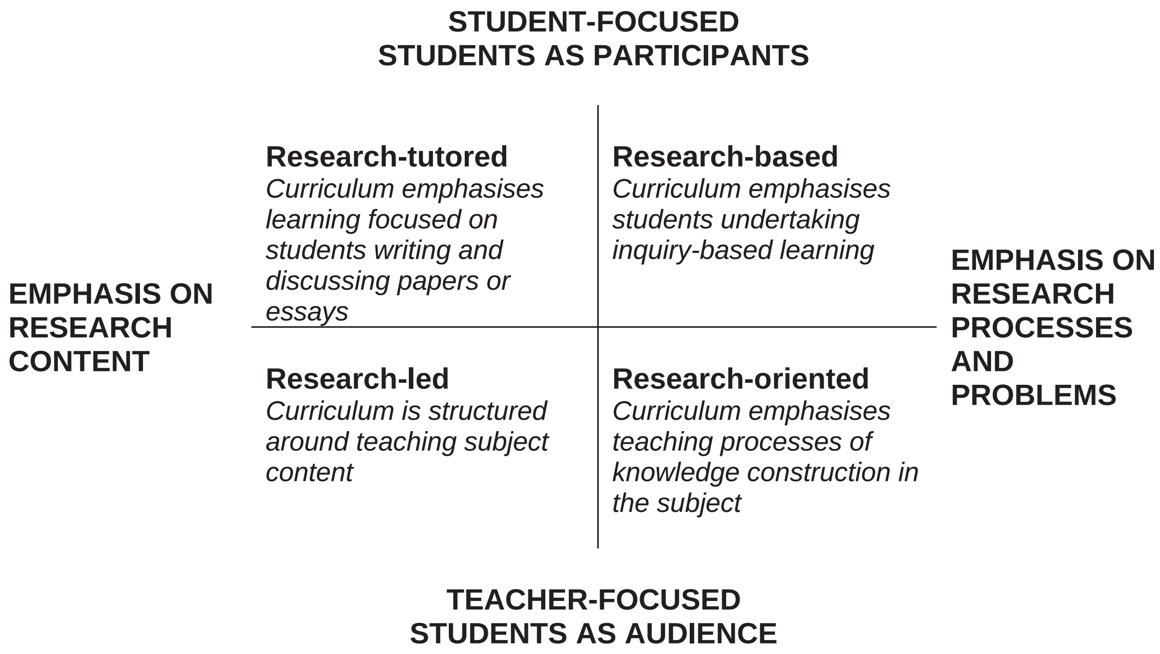

Figure 1. Curriculum design and the research-teaching nexus (Healey, 2005).

METHODOLOGY

Mixed Methods

The overall aim of this project was to examine how the links between research and teaching are perceived by faculty and how the links are realised in practice in a research intensive technical university. We intended to get an overview of these aspects on an overall institutional level, but additionally to obtain a deeper understanding of the views of a selected group of faculty members. Thus, we decided to conduct our study using a mixed methods design (Creswell, 2009) with initial interviews with key members of faculty, a survey to all faculty members, and case-studies of two schools. Additionally, the study contained an analysis of policy documents. The following themes were covered in the project: leadership and management, funding structures, career paths and incentives, and pedagogical issues. For the purpose of this paper, we focus on how the links between research and teaching are perceived and performed by faculty members, e.g. in teaching and learning activities.

The study started with six initial interviews with five key members of faculty and an additional interview with two student representatives from the KTH Student Union. The purpose of these interviews was both to capture the views of top management on the nexus, but also to find whether there were aspects that we should look further into in the survey and during case study interviews. These interviews were semi-structured and focused on themes as their view on the nexus, obstacles, strategies and policies, financial structures, and issues related to promotion and incentives. For the purpose of this paper, we have performed a tentative analysis of the results based on these themes.

Based mainly on literature, and to some extent on results from the initial interviews, a survey was constructed. A link to the survey was sent by e-mail to 1 433 faculty members and they had three weeks in total to respond. After one reminder, we received in total 302 responses, thus the response rate was 21%. Among the respondents, 81% was during 2014 teaching at master level and 61% at bachelor level. 92% was doing research during 2014 and 91% was teaching. Thus a majority do both research and teaching, while a few are involved in either research or teaching. For the purpose of this paper, we present tables with percent distributions on results concerning attitudes and activities related to the teaching-research nexus. A more thorough analysis will be performed and presented further on.

Regarding the case studies, we selected two schools which both require all faculty members to do both research and teaching (CS1 and CS2). The case studies included interviews with faculty members, 13 in total. The interviews were semi-structured and were based on the themes in the study, the policy documents, to some extent the initial interviews, and on the chosen theoretical frameworks. These interviews were tentatively analysed, partly based on the chosen frameworks and models (Healey, 2005; Neumann, 1992) and in this paper, we present these tentative results and a number of quotes from the interviews. Further on, the interviews will be more thoroughly analysed. Additionally, the case studies included documentary studies in which we analysed the policy documents by searching for text segments describing the nexus.

Furthermore, we analysed a number of policy documents on institutional level, by searching for text segments describing the nexus.

KTH Royal Institute of Technology - Our case university

Our case university, KTH Royal Institute of Technology, is a single faculty research intensive technical university, organised in ten different schools (This is KTH). In terms of ranking, KTH was in 2014 ranked as no. 126 on the Times Higher Education list of universities in the world, and as no. 18 among the engineering and technology universities in the world (Ranking placement for KTH). In 2014, KTH had a total turnover of 4,637 MSEK. 31% of the income is related to education in first and second cycle, and 69% is related to research and doctoral studies (Annual Report 2014). However, the different schools differ in a number of aspects, e.g. in terms of the division of incomes related to education and research. The case-study schools have a strong research focus; in both schools the income related to research is about 85% (KTH School Organisation Evaluation Report).

In several policy documents on institutional level, it is stated that educational programmes at KTH should be characterised by e.g. a solid research base and that contact with research should be established already in an early stage. Additionally, research is assumed to have a positive influence on the educational programmes since all faculty members will be involved in both research and teaching. Furthermore, the policy documents stipulate that teaching and pedagogical skills will be more highly valued. (KTH Strategic plan; Quality Policy for KTH; Vision 2027). In one of the case studies, it is mentioned how research can influence the students' interest in both undergraduate and graduate studies and, consequently, the importance of the research-teaching nexus is emphasised in the document.

RESULTS

How the links between research and teaching are perceived by faculty

The initial interviews with top managers reveal a common belief in the existence of a teaching-research nexus, primarily in terms of a positive impact originating from faculty members doing both research and teaching. The student representatives confirm the view that faculty should do both teaching and research. However, the top managers also address the need for being flexible since all faculty members cannot excel in teaching, research and additional tasks at all times, but on team or unit level, they see this aim as viable. A few of them acknowledge that having faculty doing both research and teaching is not enough in itself, and there are suggestions that the link must be included in both evaluations and promotions/career systems to be obtained.

Results from the survey regarding attitudes towards the teaching-research nexus are presented in table 1. A majority, 59%, agree either totally or strongly with the statement “It is important that teaching staff are active researchers”. 39% do not agree to “Those who primarily do research should participate less in teaching”, while merely 8% totally agree with this statement. 69% do either totally or strongly agree with the statement “The research conducted increases quality in the educational programmes”. Thus, it seems as if most of the respondents think it is important that all faculty do both research and teaching and, additionally, that this aspect increases quality in the curricula.

Table 1. Attitudes towards the teaching-research nexus, %

In your opinion, how well do these statements match the situation in your environment?	Totally agree	Strongly agree	Partially agree	Do not agree	Cannot determine
It is important that teaching staff are active researchers (research with the aim to publish in scientific fora)	31	28	26	14	1
It is important that teaching staff has a doctoral degree	25	26	31	18	1
Those who primarily do research should participate less in teaching	8	16	27	39	9
The research conducted increases quality in the educational programmes	32	37	20	6	4
Education increases the quality in the conducted research	11	23	42	14	9

In the case study interviews, none of the informants question whether there is a link between research and teaching. Furthermore, they refer to a number of less obvious aspects of the nexus, defined by Neumann as “the intangible connections” (1992). In the case study interviews, the informants bring up several examples of such intangible aspects, for instance “the broadening effect” (Neumann, 1992). One of the informants states: “it promotes your research when you keep up with the basic knowledge” (CS2-2) and another informant admits: “as a teacher, I have to learn the basics again, and the foundation becomes broader every time I teach these simple facts” (CS1-3), both examples of the positive effects teaching can have on the research. Another example relates to “the youthful contact” (Neumann, 1992) describing how students and their questions can stimulate faculty members and, as one informant states: “the interesting discussions, primarily on master level, affect us” (CS2-4) and another says: “the dynamics in meeting students is important” (CS2-7), also examples of how teaching can influence research. In case study 1, a few of the informants also address the issue of flexibility regarding the question of all faculty doing both research and teaching. They seem to agree to the idea on an overall level, but they also indicate that there might be problems involved: “that should be the guideline, but there are always exceptions” (CS1-5) and “I don’t know if quality increases when all faculty members are teaching, […] since not all of them are comfortable doing it” (CS1-4). Thus, there seem to be common view that there are a number of advantages when all faculty members do both research and teaching, even though there are exceptions.

Bachelor and master level

During the initial interviews and in the case studies, we had questions regarding whether there are any differences between including research in teaching on bachelor level and on master level. One of the top managers have concerns that introducing research too early might have a counter-productive effect and even scare students early in their studies. The informants in case 2 state that it is difficult to include research on bachelor level, for instance, one of them state: “it is mostly old stuff [on bachelor level]” (CS2-2) while the situation is the opposite on master level: “the link is stronger on master level, courses on master level are in the forefront of research” (CS2-5). However, in case study 1, one of the informants emphasise: “you can do similar activities [on bachelor and master level], it depends on what you expect [of the students]” CS1-1. Thus, there are opposite opinions on whether the possibilities are similar or different on bachelor and master level.

Links to industry

According to the informants in both the initial interviews and the case studies, there is no conflict between including links to research and to industry. On the contrary, many of the informants state that these two aspects are intertwined: “[there is] no conflict, you bring in what is relevant either from research or industry” (CS1-4) and “[there is] absolutely no conflict, we are very much applied and cooperate with industry to a large extent” (CS2-5). This show that faculty members use examples from both research and industry and sometimes the examples are from research-projects conducted in cooperation with industry. Thus, in this respect, research and aspects of engineering practice are both included in teaching and learning activities, examples of integrated learning experiences (The CDIO Standards, 2010).

Factors preventing the nexus

In the survey, there were questions regarding preventing factors, as presented in table 2. “Too little time for research” was the aspect that most respondents chose to agree with, 29% totally agree. There is an even distribution among the remaining response options related to this factor indicating that there is a variety among faculty in terms of how they regard this issue. The similar situation applies in the question of whether the link between teaching and research is not valued: 26% totally agree and 20% strongly agree to this statement. This indicates that giving the link more value might support an increase of the nexus. Furthermore, the results strongly indicate that the teaching-research link is a matter that engages faculty members since 79% disagree with the statement “It is nothing I care about”.

Table 2. Factors preventing the teaching-research nexus

Do you experience that the following aspects prevent you from obtaining a link between research and teaching?	Totally agree	Strongly agree	Partially agree	Do not agree	Cannot determine
Too little time for research	29	21	19	21	9
Too little time for teaching	15	12	26	37	10
It is not valued	26	20	18	22	13
It is not appreciated	19	15	21	31	15
It is not requested	17	17	25	29	12

It is nothing I care about	1	1	7	79	12

In the case studies, questions regarding factors preventing the research-teaching nexus also came to the fore, and informants in Case study 1 refer to difficulties in, for instance, including research on bachelor level, to the financing system, and to work overload. In Case study 2, they refer to work overload and lack of time, as for example: “Time, to be a successful researcher, you need to attend conferences and that means you are less present at your department” (CS1-6).

How the links between research and teaching are performed in practice

Type of course and teaching activity

In the survey, there was a question regarding the type of course in which faculty members include research, as presented in table 3. The most common course type in which research is included is the thesis on master level. Nearly as common is to include research in traditional courses and slightly more than 50% include research in project based courses. It is also rather common to include research into the thesis on bachelor level, a result indicating that there are possibilities to integrate research already on bachelor level.

Table 3. Type of course in which research is integrated, %

In what kind of course type do you integrate research into teaching?	
Traditional courses	70
Project based courses	54
Thesis on bachelor level	43
Thesis on master level	78
Other	9

The survey also included a question regarding in what type of teaching and learning activity faculty members integrate research. The results show that including research in lectures is the most common type, described by Neumann (1992) as the tangible type of connection, and denoted as either research-led or research-oriented by Healey (2005), and nearly 80% do so as presented in table 4. It is also common to let students read, discuss or write based on research papers, 68% of faculty members include this research-tutored type (Healey, 2005) of activity in their teaching. Research-based type of activities (Healey, 2005) as students participating in research projects or even conducting research projects are used by slightly less than half of the respondents, 48% and 45% respectively.

Table 4. Teaching activities in which research is integrated, %

In what kind of activity type do you integrate research to teaching?	
I give lectures based on my research/research field	79
I invite guest lecturers that give lectures based on their research/research field	50
Students participate in research projects at the department/unit	48
Students conduct research projects	45
Students visit research environments	26
Students read, discuss or write based on research papers	68
Other (research methodology, examples from research, master thesis)	6

The case studies reveal that the most commonly used type of teaching and learning activity is projects, in which students are active and to some extent participate in the research, thus research-based (Healey, 2005). Even when the informants refer to how they include research results in their lecturing, they do oppose to the thought that students should be considered as audience, on the contrary, they insist that students are active even in this kind of teaching and learning activity: “they can be active even during lectures, there are pedagogical methods” (CS1-5). This corresponds to the results of Elsen, Visser-Wijnveen, Van der Rijst, and Van Driel (2009) who in their study found that the students were active, rather than being the audience, in all kinds of teaching and learning activities that integrated research, no matter being e.g. research-led or research-based. This is in line with the idea of active learning, one of the core ideas of CDIO (Edström & Soderholm, 2007; The CDIO standards, 2010).

Research process

In the case studies, the question of including research results or processes was raised. The informants seem to, at least to some extent, integrate aspects of the research process and methodology into courses, rather than offering separate courses on research methodology. One of the informants state: “there is a progression, they follow lab instructions and later they work independently in projects, [there is] no course in research methods” (CS1-1), and another say: “I prefer this to be based on curiosity rather than on offering a course. The methodology is not an issue on bachelor level, but is important in the master thesis, and it should be integrated.” (CS2-4). This approach corresponds to the idea of CDIO, i.e., that the learning of skills should be integrated into courses rather than being offered in separate courses (Crawley et al., 2007). However, some informants state that the aspects of research processes and methodology are not part of their curricula: “The scientific methodology is about testing, you have a hypothesis… We do not have that kind of methodology here. We do problem solving.” (CS2-6).

Type of research

The results of the survey show that the most commonly used approach is to include research based literature in teaching and learning activities, 60% do so to a very large or a rather large extent, as shown in table 5. It is also common that faculty members use their own research; slightly more than 50% of the respondents do so to a very large or a rather large extent, while 41% include research from the department/unit. Research from other departments at the school or from other parts of KTH is far less common to include.

Table 5. Type of research included in teaching, %

To what extent are the following aspects included in your teaching?	A very large extent	A rather large extent	A rather small extent	A very small extent	Not at all
Research based literature	24	36	26	10	5
Research at KTH (other than at my school/department/unit)	3	14	29	31	24
Research at the school (other than at my department/unit)	4	14	33	30	19
Research at the department/unit (other than my own research)	11	30	32	15	11
My own research	16	37	30	9	8

Based on the results from the case studies, it seems as if the research included primarily comes from the informants departments: “my own and from the others in my research group” (CS1-3) and “both my own research and from colleagues in my corridor” (CS2-1). Nevertheless, there are also other approaches, as this informant states: “it is based on what we do, but since I have such a broad knowledge, it doesn’t have to be from our department” (CS1-2).

Bachelor and master level

Some of the informants in the case studies state that it is difficult to integrate research on bachelor level, but there are some examples of how it can be accomplished. For instance, in case study 1, they have included aspects of research already in the first and the second year: “we offer a course called ‘Perspectives on research and innovation’ in which the students during the first year meet alumni working with research in companies and in the second year do a research project at the department in which they learn about the research process” (CS1-6), an example of a research-based approach (Healey, 2005). As shown in table 4, it is rather common to include research in the bachelor thesis. Hence, there are a number of examples on how to do this integration already on bachelor level.

Inspire and attract students

In one of the case studies, one aspect of the tangible type of connection relating to the need for attracting students to continue studying at undergraduate or graduate level (Neumann, 1992) is mentioned as one informant states: “I want to inspire the students; I am passionate about my research” (CS1-1). Thus, an effect of having researchers teaching students might be that they influence and inspire students by being engaged in their research, just as mentioned in one of the policy documents in case study 1.

CONCLUSIONS AND IMPLICATIONS

Regarding our first research question on how faculty perceive the teaching-research links, the results from the interviews with top management, the case studies, together with the survey results, show on the one hand that faculty members agree with the ideal expressed in the policy documents stipulating that all faculty should do both research and teaching. There seem to be a common understanding in this matter. On the other hand, both top managers and a few of the case study informants, indicate a need for being flexible since all faculty members cannot excel in teaching, research and additional tasks at all times. This is a contradiction which raises further questions that may need to be addressed. For instance, within which limits is a division of labour among faculty an option, and on which organisational level – individual, team, unit, other – does this issue need to be addressed?

Additionally, the policy documents convey the ideal of a close link between research and teaching. However, in these documents it is presumed that research will have a positive influence on education based solely on the fact that all faculty members will do both research and teaching, which is something several informants oppose to.

Concerning our second research question on how links are performed in practice, the results show that when the informants describe how teaching and research are connected, it is obvious how the links appear in different ways and on different levels. For instance, the links do include presenting your own research in lectures, but also letting students participate in research projects at the department or in cooperation with industry, and, additionally, how researchers broaden their own knowledge when teaching students and get stimulated by discussions with students (Healey, 2005; Neumann, 1992). Thus, the teaching-research nexus entails so much more than just including research results in lectures; the link also embraces the aspect of how teaching can influence research. Maybe this needs to be reflected in the policy documents in order to grasp all the aspects included the teaching-research nexus and to show the complexity.

Furthermore, in the policy documents, there are no details on how the links are expected to be accomplished and performed. On the one hand, this may not be desirable, but on the other hand, finding means to provide faculty with examples on how this can be done could be an option, if there is a need for encouraging stronger links between research and teaching. This could for instance be handled in faculty development activities in which courses and teaching activities are discussed (Elsen et al., 2009). Another option, as suggested by some of the informants, is to include aspects of the research-teaching nexus in evaluations, both research and educational evaluations, in order to give the nexus more value.

In the literature on academic drift, there is a focus on the risk of losing connections to engineering practice due to stronger links to research (Christensen & Erno-Kjolhede, 2011; Harwood, 2010). However, the results from this study point in another direction and show reciprocity between links to research and to industry, even though this is a research intensive university, and there are examples of how students work in projects based on cooperation between academia and units of research and development in industry. Additionally, in these projects, students get the chance to learn both disciplinary knowledge and skills in an integrated manner, one of the corner-stones of CDIO (The CDIO Standards, 2010).

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A FRAMEWORK FOR LANGUAGE AND COMMUNICATION IN THE CDIO SYLLABUS

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ABSTRACT

How can the CDIO syllabus for *Communications in Foreign Languages* be translated into progressive and achievable goals that engineering students can aim for? How can teachers of additional languages, often with no technical background, best prepare these students before they leave for exchange semesters abroad and the world of work? This paper responds to these issues by presenting the work of the Global Engineers Language Skills (GELS) project. The aim of the project is to investigate which communication skills are most used by engineers in industry and, ultimately, to prepare a teaching guide for language departments that work with engineering students. This paper presents the results of the investigation and the resultant adaptation of the Common European Framework of Reference for Languages (CEFR) for the specific needs of engineers. By combining this framework with CDIO's syllabus for *Communications* and *Communications in Foreign Languages*, we argue that a more ambitious and effective integration of additional languages, communication, and engineering at our universities could not only be within our reach, but should rather be a priority to ensure that our students can engineer both at home and abroad.

KEYWORDS

CEFR, Communication skills, Language for Specific Purposes (LSP), Standards 2, 3, 7, 10

INTRODUCTION

Engineering and Communication

"You don't really understand something unless you can explain it to your grandmother."

Engineering students need training in effective communication skills. The reason why is often summarized in the rather chauvinist maxim above (e.g. in Grossman, 2014); but this reasoning does little to dispel any notion that such skills are superfluous. To readers who undervalue communication for engineers working on technical subjects and projects, Huckin and Olsen (1983) have this clear retort:

> In a word, if technical people cannot communicate to others what they are doing and why it is important, it is they and their excellent technical skills that will be superfluous. From this perspective, communication skills are not just handy; they are critical tools for success, even survival, in "real-world" environments.

The unambiguous wording of this forewarning should compensate for its age. Indeed, in more recent times, advice from other scientists and writers has only become even more explicit, e.g. *Don't Be Such a Scientist* (Olson, 2009), *Escape from the Ivory Tower* (Baron, 2010).

For many engineers, effective communication skills presume proficiency in one or more additional language:

> Communiquer, comprendre, écouter, négocier, argumenter et écrire dans une langue autre que le français et s'adapter aux autres us et coutumes pour fonctionner sur place ou à distance dans un contexte multiculturel, voilà le quotidien du jeune ingénieur commençant une carrière à l'international. (CDEFI, 2011)
>
> *Communicating, understanding, listening, negotiating, arguing, and writing in a language other than French and adapting to other customs and habits in order to work on-site or remotely in a multicultural context… This is the daily reality for a young engineer starting an international career.* (My translation.)

Indeed, in many parts of the world, there is simply no option to avoid the *à l'international* appendage, because all engineering is a multinational, multicultural, or multilingual enterprise. "Real-world environments" (Huckin & Olsen, 1983) and "modern team-based environments" (Crawley et al., 2011) can be presumed to transcend national, cultural, and linguistic borders.

The purpose of this paper is not to campaign for language provision in university engineering curriculums. Rather, we aim to offer a rationale and a user-friendly method for language teachers working with engineers at CDIO-affiliated universities to ensure that their students learn and practice the most useful communication skills as required by engineers working in industry.

The plan of this paper is as follows. The background section outlines the problematic situation for language teachers currently working with engineering students – especially at universities which follow the CDIO syllabus. This is followed by two descriptions: the first of the GELS project, the second of the Common European Framework of Reference for Languages (CEFR). In the methods section, the process of surveying engineers about their communication skills and needs is described. The results section presents the basic findings from the surveys and the resultant framework of skills. This is followed by a presentation of the framework's relationship to the CEFR and the CDIO syllabus. The conclusion section describes the limitations of the project so far and outlines plans for future work.

BACKGROUND

Communication and the CDIO Syllabus

"To work in a modern team-based environment, students must have developed the interpersonal skills of teamwork and communications." (Crawley et al., 2011)

The ten topics of the CDIO syllabus' *Communications* element can provide a useful stimulus for language specialists and engineering professionals alike. For example, a Spanish teacher may well be motivated to rethink a debating exercise that requires students to negotiate "without compromising fundamental principles". Similarly, a hydraulics teacher could be inspired by the requirement for students to take “rhetorical factors (e.g. audience bias)” into account for a report writing assignment.

“Our international collaborators have added Communications in a Foreign Language to this part of the syllabus.” (Crawley, 2002)

As the above quotation attests, however, the *Communications in Foreign Languages* element is seemingly unconnected to the rest of the CDIO syllabus. In stark contrast to the *Communications* element, there are no topics or suggestions for the integration of additional languages in engineering curriculums (see the *Compatibility with the CDIO Syllabus* section below). In the absence of such detail, this element of the CDIO syllabus is incongruous with the realities of engineering in many parts of the world where more than one language is commonly used. Furthermore, it does little to inspire students and teachers to engineer in truly global contexts.

If engineering graduates are expected to possess the skills of extending social and professional networks to include people of different cultures (as suggested in the *Communications* element), it is essential that classes in language skills and learning activities in inter-cultural communication be available for them during their studies. Furthermore, these activities must be geared towards the professional and social situations that engineers work within. However, the CDIO syllabus currently offers little practicable guidance to faculty hoping to include additional language skills in its engineering curriculum. On the one hand, the lack of topics and detail in *Communications in Foreign Languages* offers no support whatsoever; on the other hand, the topics in *Communications* are daunting both in their number and linguistic complexity for language learners.

There is a second practical difficulty. Those who generally plan and deliver language classes for engineers are teachers working in language centers, units or departments whose integration within technical universities and engineering departments can be as superficial or limited as additional languages seem to be in the CDIO syllabus. Furthermore, language teachers working with engineering students typically have limited scope to cooperate with engineers in academia and industry, and they even less commonly have technical backgrounds themselves.

The Global Engineers Language Skills (GELS) project aims to offer solutions to these two problems by producing a framework of language and communication skills for engineers, together with a bank of progressive teaching and learning resources that prepare students for the particular demands of working in the field of engineering. These resources should enable students to fulfil, or work towards fulfilling, the topics listed in CDIO’s *Communications* syllabus in additional languages.

The GELS Project

GELS is a collaborative project between three language teachers who work with engineering students at KTH Royal Institute of Technology (Sweden), Institut Mines Télécom (France), and the University of Cambridge (UK). The aims of the project are as follows: 1) to investigate and categorize the necessary and desirable language and communication skills for engineering graduates based on input from industry, the CDIO syllabus, and previous literature; 2) to ensure that these findings actively support the teaching and learning of additional languages in technical universities and engineering departments.

To fulfil this final aim, the GELS team is preparing a teaching guide for language departments that work with engineering students. The preparatory work for this guide begins with the two following tasks. Firstly, the language and communication requirements of engineers are clarified by means of a series of surveys completed by engineers working in industry. Secondly, these requirements are mapped against the skills and proficiency levels (A1 – C2) of the Council of Europe's CEFR and, as a result, the framework is rewritten for the specific needs of engineers. This framework, the GELS framework, will form the basis of the teaching guide.

The Common European Framework of Reference for Languages (CEFR)

The CEFR is not only a policy document, but also a departure point for language-related syllabuses, curriculums, and assessment. Language teachers and learners generally rely on the CEFR's global scale and self-assessment grids for explanations of six stages of language use and learning (A1, A2, B1, B2, C1, and C2). The full text of the CEFR, which includes 34 skill-specific classifications of communicative proficiency, can be retrieved at Council of Europe (2001).

The CEFR is used as a fundamental resource for language teaching and learning in 30 European countries and there is growing evidence to suggest that its influence has increased to Asia, Australasia, and Latin America (Normand-Maconnet & Lo Bianco, 2013). The document has been translated into 39 languages, including Arabic, Chinese, and Russian.

The CEFR is a flexible framework in three fundamental ways. Firstly, it is language-neutral and designed to be applicable to any language learning situation. Secondly, it promotes an "action-oriented" approach to language and communication, as shown in the excerpt below:

> I can understand the main points of clear standard speech on familiar matters regularly encountered in work, school, leisure, etc. I can understand the main point of many radio or TV programs on current affairs or topics of personal or professional interest when the delivery is relatively slow and clear. (B1 listening, CEFR self-assessment grid)

Finally, the CEFR is designed to be multipurpose, flexible, and non-prescriptive, meaning that it absolutely should be "applied, with such adaptations as prove necessary, to particular situations" (Council of Europe, 2001).

METHOD

Aims of the GELS surveys

Surveys were chosen as the best method for gathering quantitative data from the widest possible geographical range of engineers about their language and communication needs and skills. In a practical sense, two significant advantages of surveys for the GELS project were the low cost and the availability of efficient methods for data entry and management. There is no shortage of insightful and data-rich literature concerning language teaching and the specific needs of engineers and students (e.g. Björkman (2011)), but GELS surveys had the ulterior aims of 1) generating new and particular data to inform decisions concerning the GELS framework, and 2) creating interest in the GELS project among engineers in industry.

The first survey: How good is your Enginese?

The first survey included seven questions that required very short answers or a choice among three defined frequencies. Respondents shared information about their use of additional languages for professional purposes, their most common communication tasks, and the significance of additional language skills to their firm's recruitment process. The full survey can be viewed at http://goo.gl/forms/afKb8J8mfg

The survey was disseminated via social and professional networking websites, relying mainly on alumni associations at KTH, the Ecoles des mines, and the University of Cambridge. Respondents were encouraged to forward the link to their own contacts within their engineering fields.

The survey was often attached to a post with the title *How good is your Enginese?* and a text that introduced GELS, assured the respondents of their anonymity, and explained that all engineers could complete the survey (i.e. anyone qualified in engineering and/or employed to work on the design, construction or maintenance of engines, machines, ICT or structures).

The follow-up survey: How often do you carry out the following activities?

The follow-up survey focused on the most common communication tasks of engineers in any language. After four questions about the precise nature of the respondents' work, the survey was divided into five sections that reflected the divisions of the CEFR's skills (i.e. listening, reading, spoken interaction, spoken production, and writing).

Each section included questions about specific tasks, to which the respondents could choose a frequency reflecting how often they were expected to carry them out (see Figure 3). The tasks were chosen to reflect not only the communicative competences included in the CEFR, but also findings from previous literature (e.g. Dlaska (1999)), and any further topics featured in the *Communications* element of the CDIO syllabus. The full survey can be viewed at https://goo.gl/MF2lof

RESULTS

Survey results

At the time of writing (January 2016), 180 engineers from 29 countries on all five continents have responded to the surveys. Respondents range from self-employed designers of web-based database applications to regional managers for multinational oil and gas suppliers. What is clear from the results is that engineers claim to communicate a great deal and in a variety of ways. This generalization is clearly supported in figure 1.

As can be seen in Figure 1, engineers regularly use all five communication skills at work and more than half carry out all but two of the tasks more than once per week. According to the bar chart, the most common tasks are *interacting in and understanding information given at meetings, reading short documents* (less than two pages of text), *writing correspondence* (casual more often than formal), and *talking on the telephone*. By far the least common tasks are *writing longer documents* (more than two pages of text) and *delivering oral presentations*. The predominance of concise, dialogic, informative but less formal communication is noteworthy.

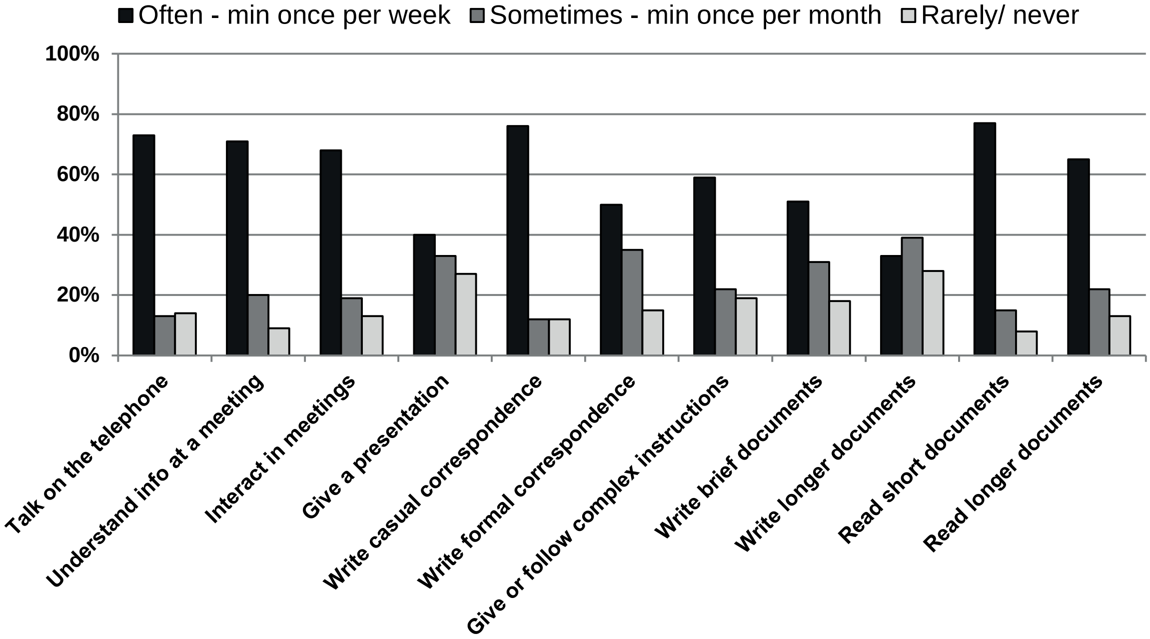

Figure 1. Result from survey 1 question 5: *How often do you do the following in any language?* (N=180)

Figure 2 presents respondents' communication in an additional language with employees within and outside their company. The bar graph shows that communication with colleagues is the main reason for using additional languages. These colleagues are presumably the interlocutors and recipients for the previously mentioned dialogic, informal communication.

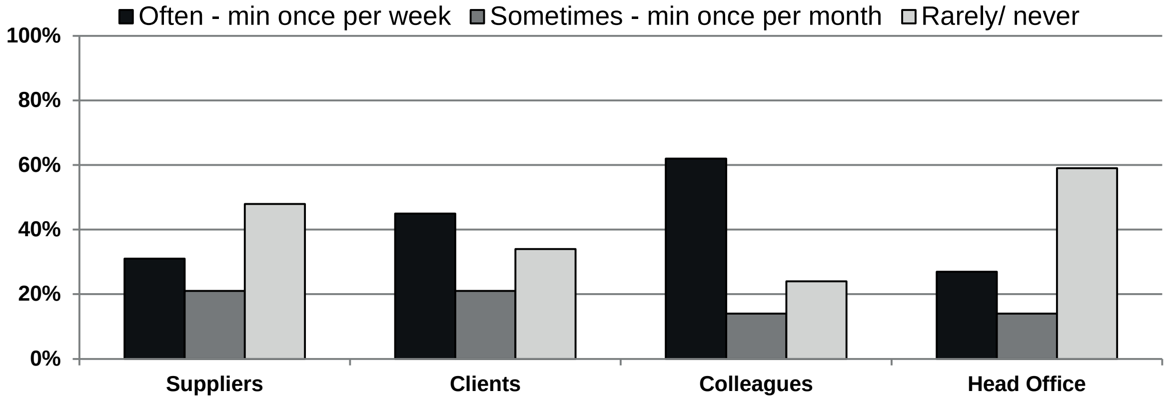

Figure 2. Result from survey 1 question 4: *Who do you need to communicate most with in an additional language?* (N=180)

That engineers should be prepared to communicate with clients in additional languages is no surprise, but the above result suggests that a globalized workforce and an increase in multinational engineering have presented new and different challenges for graduate engineers' language and communication skills.

The results from the follow-up survey confirm that engineers can be expected to communicate frequently and in diverse ways. Out of the 37 discrete tasks listed in the survey, 35 are apparently carried out at least once per month by at least half the respondents. Figure 3 presents 11 of the most common features of how respondents claim to communicate in industry, and with what frequency. As the bar graph shows, writing correspondence and communicating by telephone rank highly once again, but a range of new skills emerges for consideration in the GELS framework. Reading and listening for gist or specific detail is clearly a necessary passive skill, as are understanding and following instructions.

In terms of active communication skills, and with a nod to the CDIO syllabus and Dlaska (1999) respectively, the skills of negotiating using facts and data and verbalizing numerical data are considered everyday necessities by the respondents. Less obvious, though almost as frequent in an average working month as writing formal correspondence, is collaborative writing.

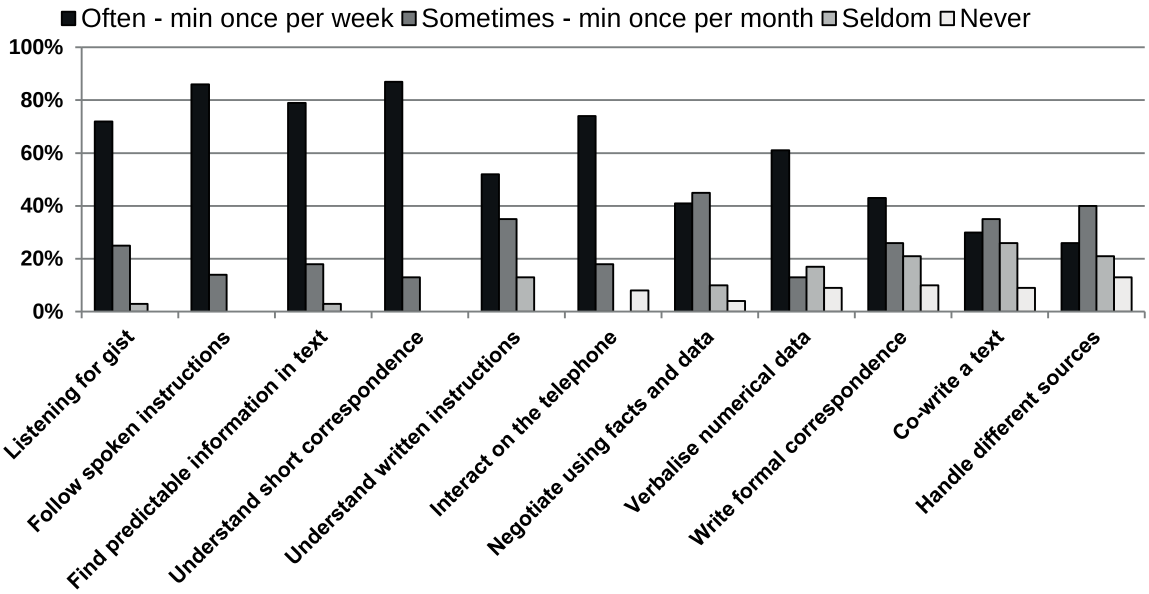

Figure 3. Combined results from survey 2: *How often are you required to carry out the following activities?* (N=24)

The follow-up survey confirms a result from the first survey: engineers deliver fewer prepared oral presentations than universities, and especially language courses, prepare them for. Almost half the respondents seldom or never deliver a rehearsed oral presentation.

The GELS framework: an adaptation of the CEFR for engineers

Compatibility with the CEFR

As shown in Figures 4 and 5, the GELS framework is intentionally similar to CEFR's self-assessment grid in terms of its arrangement: there are six levels of proficiency (A1 – C2) and five skills. This similarity facilitates an effective combination of general and engineering-specific work in language classes.

	A1	A2	B1
Listening face-to-face & distant communication	I can recognize frequently encountered lexis* from my engineering field. I can understand a message that includes this lexis. * e.g. numbers & equations, terminology, vocabulary of the workplace.	I can listen out for important information and understand enough of a speech to answer simple questions. I can understand simple instructions that use a wider range of frequently encountered lexis.	I can follow instructions from other engineers. I understand enough from radio/ TV/ lectures to summarize the main facts and figures, provided the speech is designed for non-experts and the topic is familiar to me.
Reading short → longer texts	I can recognize frequently encountered lexis* from my engineering field. I can understand short, simple sentences that include this lexis.	I can read simple paragraphs and can infer meaning where necessary in more complex text. I can follow instructions given in simple everyday correspondence.	I can understand short correspondence and recognize distinctive differences in register. I can scan texts for information and can learn from longer, instructive texts on familiar engineering topics.
Spoken interaction networking face-to-face and distant communication	I can meet new people and respond to basic questions about myself and my studies/ work. I can ask basic, corresponding questions.	I can exchange more detailed personal and professional information and can cope in brief, routine situations with my peers. I can inform others about common difficulties with e.g. language or technology.	I can use a range of simple language to deal with formal and informal situations and suggest solutions. I can interact in a conversation about my work and ask questions to develop the topic of conversation.
Spoken production pre-learnt → spontaneous speeches	I can present myself, my background, my field of engineering and my future plans. I can read out numbers and frequently encountered equations from my field of engineering.	I can use simple/ pre-learnt and frequently encountered lexis from my engineering field to describe experiences, observations and plans, verbalize formulae and communicate data in simple language.	I can recount my current work and previous experiences in connected phrases. I can present data, describe specific processes, and deliver a presentation that informs non-experts about topics within my field of engineering.
Writing individual & collaborative texts	I can fill in documents with basic information. I can compose texts with simple sentences about myself, my background, my field of engineering and my future plans.	I can compose short texts for my peers about routine occurrences and to make requests at school/ work. I can describe technical objects in text and use reference materials to enhance the quality of my written work.	I can compose succinct definitions and produce simple, cohesive text to inform non-expert readers about familiar topics in my engineering field. I can use the conventions of formal correspondence.

Figure 4. The GELS framework for engineers (levels A1 – B1)

	B2	C1	C2
Listening face-to-face & distant communication	I can understand extended, well-structured speech and can follow potentially complex arguments and counter-arguments. I can form thoughtful questions that show that I have listened carefully.	I can follow a presentation designed for an expert audience on a new topic within my engineering field. I can understand and infer meaning in discussions and unplanned speech about technical topics.	I can understand extended speech on any topic of my engineering field and can simultaneously analyze and evaluate the information provided.
Reading short → longer texts	I can find the answers to specific questions in longer texts on familiar but complex topics. I can read journalistic texts on a range of subjects and follow potentially complex arguments and counter-arguments.	I can skim and read long texts written for experts within my engineering field and infer meaning where necessary. I can follow complex instructions on unfamiliar processes and understand the subtleties of register.	I can understand long texts on any topic of my engineering field and can simultaneously analyze and evaluate the information provided.
Spoken interaction networking face-to-face and distant communication	I can interact effectively on a range of topics within my engineering field and address specific problems. I can substantiate my opinions with evidence, negotiate with colleagues and interact effectively to reach a consensus.	I can express my under-standing and motives fluently to an expert audience in all situations. I can interact spontaneously with a high degree of fluency to enhance dialog and resolve problems.	I can participate constructively in discussions on any topic in my engineering field. I can adapt the lexis, register, technical complexity, and arguments of my speech to the situation and the audience.
Spoken production pre-learnt → spontaneous speeches	I can describe and give effective instructions about specific processes and methods within my field of engineering. I can interpret data spontaneously and share my understanding precisely and concisely.	I can apply the structures used in prepared presentations in more spontaneous speech to ensure that both my non-expert and expert audiences pay attention, are convinced, and well-informed.	I can speak fluently about any topic within my engineering field. I can adapt the lexis, register, technical complexity and arguments of my speech to the situation and the audience.
Writing individual & collaborative texts	I can summarize and/or paraphrase complex texts about technical topics. I can compose longer texts which are effectively structured. I can write in both a neutral style to inform, and in a persuasive style to convince.	I can co-write coherent texts with my peers. I can apply the conventions of academic/ technical writing to produce effective, informative text with supporting evidence and an appropriate combination of media.	I can compose fluent, coherent, reader-friendly text on any topic within my engineering field. I can adapt the lexis, register, technical complexity, and arguments of my writing to the situation and the audience.

Figure 5. The GELS framework for engineers (levels B2 – C2)

Where possible, the character of each proficiency level is also maintained. The most obvious examples of this can be found at the intermediate level. In both frameworks, successful completion of B1 level signifies a threshold to independent language use. In the CEFR, learners should be able to “maintain interaction and get across what [they] want to” and “cope flexibly with problems in everyday life” (Council of Europe, 2001). In the GELS framework, successful completion of B1 means that learners can study abroad and use their additional languages to cope at foreign universities and engage in their studies. At B2 level, the GELS adaptation is faithful to the original framework in its emphasis on argumentation.

Details aside, the GELS adaptation makes four significant departures from the original CEFR. Firstly, there is an emphasis away from expressing *opinions* and towards presenting *reasoning* (e.g. Spoken interaction C1). Secondly, there is distinct progression from communication with or for a lay audience towards an expert audience, e.g. Writing B1 → C2. Thirdly, the skills connected to problem solving are more prominent in the GELS framework than in the more general CEFR, with a progression from *informing* others about problems (A2 spoken interaction) to *resolving* specific problems (C1 spoken interaction). Finally, there is an intentional focus on the language learner’s specific field of engineering. We suggest that an engineering field (for the purposes of e.g. vocabulary learning) be similar to the level of specificity of a Master’s degree (level 2 or 3 or in Figure 6).

CIVIL ENGINEERING (1)
↓
HYDRAULIC STRUCTURES ENGINEERING (2)
↓
DAMS (3)
↓
CONCRETE-FACE ROCK-FILL DAMS (4)

Figure 6. Example of the levels of specificity in an engineer’s education from Bachelor’s level to PhD.

Compatibility with the CDIO syllabus

Language classes already contribute indirectly to students’ fulfilment of many aspects of the CDIO syllabus. These classes often provide students with the low-stakes setting to (re)consider the societal and enterprise contexts of their work. Practically speaking, language classes are also an ideal opportunity for students to work in multidisciplinary teams. This paper has a more specific focus on language learning, however, and this subsection outlines the GELS framework’s compatibility with the CDIO syllabus for *Communications* and *Communications in Foreign Languages*.

The relevant sections of the CDIO syllabus are listed in italics below, followed by a short description of how the GELS framework aims to be compatible with each section:

3.2 Communications

3.2.1 Communications strategy. Strategy refers to considerations such as audience, purpose, context, content, and the organization of the communication. In the GELS framework, audience awareness is explicit in all active skills at C2 level, as are the resultant considerations concerning the appropriate levels of formality, persuasion, and technical complexity. Attention to technical and semi-technical lexis, and international and local terms, is also an important consideration at this level. A sensitivity to register is ensured in Reading B1, Spoken Interaction B1, and Reading C1, and learners are required to consider the appropriate rhetoric and combination of media in Writing B2 and C1 respectively.

3.2.2 Communications structure. The importance of effective macro-structure (i.e. the arrangement of ideas and supporting evidence) is made explicit in Writing B1 and B2, and can be reinforced in Spoken Production C1 and Writing C1 as part of the conventions of academic communication. The task of communicating succinctly and precisely at the micro-level (e.g. vocabulary choice) is set in Writing B1 and Spoken Production B2. Effective cross-disciplinary communication and appropriate uses of rhetoric emerge in the active skills at B1 level and are developed until they form the basis of all the active skills at C2 level.

3.2.3 Written communication. The important meso-structures for cohesive paragraphs and concise, reader-friendly sentences appear first in Writing B1, but continue in every active skill thereafter. The skills of technical writing are important in Writing C1, and learners are prepared for this in A2 (describing technical objects and using reference materials), B1 (composing succinct definitions and cohesive text), B2 (paraphrasing, structuring, using a neutral style), and C1 (using evidence, ensuring an appropriate combination of media).

3.2.4 Electronic/ Multimedia Communication. Specific methods of communication are avoided in the GELS framework. However, the importance of distance communication is made explicit in Listening and Spoken Interaction skills. The protocols of composing e-correspondence can easily be covered in Writing A1, A2, and B1, and Reading B1 and C1. The skills required for delivering effective presentations with electronic aids can feature in Spoken Production B1.

3.2.5 Graphical Communication. Writing C1 makes explicit the need for an appropriate combination of media in written work. Learners are prepared for the effective inclusion of data, including graphical data, in their work in Spoken Production A2, B1, and B2. This skill can also be developed in Writing B1.

3.2.6 Oral presentation. Oral presentation is synonymous with Spoken Production. It will be important in later work to specify how using the appropriate media, language, style, timing, flow, and body language contribute to delivering informative presentations (Spoken Production B1) and ensuring that audiences pay attention and feel well-informed (Spoken Production C1). Practice in answering questions effectively can be included in Spoken Interaction B1 – C2, where learners are challenged to interact effectively and, at a more advanced level, spontaneously in conversations about their work.

3.2.7 Inquiry, Listening, and Dialog. Listening C2 challenges learners to listen and simultaneously analyze and evaluate the information provided. Learners are prepared for this skill in Listening B2. Listening carefully for detail is an early challenge for learners (Listening A2), and the skill of following spoken instructions from other engineers is made explicit in Listening B1. The skills of ensuring dialog are implied throughout Spoken Interaction and are explicit in Spoken Interaction C2, but the progressive challenges of asking questions to develop the topic of conversation, reaching a consensus, and resolving problems are set in Spoken Interaction B1, B2, and C1 respectively.

3.2.8 Negotiation, Compromise and Conflict Resolution. The skill of following complex arguments and counterarguments in speech and text emerges at B2 level and the challenge of evaluating the arguments is set at C2 level. To prepare learners for negotiations beyond the classroom, the GELS framework introduces the communicative skills required for dealing with potential problems, reaching a consensus, and resolving problems in Spoken Interaction B1, B2, and C1 respectively.

3.2.9 Advocacy. The communicative skills listed in this topic, such as explaining a rationale and justifying a methodology, are introduced in Spoken Interaction B2. Opportunities for development feature in Writing B2 and Spoken Interaction C1. The importance of audience awareness is central to the active skills at C2 level.

3.2.10 Establishing Diverse Connections and Networking. The requirement of networking is explicit throughout Spoken Interaction. We hope to create opportunities for learners to use additional languages to practice establishing and maintaining social and professional networks at every stage of the framework.

3.3 Communications in Foreign Languages. The GELS framework, like the original CEFR, is language-neutral. The intention is that teachers and learners can use these schemes to develop level-specific language and communication activities – in any additional language. The distinctions made below in 3.3.1, 3.3.2, and 3.3.3 are, therefore, irrelevant to the GELS framework.

3.3.1 Communications in English.

3.3.2 Communications in Languages of Regional Commerce and Industry

3.3.3 Communications in Other Languages

CONCLUSION

This paper has presented a framework of progressive communicative competences for the specific needs of engineers in universities and industry. The framework has four aims.

Firstly, it is intended to serve as a counterpart to the CEFR. Language teachers can use the GELS framework with confidence as a support for including more activities and exercises in their courses that are specific to the needs of engineers. Some of the ideas are ambitious, particularly at A2 and B1 level: they require extra effort from learners to create their own glossaries of frequently encountered lexis for their own engineering fields, and to engage with material designed to explain technical subjects before learners have mastered the fundamentals of grammar.

Secondly, it is a scheme of work to render the taxonomy of the CDIO syllabus accessible for language teachers and learners. The framework is broadly compatible with the ten topics of *Communications* and offers a structure for studying additional languages where there currently is none.

Thirdly, it is the first draft of a scheme of work that is intended to inspire discussion among engineers and language and communication specialists around the world.

Ultimately, it will form the basis of a teaching guide that aims to highlight the potential contributions that additional language classes can make to an engineering education.

Limitations of the work so far

180 responses provide only a glimpse of what engineers do and, due to the small number yet broad range of the engineers who responded to our follow-up survey, it is difficult to grasp the differences between employees' communication needs in different branches of engineering.

The geographical distribution of our 180 respondents presents a similar problem. Almost 30 countries are represented in the GELS surveys, but this is not enough to analyze the potentially different language and communication needs of engineers in different parts of the world.

Bias must also be recognized in surveys, and the GELS survey is no exception. It is more likely that engineers with an interest in languages and communication responded to the survey and, therefore, the breadth of needs and skills recorded may be skewed.

Plans for future work

This paper has outlined the first two stages of the GELS project: collection of data and categorization of the language and communication skills of engineers. More data needs to be collected and a consultation period is necessary, where as many stakeholders from academia and industry as possible comment on the GELS framework. Once a consensus is reached, the third stage of the GELS project can begin, which is to research suitable teaching and learning activities for each detail of each skill at each level of proficiency of the GELS framework. The final stage is the dissemination of a comprehensive bank of teaching and learning activities, together with a summary of the project's findings and conclusions.

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ON THE EFFECT OF EMPLOYMENT DURING THE LAST YEAR OF STUDIES TO TIMELY GRADUATION AND DEEP LEARNING

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ABSTRACT

Engineering students in Finland have quite commonly been hired by the employers already before graduation. This happens particularly to the best engineering students. The students are quite keen on starting their engineering work life a bit early. One reason may be the lack of tuition fees; it is economically attractive to enjoy the benefits of being a hired engineer. This is not the only reason; the best engineers are enthusiastic about their engineering work and too impatient to wait for the final graduation if they get a chance for “real life” engineering work earlier.

The Ministry of Education and Culture in Finland is emphasizing the importance of cost effective universities where students graduate fast and become tax payers in the society. Timely graduation is one of the goals affecting the government financing of the universities. In order to reach this objective, the universities should push the students to limit their practical engineering working to minimum and concentrate on theoretical studies and fast graduation.

Working during the studies does delay graduation, but it also has its benefits. Working within one’s own engineering profession provides valuable experience on how to apply the theoretical knowledge learned in the university to practice. It may also boost the students’ motivation for deep learning of the subjects instead of just collecting the credits needed for graduation. Working in a non-engineering job does not provide perspective in engineering skills, but it is helpful in achieving important working life soft skills needed also in the engineering profession and thus improves the employability of the student.

CDIO capstone projects provide to the student similar advantages as working in an external engineering enterprise, but in a faster and better managed way. In this paper we analyze the effects of employment during studies to timely graduation and deep learning, and the capabilities of a CDIO based curriculum in filling up working life skill gaps. We present our method of reaching recent graduates of the department and the design of a survey for gathering the data on which this study is based. The study showed a clear correlation between the amount of study time working and the delay in graduation time. On the other hand, the study revealed clear benefits of study time employment to the students engineering way of thinking and problem solving abilities, to their professionalism in their current jobs, and to the application of learned skills and knowledge into practice.

KEYWORDS

Deep learning, timely graduation, capstone, employment, survey, CDIO Standards: 2, 3, 7

INTRODUCTION

In addition to traditional holiday time working, a majority of university students is taking jobs also during term time. The study by Mathei and Gilmore (2005) shows an average of 14 hours of weekly working during studies. According to Robotham (2008) some students spend more time in their job than in time-based classes, especially in a relatively narrow range of industrial sectors. In these cases the notion of full-time student could be considered as no longer applicable (Curtis and Shani, 2002).

The primary motivation for the students to take jobs is to finance their daily living expenses, and secondarily to enhance their CV's (Curtis, 2007). In a study by Curtis and Williams (2002) it was noted that almost half of the students worked for the reason of obtaining work experience; however, in another study Holmes (2008) found that only 9% of the students considered counting the job as work experience as an essential factor for the job selection. The most essential requirement in this study was flexible working hours (72%). This fits quite well with the findings made by Robotham (2008): in his study more than half of the students were working in retail, pubs, wine bars or restaurants.

Working has some negative effects on studying. Holmes (2008) found that half of the students felt working could have a negative impact on their degree classification. Watts and Pickering (2000) reported a conflict of interest and a sense of pulling students in two directions, leaving them feeling constantly overloaded and stressed. Mathei and Gilmore (2005) report on less time than desired for social activities, study and recreation. However, according to Robotham (2008) the students reported more positive than negative outcomes, such as enhanced time management and group working skills contributing to improved employability. These skills are more vocational than academic. A study by Tuononen et al. (2015) showed that work in connection with university studies is related to a deep approach to learning whereas other work was related to a surface approach and unorganized studying.

The majority of students in the study by Holmes (2008) felt they could balance work and study. Watts and Pickering (2000) talked about increasing employability by contributing students' personal growth. Curtis and Williams (2002) mention also that whatever skills the student gains during employment can be used as experience examples when faced with future job interviews.

Also engineering students in Finland need the salary to finance their studies and daily living. As shown in study presented in this paper, most of the engineering students at University of Turku are working massively, often in the area of their own studies. Same general benefits apply as in the studies presented earlier, like learning group working skills, understanding how businesses operate, or just getting to know how to act in an industrial enterprise. In addition to these, working does have also academic benefits improving one's ability to connect the theoretical studies to the real world and thus enhancing the deep learning of the skills and knowledge from the university classes. A high percentage of the students get their first job with Master level qualifications already before the actual graduation. The combination of almost full-time work and the lack of tuition fees delay the graduation.

A CDIO capstone project provides similar advantages to the student as working in an engineering enterprise outside the university. A pedagogically professional approach to the practical engineering work done in a capstone project may bring equivalent skills to the student with a faster and a better managed way as a part of the curriculum. University of

Turku joined CDIO in 2012, so we currently have both students that follow the new CDIO curriculum and older students who still follow the old non-CDIO curriculum.

27% of the graduates surveyed in this study are from countries outside of the European Union with a high motivation to graduate timely. The Finnish Immigration Service provides limited time residence permits for the studies allowing no more than 25 hours of employment weekly. The difference between Finnish and international students in timely graduation and working during studies is significant. This paper examines an analysis of the effects of employment during studies to timely graduation and deep learning. We present a method for reaching the graduates who have already started their working life and analyze how the knowledge and skills learned at the university fit to the requirements at their present jobs. We conducted a survey among engineering students who have graduated in 2014-2015. Some of the surveyed students were enrolled in our new CDIO curriculum with remarkable changes targeting practical engineering working life skills and also including a capstone project. In this research we analyze how much practical engineering work as an employee was done during the last year of studies, how much did working during studies delay graduation, and did working during studies help in deep understanding of engineering theories. We also compare the outcomes between students following the new CDIO curriculum including a capstone project and students following the previous non-CDIO curriculum.

THE SURVEY

The survey was targeted to students who graduated from a full 2-year MSc (Tech) degree program in University of Turku during 2014-2015. Most of the Finnish students had also their BSc (Tech) degree from the same university thus spending at least 5 years with these studies. The survey was made online using the Webropol service. One of the objectives of the survey was to analyze optimal ways to contact the graduates annually in the future in order to create a continuous feedback process. Most of the students were contacted using email (when address known) or via the LinkedIn service. A few students were contacted with conventional mail providing them with a shortened link to the survey and the student's survey ID code.

Related surveys

The Organization for Academic Engineers and Architects in Finland (TEK) conducts an annual survey for graduates. At the point of graduation University of Turku (in co-operation with TEK) sends a link to the survey to the student's still active university email account. The TEK survey 2015 had 22 replies of which 11 were from international students and 11 from Finnish students. All 7 students answering “My graduation was delayed by more than a year” were Finnish (63.6%). The answer “Delay was caused by working during the studies” was selected by 54.5% of Finnish students, none of the international students.

The Career Services of the University of Turku (Rekry) conducts a survey for all university graduates at one and five years after graduation. The survey is sent by conventional mail to addresses obtained from the Population Register Centre of Finland which has the official addresses of virtually all residents of the country. The response rate of the mail survey among 2013 engineering graduates was 30.6%. The results of the 2009-2013 survey were used as reference data on skill gaps from the earlier years.

Reaching the Graduated Students

Reaching the graduated engineers is somewhat complex as the university emails are deactivated shortly after the graduation. Several different methods were tested in order to find an optimal approach for an annual questionnaire for the forthcoming years. The students' union's alumni register at the university had the contact information for only a few most active graduates. Conventional mail option leads to heavy workload and high cost while likely yielding a poor response rate.

During the period from the beginning of January 2014 to the end of October 2015, 89 engineering students graduated from 2-year Master's programs in University of Turku. 30.3% of the graduates were international students and 69.7% Finnish. Five of the graduates were already connected to the author via the LinkedIn service. A LinkedIn contact request was sent to 44 graduates of whom 63.6% accepted it. Some of the LinkedIn accounts, especially among 2014 graduates, seemed to be passive without recent activity. There was a remarkable difference in the contact request accept rate between 2014 and 2015 graduates.

The response rate by conventional mail was poor. The survey was made during the Christmas holiday season and no conventional mail reminders were sent due to time issues. The big difference in the response rates shows clearly the benefits of contacting the graduates electronically. The highest response rate was achieved by direct email contacts. Of these 16 contacts 68.8% were employed by local universities thus not representing the target group well. Connection via the LinkedIn service provided almost the same response rate (66.7%) and can be ranked as the best way for connecting the graduates. Facebook was considered as well, but virtually all graduates identified in Facebook could be found also in the professionally more suitable LinkedIn service. The Alumni database included accurate contact information for only a few most active graduates, and they were found in the LinkedIn service as well. The best option for the future seems to be creating an active department Alumni group within the LinkedIn service.

Table 1. Reaching the students. Number of graduates,
LinkedIn contact request accept rate and response rates of the survey.
(a few responders did not answer on every questions)

	2014	2015	Total	
Graduates	49	40	89	
-Finnish	32	30	62	69,7 %
-International	17	10	27	30,3 %
eMail	7	9	16	
-responses	5	8	11	68,8 %
Conventional mail sent	18		18	
-responses	4		4	22,2 %
LinkedIn contact requests	24	20	44	
- accept rate	54,2 %	75,0 %	63,6 %	
LinkedIn contacts in total	16	17	33	
-responces	11	11	22	66,7 %
Total responses	22	21	43	**48,3 %**
-Finnish	17	15	32	51,6 %
-International	5	6	11	40,7 %

FINDINGS

According to the survey results, the majority of the respondents were working with salary especially during the final years of their studies. Finnish students participating in the full 3+2 year degree program studies (Bachelor's and Master's Degrees) (n=23) reported having worked on average 3.98 years during their studies. During the last year of the studies this group reported an average of 30.1 hours weekly working for pay of which 28.4 hours was directly connected to the topical area of their own studies. 86.7% of this group had been employed to a job with Master's level qualification requirements before graduation.

Students with a Bachelor's degree from a Finnish University of Applied Sciences (n=8) reported on average 1.95 years of working for pay during their 2-year studies and 31.3 hours of weekly work during the last year of their studies. Half of the students in this group had been completing their degree on the side of their daily full-time engineering job resulting in 5 years of study time in a 2-year program. Both of these two cases fit well with the conclusion made by Curtis and Shani (2002) that the notion of a full-time student can be considered as no longer applicable.

International students (n=10) reported an average of 9.9 months employment during their two years of Master's degree studies, and an average of 15.8 hours of weekly work for pay of which 8.75 hours directly connected to the topical area of their own studies. 56% of this group were employed to a job with Master's level qualification requirements before graduation. The number of responders among international students is very low, but the difference against Finnish students is remarkable.

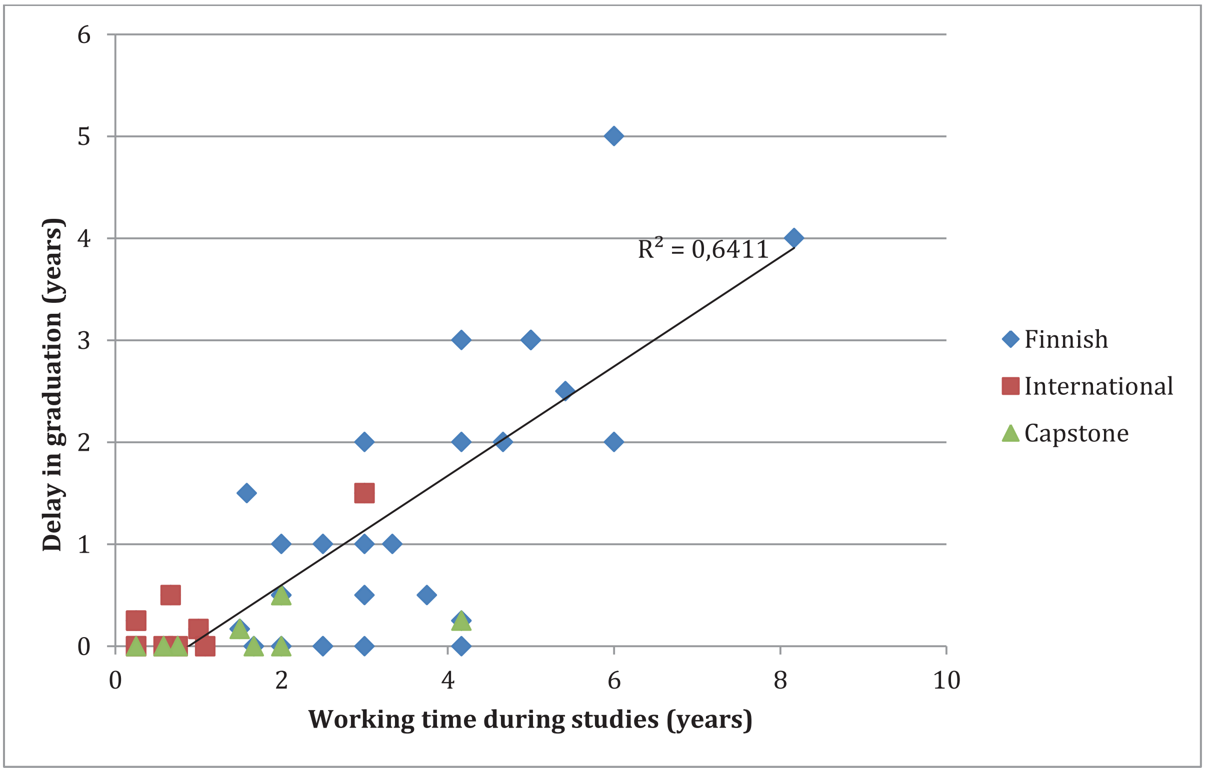

Figure 1. Delay in graduation versus the working time during the studies among Finnish (n=30) and International students (n=10) with a marking on the students who participated in a CDIO capstone project (n=9).

Delay in graduation

Figure 1 shows the delay in graduation versus the working for pay time during studies. The Finnish and International student groups are easy to spot from the diagram. Everyone reported at least 3 months of work. Only one Finn reported less than one year of employment during the studies. A remarkable share of Finnish students has no need to hurry with graduation due to being employed already and due to not having tuition fees. These students are full-time working and tax-paying citizens of the society, but show up in university statistics as students with often remarkable delays in graduation incorrectly indicating poor educational efficiency of the university.

Figure 1 has also a marking on the students who participated in a CDIO capstone project. These students seem to be graduating timely and working less for pay. However, capstone projects are quite new and they are obligatory only for students who started their studies in 2012 or later, thus having a maximum of one year delay in their graduation at the time of the survey. The possible effects on timely graduation are yet to be seen.

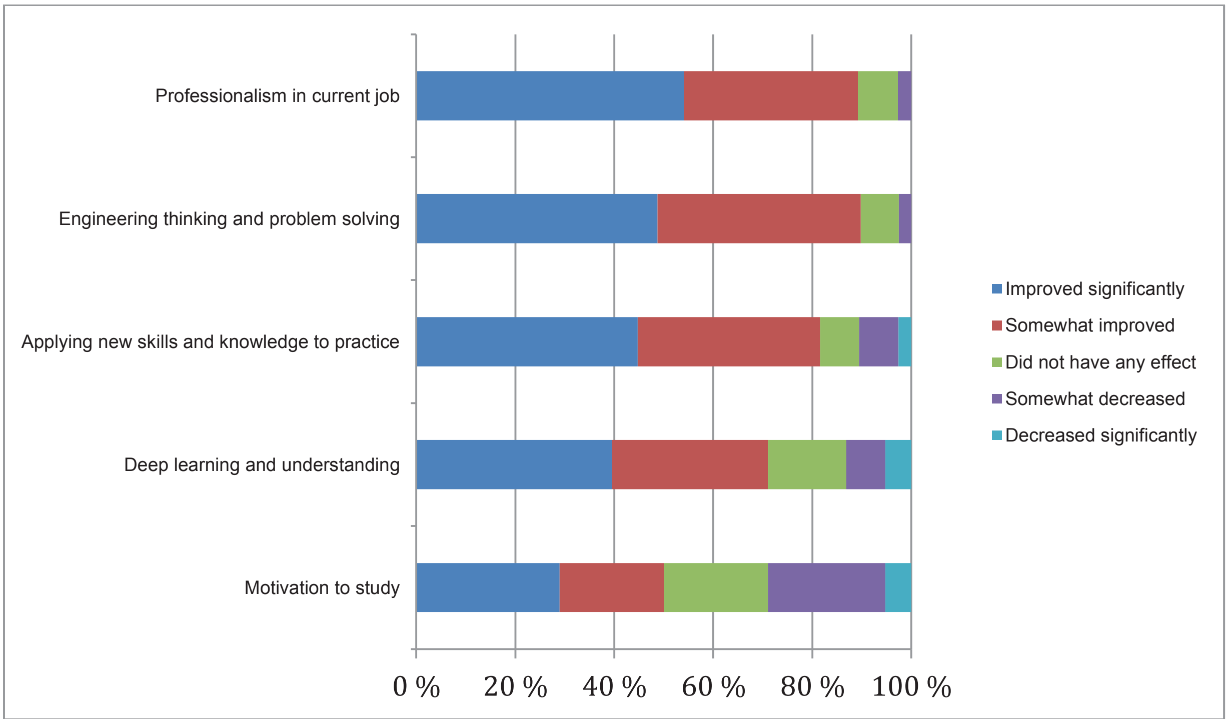

Figure 2. Answers from the graduates to the questions “How did the working for pay during your last year of studies affect on…” (n=38).

Effects of working for pay during studies

Additional questions were posed to the graduates on the effects of working for pay during the studies. Questions regarded effects on motivation to study, on deep learning and understanding of the new knowledge and skills, on the ability to apply new skills and knowledge to practice, on the engineering way of thinking and problem solving, and on graduates’ professionalism in their current job. 76.3% of all 190 answers were indicating a positive effect; the skill was either significantly or somewhat improved. 11.6% of all answers showed a negative effect where a particular skill was either somewhat or significantly decreased due to working for pay during studies. Figure 2 shows results on these questions. Answers from the graduates who had participated in a CDIO capstone project (n=8) did not have significant differences to the rest of the group.

Figure 2 shows that the most common reported impacts of working during the last year of studies are improved professionalism in the current job and improved engineering thinking and problem solving skills. Decreased motivation to study is the main negative finding (29% of responders) in this study, however, 50% of responders reported on increased motivation to study.

A surprising finding was that these effects did not correlate (R^2 = 0.002 – 0.065) with the amount of weekly hours during the last year of studies. The survey data did not show a significant difference between students working 7.5 hours in a week or more than 30 hours a week and the rest of the group. Only three students responded "Skill decreased significantly" on any of the questions. Two of them were working more than 35 hours weekly. The low number of responses prevents the drawing of any conclusions on the negative effect when working over 35 hours weekly.

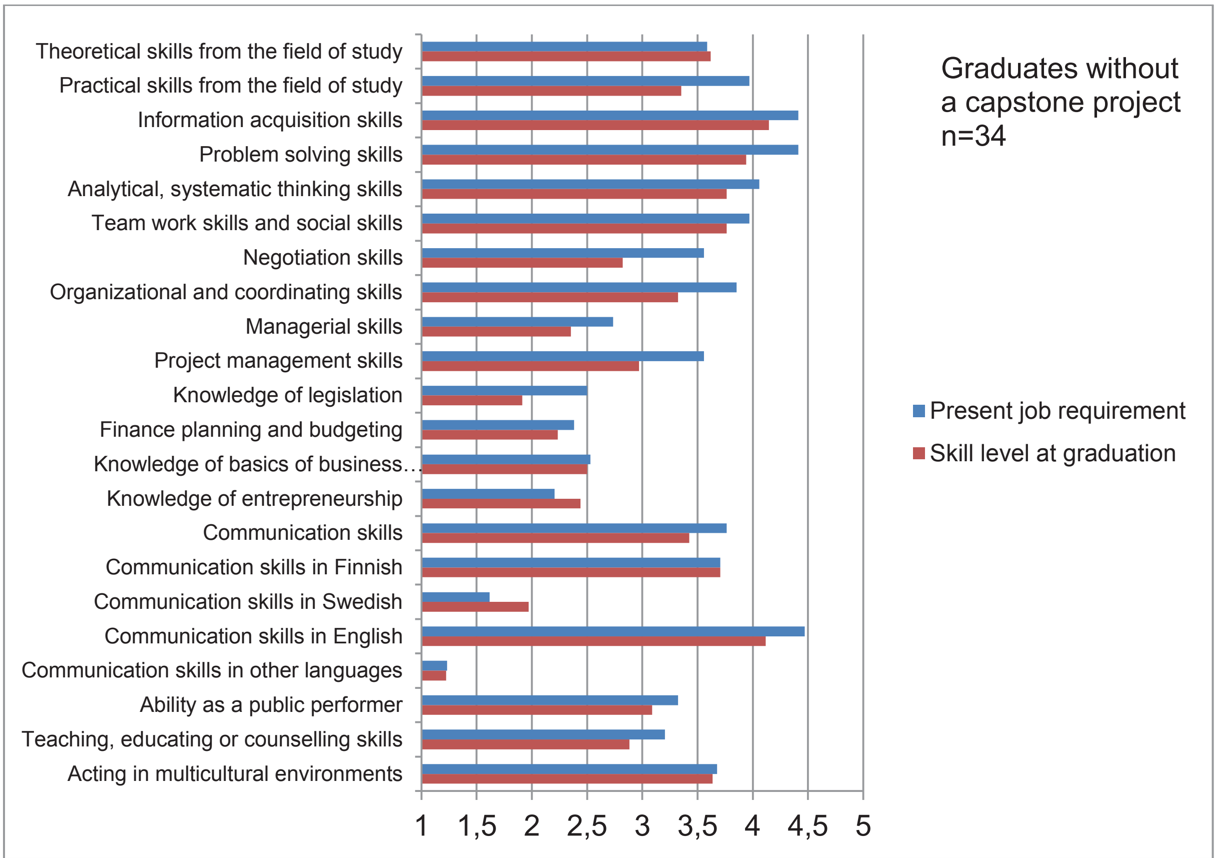

Figure 3. Present job requirements and self-estimated skill levels at the time of graduation in different working life skills among students who did not participate in a capstone project (n=34).

All findings indicate clearly more positive than negative impacts from working during the studies, virtually independent of the amount of weekly working hours. Earlier studies indicate negative effects on some students, like conflict of interest, a sense of pulling students in two directions and feeling constantly overloaded and stressed (Watts and Pickering, 2000), or less time than desired for social activities, study and recreation (Mathei and Gilmore, 2005). These effects were not studied in this survey. Instead of working in their own topical area of studies, students studied in these surveys were working mainly in retail, pubs, wine bars and restaurants. Although similarities in working life soft skill requirements exist, employment among engineering students seems to be somewhat different.

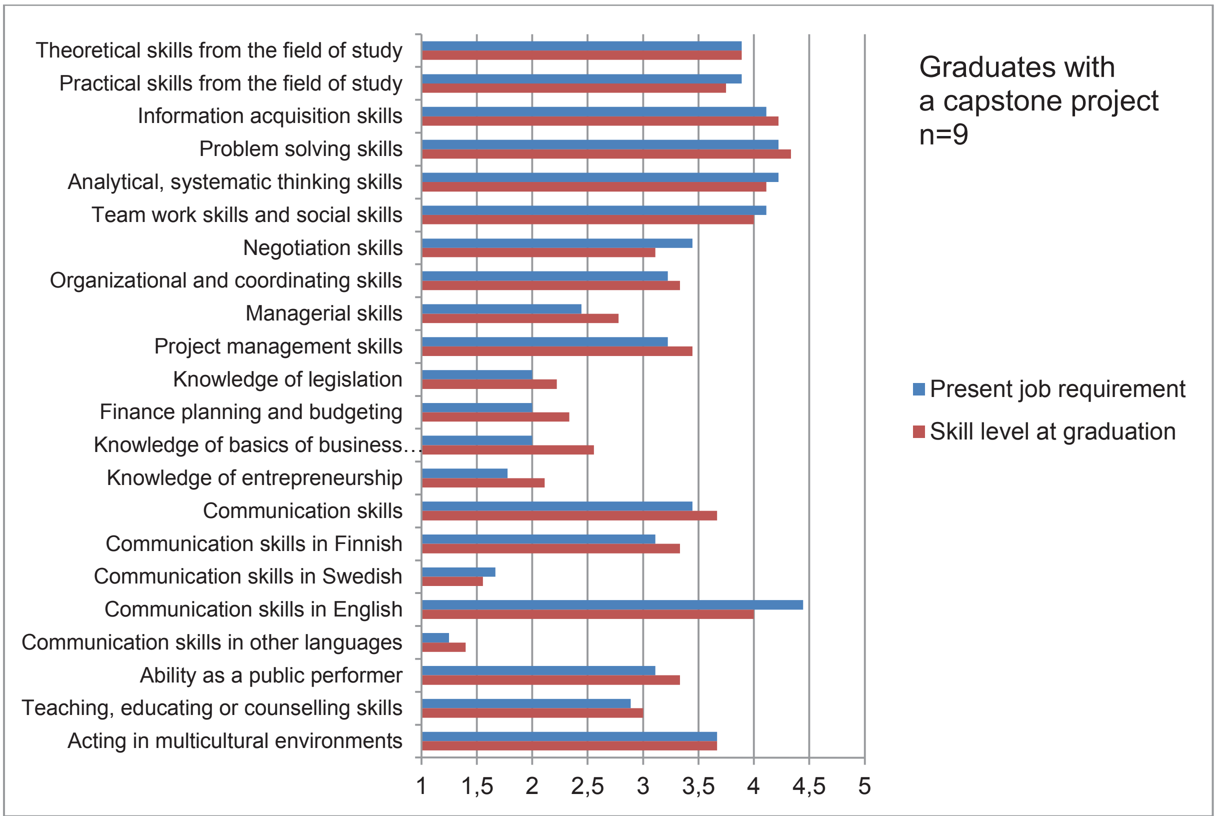

Figure 4. Present job requirements and self-estimated skill levels at the time of graduation in different working life skills among students who participated in a capstone project (n=9)

Working life skills at graduation and requirements in the present job

A list of 22 working life skills was presented in the survey with a double question: “How important are the following skills and knowledge in your current job and how well did you manage them when you graduated?” The results of these questions are presented in two groups: figure 3 shows the answers from graduates who did not join a capstone project (n=34) and figure 4 the answers from the graduates who participated in a capstone project (n=9). The main skill gaps (>0.2) are listed in tables 2 and 3. Despite the small number of responders, the results from the responders following the full CDIO curriculum and joining a capstone project show a clear improvement in filling the gaps in the skills required by the job.

Table 2. The self-estimated skill gaps among the graduates who joined a capstone project (n=9). (1=skill needed/managed not at all, 5=skill extremely important/managed skill very well)

	Present job requirement	Skill level at graduation	Difference
Communication skills in English	4,44	4,00	-0,44
Negotiation skills	3,44	3,11	-0,33

Theoretical skills from the field of study were well matched with job requirements also in the older surveys from Career Services of the University of Turku (2015) indicating a traditional strength on basic theories at the university.

Table 3. The self-estimated skill gaps from the group not joining in a capstone project (n=34) (1=skill managed/needed not at all, 5=skill extremely important/managed skill very well)

	Present job requirement	Skill level at graduation	Difference
Negotiation skills	3,56	2,82	-0,65
Practical skills from the field of study	3,97	3,35	-0,52
Knowledge of legislation	2,50	1,91	-0,42
Project management skills	3,56	2,97	-0,42
Organizational and coordinating skills	3,85	3,32	-0,40
Communication skills in English	4,47	4,12	-0,37
Problem solving skills	4,41	3,94	-0,35
Analytical, systematic thinking skills	4,06	3,76	-0,26
Managerial skills	2,74	2,35	-0,23
Teaching, educating or counselling skills	3,21	2,88	-0,23
Communication skills	3,76	3,42	-0,22

Career Services of the University of Turku has an annual survey for all its students one and five years after the graduation. The survey has a few similar questions with this study, and provides interesting reference material from earlier years. Table 4 indicates the skill gaps from students that graduated in 2009-2013 from the Department of Information Technology. The results are rescaled to match this study.

Table 4. The self-estimated skill gaps from a previous study on 2009-2013 graduates (Career Services of the University of Turku, 2015), rescaled to match this study

	Present job requirement	How well improved at the university	Difference
Practical skills from the field of study	4,42	2,50	-1,92
Negotiation skills	3,33	1,92	-1,42
Problem solving skills	4,67	3,58	-1,08
Communication skills in English	4,33	3,29	-1,04
Team work skills and social skills	4,17	3,17	-1,00
Organizational and coordinating skills	3,58	2,58	-1,00
Information acquisition skills	4,50	3,58	-0,92
Project management skills	3,50	2,67	-0,83
Communication skills in Finnish	4,21	3,42	-0,79
Ability as a public performer	3,75	3,00	-0,75
Analytical, systematic thinking skills	4,25	3,92	-0,33

The skills with largest gaps seem to be almost the same in the earlier study by the Career Services from the University of Turku. The study presented in this paper indicates that most of the skill gaps are presently remarkably smaller or fulfilled. The number of responders fully following the new CDIO curriculum is small, but it indicates further progress in matching the graduate skills to the job requirements. The engineering education in University of Turku has clearly been developing in the correct way.

CONCLUSION

The number of responders in this survey is quite small, especially in terms of students joining a CDIO capstone project, but it shows a clear improvement on the self-estimated skill gaps between students' competences at graduation and the requirements of their engineering jobs. Reference data on 2009-2013 graduates indicate the same trend as quite a large gap in for example practical skills in the students' own topical area of studies has almost disappeared. Other skills with a clear improvement include project management skills and negotiation skills. The new CDIO-style curriculum from 2012 as a whole is clearly working as planned.

The amount of work for pay the students do during the studies is very large especially during the final year. Many students are working full-time; studying seems to be more like a part-time activity. Employment indicates clear benefits in many topics, like the engineering way of thinking and problem solving (90%), professionalism in the current job (89%) and applying the learned skills and knowledge into practice (82%). These benefits do not correlate with the hours of weekly working for pay during the studies; one day per week would be enough.

This survey did not indicate the difference found by Tuononen et al.(2015) in deep learning between working on own topical area of study or in another job. Only a few of the students were working in areas not connected to their studies, making this result unreliable. Negative effects of the employment, such as additional stress and possible problems with passing the courses were not covered in this survey. Earlier studies have shown such effects reported by a minority of the students (Holmes, 2008; Watts and Pickering, 2000; Mathei & Gilmore, 2005; Robotham, 2008).

The study shows a clear correlation between the amount of working during the studies and the delay in graduation among engineering students at University of Turku. Most of the students are employed before graduation. Additional motivation for the graduation would be needed, either a bonus for timely graduation or a tuition fee or equivalent for extra years. On the other hand, the students employed before graduation are already working and tax paying citizens of the community and one can question what the benefit of timely graduation is in these cases. Moreover, Tuononen et al. (2015) showed that the deep learning approach has a negative relation to study pace.

The graduation delay of international students in this survey was small; motivation for timely graduation is provided by the immigration office in the form of limited-duration residence permits for foreign students.

This study will continue towards developing an annual feedback survey with a direct connection to curriculum design. The best way to reach the graduates seems to be the LinkedIn service, taken further with a possible LinkedIn Alumni group for graduates of the department. Some Alumni reached in this survey are already participating as visiting lecturers in a course called Engineering Working Life Skills.

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STUDENT PERSPECTIVES ON FLIPPED CLASSROOMS IN ENGINEERING EDUCATION

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ABSTRACT

We used focus group interviews and the student perspective in order to investigate student perceptions of flipped classroom in engineering education. The learning environment included web-based interactive video films, where students had to answer quizzes in order to continue seeing the films, and interactive in-class sessions with clickers. In general the students had experience of flipped classroom in many courses and subjects, and could compare different implementations in physics, mechanics and calculus. We studied perceived advantages, strengths, drawbacks, or difficulties, and students' views on learning with flipped classroom. Overall, the students were positive, or in one case indifferent to flipped classroom. They saw many advantages, but they also pointed out difficulties and had many opinions about how a flipped learning environment was best implemented. In the interviews, they also expressed their views on learning and described how they studied. Many used rote learning and surface approaches to learning, but many also had a focus on understanding. Some declared an intention to focus on understanding but still used rote learning. Some students expressed a strategic approach to learning with focus on the examination. Heavy workload and a threatening examination system seem to favor surface approaches to learning also in a flipped classroom learning environment. One of our interviewees had dyslexia and described her experience and special conditions. We conclude by suggesting a list of five key elements for flipped classroom. We think that the interplay between these elements is important, and that they are considerably weaker without the support of the others.

KEYWORDS

Student perspective, flipped classroom, approach to learning, dyslexia, CDIO Standards: 8,10

INTRODUCTION

Evidence that active or interactive learning can improve student performance (Deslauriers et al., 2011, Freeman et al., 2014) has inspired many teachers in engineering education to experiment with new methods for teaching and learning. Active learning is a broad and somewhat fuzzy concept and can include a variety of activities (Carr et al. 2015). In some subjects, projects could be a suitable form to activate students. In other subjects, where lectures are the traditional form of teaching, student activity may be promoted by increased interactivity in lectures. This can be done in very many different ways (Naccarato & Karakok, 2015), not only in different subjects, but even in a single course (e.g. calculus) which is taught by different teachers to several engineering programmes. In addition to differences in individual strengths and preferences, teachers have different experiences and different beliefs about teaching. These differences may affect to what extent they embrace the notion of active learning and, in turn, whether and how they incorporate active learning in their teaching. Some teachers incorporate only a few active learning elements in their teaching, others change their teaching more radically. And there are differences between student groups and study programmes, as well. What works extraordinary well one year for a certain study programme might prove to be comparable to ordinary lectures the next year. As teaching and learning are such complex phenomena, it is difficult to analyze the effects of teaching. There are also many different measures of success. Therefore, we do not think it will be possible to find one optimal way of teaching, which will once and for all be superior to other ways of teaching. Rather, we think that we need to identify important components in teaching and learning, which can be applied, when needed, in different situations.

It has long been evident that not all students embrace active learning and that there is a connection to deep and surface approaches to learning (Jenkins, 1992). This is also supported by results from a previous study, indicating that aversion to interactive teaching is connected to certain beliefs about teaching and learning (Weurlander et al, 2015). We believe that students' views on learning are related to the success of a flipped classroom.

At KTH Royal Institute of Technology there is presently a growing number of teachers experimenting with flipping their classrooms. With flipped classroom we refer to teaching where students receive the teacher's view on the subject and prepare for class by reading materials or watching films, and in class they work actively in interaction with peers and the teacher. Others report of a similar development (Love et al., 2014; Murphy et al. 2015; Naccarato & Karakok, 2015; Petrillo, 2015, de Boer & Winnips, 2015). The development at KTH began with experiments with Peer Instruction (Mazur, 1997) in solid mechanics and calculus (Cronhjort et al., 2013). In calculus, students expressed that understanding the textbook was the main obstacle, so a natural next step was to introduce short video films. At that time, many teachers were interested in developing flipped classroom implementations in a wide range of subjects, and received funding from KTH Royal Institute of Technology to do so in a three year development project called *E-science*. In the implementations, filmed presentations were offered as interactive web lectures on the platform Scalable Learning (www.scalable-learning.com), to help students prepare for in-class activities. The films were interrupted by quizzes, which had to be answered in order to continue watching the film. Statistics from the quizzes were available for the teacher before classes. Lectures were replaced with interactive teaching sessions, in general based on multiple choice questions or problems, and the students gave their answers by clickers. On a specific engineering programme at KTH, most courses in the first two years of study now contain flipped teaching.

The utility of flipped classroom still needs to be researched and documented, especially for introductory courses with many students (Love et al., 2014; Murphy et al. 2015). We use the student perspective to address the question of how to implement flipped classroom in engineering education. We focus the specific question: What advantages, strengths, drawbacks, or difficulties do the students perceive with flipped classroom? This is related to CDIO Standards 8 and 10: Standard 8 concerns teaching and learning methods based on active learning, which is a central theme in flipped classroom. Standard 10 concerns actions to enhance faculty competence in active and experiential teaching and learning methods. The *E-science* project aims at development of faculty competence at KTH Royal Institute of

Technology, and by sharing our findings we hope to facilitate for faculty, even elsewhere, to implement flipped classroom in engineering education.

METHODOLOGY

The present study focuses the second-order perspective (Marton, 1981) of students' experience and perceptions of flipped classroom in four different courses: solid mechanics, physics (medical imaging systems), single-variable and multi-variable calculus. Six teachers were involved in the courses. Data was collected from 13 students in semi-structured interviews. Three students were women and ten men. Ages varied from 18 to 25. We used focus group interviews and analyzed the transcripts by qualitative content analysis (Graneheim & Lundman, 2004) with focus on manifest as well as latent content.

Our largest focus group had five interviewees. Two groups ended up with only a single interviewee. The interviews were scheduled about a week after the examination of a course with flipped classroom, in two cases in the second year of study and in three cases in the first year of study. The groups were composed differently: One group had students who had failed the examination, one group had students with excellent results, one had mixed results, one of the single students had dyslexia, and the other single student had excellent results. Most students had experience of implementations of flipped classroom in other courses. Some mentioned and compared up to three courses. All interviews were held in Swedish, and all results and quotes were later translated into English.

The students were asked questions regarding their perception of the course, the flipped classroom design, what they thought helped them in their learning and what they thought was difficult. The interviews were recorded and transcribed.

We used different units of analysis for different purposes. Regarding perceived advantages, strengths, drawbacks, or difficulties with flipped classroom, it was not essential from whom statements came, as teaching should benefit all students, as far as possible. Therefore, isolated statements were in general sufficient units of analysis. In some cases, however, statements were better interpreted in the light of nearby statements from the same person. Regarding students' views on learning with flipped classroom, persons were suitable units of analysis.

In the analysis we coded statements containing views on flipped classroom. The codes were generated from the data. Statements were categorized as *Perceived advantages/strengths*, *Perceived drawbacks/difficulties*, and *How is flipped classroom implemented?,* respectively. We discovered that all interesting materials did not fit into these categories, and added three more categories: *Perceived equal to traditional teaching*, *Student suggestions about how to implement flipped classroom*, and *Views on learning with flipped classroom*.

FINDINGS

Views on flipped classroom

In general the students expressed a positive view on flipped classroom in the interviews (Table 1). This was valid for all focus groups, regardless of whether the students passed or failed the examination. Students who passed or failed the examination, respectively, expressed positive views to a similar extent. One student said regarding the film-based interactive web presentations: "So I have nothing negative to say about it. But it was something fun, positive, and made it enjoyable to learn, you felt that you were given the relevant explanations before the lectures [in-class activities], I think."

Table 1. Perceived advantages or strengths with flipped classroom. Comments not expressed in the data are added [in brackets].

Films	• Usable for repetition, e.g. before examination • Possible to rewind, allows time for making notes • Flexible: adjustable pace and watched at suitable occasion • Offer more possibilities than live lectures: may include pictures, animations [and show specific locations or situations discussed in the lecture] • Effective, well used time, lectures would be superfluous if films covered more • Super as preparations for dyslexics
Quizzes during films	• Facilitate critical thinking • Give insight that you have not yet understood • Teacher receives feedback before lectures about what students find difficult
Encourages students to prepare for lectures	• Makes cheating more difficult. Quizzes are better than handing in a paper [as a proof of your preparations]. With papers, many students only copy a peer • Students feel seen. The teacher can see if I have prepared. • Easier to understand concepts during lectures when you are prepared. Acquiring the concepts goes faster
Creates a structure	• Deadlines and partial goals are appreciated. • Preparations for lectures get done
Guidance	• Better than YouTube as it reflects what the teacher finds important
In-class activities	• Clickers make you more active. You desire to perform well. • Students remain awake and focused with clickers
In-class feedback	• Clickers give feedback to each student • The teacher receives feedback from all students
In-class interactivity	• Gives faster communication and closer relationship between students and teacher • Facilitates asking questions. It is evident to what extent my peers [don't] understand • Interactivity is important, rather than a specific technique. Analogue discussions are also possible
General aspects	• Better perceived retention • The course is perceived as a role model • Fun • Gives confidence • No perceived drawback

The negative statements in general concerned how flipped classroom was implemented, rather than the concept in itself (Table 2). Many students claimed that it has been very helpful in their studies, but one student declared that flipped classroom has not helped him to learn the subject better or increased his motivation compared to traditional studying, even though he said it is likely to be beneficial to other students. This specific student had excellent results in the examination (and was probably coping rather well regardless of how teaching was arranged).

Table 2. Perceived drawbacks or difficulties with flipped classroom

Films	• Difficult to find a suitable degree of difficulty. It depends on whether students have read the textbook before the films • There is no index: It's difficult to find a certain passage • Ineffective [too long], too short, too easy or too personal films • Technical problems: Bad sound, didn't work on tablets • Students are distracted at home or on the web while watching the films
Ineffective in-class activities	• Too easy clicker questions, too much like repetition of the films, miss the challenge • Too difficult questions, I merely waited for him to present the correct answer • Too big span between the easiest and most difficult clicker questions • I get a feeling that the teacher is unprepared • Too many clicker questions give a messy impression • The greatest risk with clickers is that the lecture is merely a long sequence of questions, and nothing is ever presented
Examples	• Students request more contextualization and real world examples • Students request more examples of examination problems including hints and guidance, or step-by-step solutions and confirmation that they have done correct
General aspects	• Reading the textbook is not considered as an option • Better overview with traditional lecture notes. I need to go through the films before the examination in order to know that I don't miss anything • High pace and high work load • Difficult to take responsibility for one's learning, and judge whether I work enough • Clicker questions with a lot of text are difficult for dyslexics

Students had many opinions on how flipped classroom should be implemented (Table 3). These views displayed a large variation and were often contradicting. It is evident that views varied between individuals. In different focus group discussions, different themes were developed, also adding to variation. One focus group began to discuss how long a film should be, and had difficulties reaching a common position.

Table 3. Student's suggestions about how teaching should be

Films	• Focus on introduction of basic concepts, not on details • Short and informative • More materials should be covered in films • More challenging • Should whet the appetite and build confidence, establish a positive attitude to the subject • It mustn't be too difficult, you should not lose your self-esteem • Longer films could be divided in parts with add-ons to a basic film • Good when it contains reading instructions, a brief presentation, and some increasingly difficult examples
Clickers	• Should be used sparingly, giving the teacher necessary feedback • Important to find the right difficulty level and number of questions
General	• Films should focus the lowest pass grade, class activities intermediate to high grades, and additional assignments the highest grade • The lecturer needs to complement the presentations of the textbook • Include an intermediate test with examination problems early in the course for feedback to students

Views on learning with flipped classroom

In the interviews, students expressed their views on learning. Many described how they studied. Several students explained that they used multi-modal learning. In their opinion, it was important to watch the films (combines seeing and listening, and sometimes they watched the films several times), to make notes from the films, write summaries, discuss with peers, and work actively in class or with exercises at home. One said that without being active, it is difficult to learn. One student emphasized that the most important is to make many exercises. Another described flipped classroom as superior to tutorials: "If you compare, sometimes tutorials can be worthless, in my opinion". Some students expressed that solving earlier examination problems is important. One student expressed that there is no difference between how he learns with flipped classroom and traditional teaching. Without flipped classroom, he looks for relevant YouTube films. This student had excellent results on the exam. The student with dyslexia expressed that it is important to her to hear everything twice: first in a film, then in class.

Some students developed more abstract perspectives on learning. One student expressed that with flipped classroom, the student has the initiative and responsibility for making proper preparations and asking questions. Another described the cognitive aspect: In the films, the concepts are introduced and you start thinking. Then, in class, focus is on development of your thinking on a higher level. This student suggested that films should end with a 'cliff-hanger': A challenging question that would keep one thinking until class.

In a few cases, the discussion in the focus groups described students' approaches to learning. We identified three different approaches: Rote learning, understanding, and a strategic approach.

Rote learning was perceived to have a role for many students. At least four students expressed that it was important for the following purposes: Learning the basics ("…then one can begin being woolly and think for yourself…"), facts, information, theory or proofs. One student said that some things have to be accepted without understanding. As an example, she mentioned Compton scattering. Some students expressed that they used an imitative approach. This is similar to rote learning, as it implies accepting things without trying to understand. Some expressed an orientation towards rote learning. The student with dyslexia described rote learning as a major approach: "So you have to kind of adjust to this way of thinking [which is different to the upper secondary school] and to be able to learn things by heart, and it's also a bit difficult for us dyslexics to learn …uh, I think it's hard to learn all things by heart, for I have little blockage there with rote learning, it's a bit difficult, but uh finally it worked out, after about a hundred exercises, then it will work, perhaps…" One student expressed that his preferred way of learning was listening to presentations. The student contrasted presentations to reading the book, and no other ways of learning were considered.

Four students expressed that focus should be on understanding. One of them said: "I focused only on understanding the principles all the time. It was enough for me to get a good understanding…" The other three expressed that the teacher had a focus on understanding, and it was a little unclear to what extent they themselves embraced understanding as an approach to learning. One of them said: "[My teacher in Mechanics has emphasized that one should] understand why things turn out as they do. One should not only be able to use the tools, but really understand why they look the way they do. […] And actually be able to derive the most important concepts from the start. And then use math to solve it." Another student said: "For it will be very demanding when teachers want us to understand, which is good, that we shall surely do." On one hand, understanding is admitted as the preferable approach, but on the other hand, before and later, lack of time and a high pace are admitted to make it difficult. Two of the students who expressed that they used rote learning, also expressed that focus should be on understanding.

Two students talked about a strategic approach to learning, with focus on the examination. One of them said that what helped him most to learn were specific and detailed reading instructions, specifying the importance of "this small part of chapter one". He watched the films focusing on identifying what the teacher regarded as most important. The other student said that other students answered the quizzes by guessing, with the only purpose of getting an extra credit for the exam.

DISCUSSION AND CONCLUSIONS

Overall, the students in our study seemed to appreciate the flipped classroom design, although they identify some difficulties and areas of improvement. Furthermore, the positive and negative views expressed by students (see tables 1 and 2) are similar to what others have reported (Love et al., 2014). The flipped classroom design, with films and interactive lectures, offer students to use a variety of strategies when learning. This seems, according to our findings, to help many students. In this paper, we limit our study to qualitative aspects of flipped classroom. We intend to study quantitative results in a future paper.

Compared to the results by Weurlander et al. (2015), very little aversion is expressed to flipped classroom, but in some cases students indicate vaguely that other students may have objections. We see two possible explanations. Negative views are more easily expressed in a written survey than in a face-to-face interview. Also, the teaching method has been under development for some years by now, aiming at coming to terms with the problem students expressed earlier. One of the main difficulties students had in the previous study was that the course book (in calculus) was too difficult to read and comprehend on your own (Weurlander et al, 2015). In this setting, the films may have served as a complement to the book and students may have experienced fewer difficulties with the book.

Students expressed more criticism of the clicker questions than the films. An explanation may be that if you don't like the films, they are easily avoided, e.g. by doing something else on your computer while playing a film. Those who like the films may watch them as many times they wish. In-class activities, on the other hand, are not easily avoided once you are in class. A conclusion is, as one student points out, that there are no drawbacks with adding films, but in order to get the benefits the films should be made considering the advantages, drawbacks and suggestions described in our results. As it is impossible to meet every student's desires about the films, a structure with short films is preferred. This makes it easier for students to watch the material they need or like, and avoid those that do not meet their needs. We wish to point out that the students' suggestions should be considered with some care. As we point out below, some students use surface approaches to learning, and their suggestions might not be the best for high quality learning. We believe that e.g. reading instructions should not be too detailed. Students may suggest things in order to reduce their responsibility or workload, rather than to increase their learning.

Our results show that an individual student may have several approaches to learning. Different approaches may coexist and be used for specific parts of a course, or they may compete on a more general level: A student may, on one hand, say that understanding is essential; on the other hand, he actually ends up using rote learning. Similar findings where students aim for different kinds of understanding during a course have been reported for medical students (Weurlander et al, 2016). Classical factors known to favor surface approaches to learning, e.g. a heavy workload and a threatening examination system, seem to apply as normal (Gibbs, 1992). For some students, surface learning is still the major learning approach, even in an active learning environment like flipped classroom. Students with a surface approach are likely to watch the films with a very different perspective than students focusing deep learning.

Flipped classroom may be suitable for dyslexics, as long as their special conditions are considered. Films are valuable complements to the textbook. Clicker questions containing long texts should be avoided in class, and even short texts and multiple-choice answer alternatives should preferably be read out loud, as reading may take significantly longer time for dyslexics.

Love et al. (2014) suggest that films are a key element of flipped classroom. Based on our findings, we suggest the following five components as key elements:

- Preparatory films with focus on basic concepts, as a complement to textbook presentations
- Quizzes connected to the films, to stimulate critical thinking and provide feedback to the teacher
- Individual response from each student on preparatory films or quizzes. Students feel seen and encouraged to do the preparations
- In-class interactivity, which challenges to performance and provides feedback to each student and the teacher. This can be achieved by clickers but also in other ways.

- Suitable degrees of difficulty on films and in-class activities, giving confidence as well as challenges.

We do not wish to highlight any single of these components as more significant than others. Most likely, the complex interplay between them is essential, and one component would be considerably weaker without the support of the others. The films, for example, are made more important by quizzes, which stimulate student thinking, provide feedback to the teacher, and motivate students not to skip the films, as individual responses are visible to the teacher. In addition, the proper degree of difficulty on films would be difficult to achieve without in-class interactivity.

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BIOGRAPHICAL INFORMATION

Mikael Cronhjort, Ph. D. is lecturer, researcher and educational developer at KTH Royal Institute of Technology, Stockholm, Sweden. His background is in theoretical physics and mathematics, and he has many years of experience from teaching physics, mathematics and educational science. His field of research is Engineering Education, with a special interest for Mathematics Education and Teacher Education.

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AN EVIDENCE-BASED APPROACH TO ASSESSING AND DEVELOPING TEAMWORK SKILLS

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INTRODUCTION

Real-world engineering practice requires a strong set of both technical and professional skills. Although graduating students are proficient in technical aspects of their work, they often lack the interpersonal skills required to succeed in today's modern team-based environments. This gap is likely due to difficulty associated with explicitly training and assessing soft skills such as self-awareness, communication, and teamwork.

This paper describes a collaborative project between Psychology and Engineering that was established to build strong teamwork capabilities in engineering students. This three year partnership has resulted in the development of evidence-based reflective team and individual assessments and participative activities. The aim of this paper is to describe and disseminate resources we developed that improve the professional skills of engineering students. Accordingly, we offer free access to the tools described in this paper at www.itpmetrics.com and we encourage engineering educators to adopt them to assess and develop teamwork skills in their students.

Team-based work is often implemented with the assumption that students will instinctively develop teamwork skills through these experiences. Unfortunately, simply participating in team projects does not necessarily allow students to develop appropriate teamwork capabilities. In reality, students are unaware of which specific behaviors lead to effective teamwork. Teamwork that is not properly supported may leave students feeling ill-equipped for work in today's dynamic work environments. Taken together, the research and tools presented in this paper align with CDIO's vision to better integrate learning of professional skills, such as teamwork, into engineering curriculums.

TEAM DYNAMICS – CARE MODEL

Based on an exhaustive review of the teamwork literature, we developed the Team CARE assessment, which provides students with specific information on the "health" or effectiveness of their team by aggregating team members' responses to survey items. The CARE model encompasses four key aspects of teamwork and stands for Communicate, Adapt, Relate, and Educate. The CARE feedback report gives students an understanding of aspects related to successful teamwork, and an accompanying debrief activity prompts teams to commit to action steps that will improve their team's functioning. CARE teaches students about important team-level considerations such as goal progression, role clarity, process conflict, strategy and planning, task conflict, information exchange, trust, and cooperation. By introducing students to this model, we offer them a basis for understanding and developing strong teamwork skills. The following section will explain the model, theoretical background, preliminary data, how to access the tool, and will provide an example of a team diagnostic report. We present the CARE model as a valuable tool and framework for assessing, teaching, and tracking the development of teamwork skills in engineering students.

The CARE Model

The first dimension of the CARE model represents communication norms. Communication encompasses strategy formation, role clarity, and conflict management. First, strategy formation and planning is important because it involves decision making on how team members will go about meeting their objectives (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). During strategy formation students should be discussing situational constraints, time restrictions, team resources, and member expertise. Second, role clarity ensures that team members know exactly what is expected of them. Having a clear understanding of roles provides each team member with a sense of purpose and direction and helps to appropriately distribute work (Rizzo, House, & Lirtzman, 1970). Third, cooperative conflict management is a communication style associated with high team performance (Alper, Tjosvold, & Law, 2000). Because of the interdependent nature of teamwork, conflict is unavoidable (Johnson, 2003). Thus, students should discuss how they intend to approach conflict. Teams that adopt a cooperative conflict management approach view conflict as a mutual problem and seek solutions that will be good for the whole team.

The value of communication in teamwork is intuitive. Typically, communication is simply thought to represent the transmission of information among members. However, the CARE model extends beyond this simple conception and offers pedagogical value by encouraging teams to discuss their strategy, roles, and approach to dealing with conflict.

The second dimension of the CARE model stands for Adapt. Adaptability is related to a team's ability to coordinate efforts, monitor team progress, and provide each other support through backup behaviors. Coordination is an important skill to develop in student teams as it leads to productivity gains (Shaw, 1971). Teams with poor coordination end up duplicating each other's work and waste time on logistical issues which can result in frustration and provoke conflict (Behfar, Mannix, Peterson, & Trochim, 2010). Students should also be encouraged to monitor their team's goal progress, which involves using clearly defined metrics to assess progress. Through monitoring, teams are able to identify problems and take action. Accordingly, backup behavior follows monitoring, and entails providing each other with the appropriate support when needed. Engaging in backup behaviors can include things such as coaching, providing feedback, or offering tangible support to other members of the team.

Adaptability allows a team to maintain awareness of changing factors, and such vigilance moves the team toward its objectives (Burke, Stagl, Salas, Pierce, & Kendall, 2006).

Developing an adaptable team can be challenging for students because each member has different schedules, time constraints, and priorities. Therefore, teams need to integrate their efforts, monitor progress, and assist one another in working toward the team's objectives.

The third dimension of Team CARE is concerned with how team members interact with one another and therefore stands for Relate. Interactions leading to positive team outcomes are driven by several factors such as trust, a lack of personal conflict, healthy fact-driven debate, and contribution equality (Jehn, Northcraft, & Neale, 1999). Trust is important because it facilitates cooperation, information sharing, and open communication (Dirks, & Ferrin, 2001). Relatedly, conflict due to interpersonal tension or inadequate member contributions should be monitored and addressed as it may detract from the benefits of learning in a team setting. Additionally, healthy fact-driven debate is a critical skill to develop as it allows students to comfortably and intellectually discuss the merits of different perspectives, views, and opinions **(**de Wit, Greer, & Jehn, 2012).

Team member interactions are often described as one of the most challenging aspects of student team-based work. Students are typically unaware of how their individual behavior helps or hinders the overarching climate of their team. Consequently, students need to gain awareness of the interpersonal aspects of teamwork and work to foster positive interactions. To accomplish this, instructors should facilitate positive relations by implementing team charters and contracts, which aligns the team's expectations of one another.

The fourth and final aspect of the CARE model is Educate. This dimension is related to team learning and encompasses exploratory learning, exploitative learning, and constructive controversy. Exploratory learning occurs when a team goes beyond their current knowledge-base to search for new information, whereas exploitative learning happens when teams refine, leverage, and capitalize on their existing knowledge (March, 1991). Constructive controversy is another type of learning behavior that entails gaining an in-depth understanding of each member's ideas and integrating the best components into a final solution (Tjosvold, 2008). Taken together, this dimension offers value as it makes explicit three different types of behaviors that can lead to the acquisition of knowledge and improve team functioning.

The Educate dimension of the CARE model highlights the participative and experiential aspects of cooperative team-based learning that instructors strive to foster. Specifically, exploratory behavior leads students to develop novel ideas and solutions, exploitative behavior results in well practiced skills leading to enhanced understanding and efficiency, and constructive controversy allows students to gain knowledge directly from their peers.

In the following section we provide information regarding technical aspects of the scales encompassed in the Team CARE model. We then present a complementary addition to the CARE assessment, specifically, individual peer feedback.

Team CARE Scales

Our assessment tool utilizes several scales in order to evaluate how teams are functioning in each of the four CARE dimensions (Communicate, Adapt, Relate, Educate). For an example of survey items used for each CARE dimension please see Table 1. All scales used in the current assessment are derived from well-established measures that have demonstrated stable and predictable relationship with several important team outcomes (e.g., team satisfaction, learning, potency, cohesion, and performance). Thus, although we have yet to empirically validate the model in its entirety, the variables under each dimension were extrapolated from an exhaustive review of the teamwork literature. Additionally, we have collected preliminary data that support the reliability of the facet level scales (see Table 2).

Table 1

Example of questions assessing each dimension

Communication	**Relate**
"We develop an overall strategy to guide our team activities." *"There are clear, planned goals and objectives for each of our roles."* *"Team members seek solutions that will be good for all of us."*	*"How much were personality clashes between members of the group evident?"* *"How often is there tension in your team caused by member(s) not performing as well as expected?"* *"I can rely on those with whom I work in this group."*
Adapt	**Educate**
"Our team will re-establish coordination when things go wrong." *"We regularly monitor how well we are meeting our team goals."* *"We seek to understand each other's strengths and weaknesses."*	*"We work to improve and refine our existing knowledge and expertise."* *"We evaluate diverse options regarding the course of the project."* *"We use our opposing views as a learning opportunity to better understand the problem."*

Note. Responses are recorded on 5-point Likert scales (e.g., 1 = Strongly disagree to 5 = Strongly agree).

Table 2

Reliability of Team CARE Model Variables

Variable	Cronbach's Alpha	Variable	Cronbach's Alpha
Communication		**Relate**	
Strategy Formation	.70	Trust	.87
Role Clarity	.80	Relationship Conflict	.85
Cooperative Conflict Management	.89	Task Conflict	.76
		Process Conflict	.75
Adapt		**Educate**	
Coordination	.87	Exploratory Learning	.84
Monitoring	.80	Exploitative Learning	.68
Backup Behaviours	.73	Constructive Controversy	.88

Note. Reported Cronbach's Alpah scale reliabilities for all variables in the CARE Model sorted by bucket.

PEER FEEDBACK

To complement the CARE model we also developed a peer feedback platform to target individual team members' skill development. Team members anonymously rate each other on five teamwork competencies we adapted from Ohland et al.'s (2012) extensive research. Additionally, the tool is flexible and allows team members to provide each other with written feedback, if the instructor/administrator chooses. Introducing students to the behaviors of effective team members, observing and rating members on these behaviors, and receiving personalized feedback on the behaviors, allows students to learn how to become a highly effective team member.

Peer Feedback Background

The utility of using peer feedback to improve target behaviors has been well established in past research. The underlying premise of peer feedback postulates that introduction to the interpersonal competencies required to be an effective team member, combined with providing feedback on team member's competencies and receiving feedback on one's one competencies, will help students develop and improve their teamwork skills (Brutus, & Donia, 2010). One benefit of using peer feedback is that students working in a team interact more with one another than with the instructor. This means that teammates are able to provide insight that may not otherwise be accurately captured (Brutus, & Donia, 2010). Additionally, gathering performance feedback from multiple team members, rather than solely from an instructor, reduces the possibility of bias and increases response reliability (Brutus, & Donia, 2010). Exposing students to the required team competencies early in their education will allow them to gain familiarity with these soft skills, providing a rich developmental opportunity. Furthermore, repeated use of a peer feedback assessment has previously been shown to improve students' faith in their ability to accurately provide feedback to their peers (Donia, O'Neill, & Brutus, 2015). Increased confidence in providing feedback could also lead to increased confidence in the accuracy of the feedback one is given. Additionally, using peer feedback tools provides students with support and structure in their skill development process.

In order for peer feedback to be effective the feedback tool must be user-friendly, psychometrically strong, and well received by students, instructors, and researchers alike. These attributes are essential in order to encourage participation and promote accuracy of the feedback provided. Accordingly, our tool asks students to rate one another on a number of attributes, which load onto the following factors: communicating with team members; strong foundation of knowledge, skills and abilities; commitment to the team's work; emphasizing high standards; and keeping the team on track. These dimensions were included in the assessment as they have previously been validated as critical components for effective team performance, and have demonstrated strong validity and reliability in past research (Festinger, 1954). The peer feedback tool, which can be accessed at www.itpmetrics.com, presents dimensions using a different interface than the ones used in other platforms. Our interface is designed to make use of social comparison theory, which proposes that we are able to provide more accurate ratings of both others and ourselves when we are comparing multiple people on the same dimension at the same time. Therefore, participants rate both themselves and others with regards to each dimension in sequence, rather than providing ratings across all dimensions for one person at a time. This approach has been linked to higher reliability and validity, thereby encouraging participation, response accuracy, and superior effectiveness of the tool in educational settings.

As the overarching goal of using peer feedback assessments is to guide students on the path to skill development, it is critical to assess whether or not they intend to change their behaviors based on the feedback with which they have been provided. It has previously been established that if an intention to change is expressed, a corresponding behavioral modification can reasonably be anticipated (Wood et al., 2015). The underlying theory behind this postulates that behavioral intentions are the most proximal construct to behavioral change. Intentions represent one's attitude towards the behavior, capturing the effort individuals are willing to expend in order to engage in a particular behavior. Therefore, our platform aims to encourage students to set intentions to change. In order to most effectively accomplish this goal, it is critical to assess students' reactions to the tool: perceived usefulness and satisfaction have previously been positively linked to behavioral intentions regarding further use of the system (Liaw, 2008).

We are therefore interested in students' perceptions of the usability of the tool, and the usefulness of providing and receiving peer feedback. Tool usability refers to student perceptions of how easily they could navigate the interface and their understanding of the tool. The usefulness of providing and receiving peer feedback refers to student beliefs about the accuracy of the feedback they received, and how confident they felt in providing feedback to their peers.

We discovered that students responded positively to the use of our tool, indicating strong satisfaction with its usability (M = 4.08, SD = .91) and a high degree of confidence in the feedback accuracy (M = 3.63, SD = 1.03). Students also indicated that they intended to change their behavior based on the feedback received (M = 3.76, SD = .97). Furthermore, the spread of the responses was largely clustered toward the high end of the scales for each dimension, indicating high satisfaction and expressed intentions to change, as seen in Figures 1, 2, & 3 below.

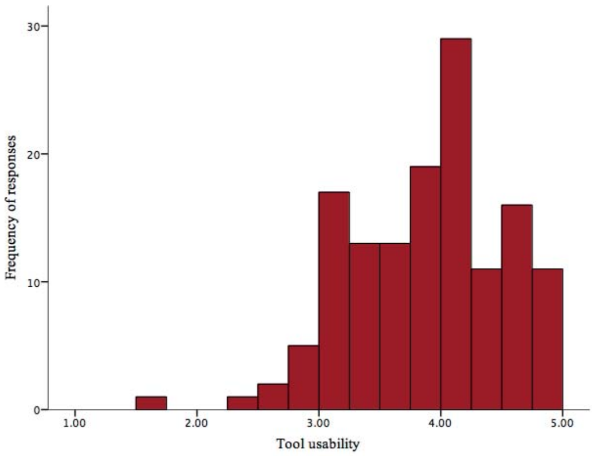

Figure 1. Students' average score on perceptions of the tool's usability, where the y-axis indicates the frequency of that score in the sample.

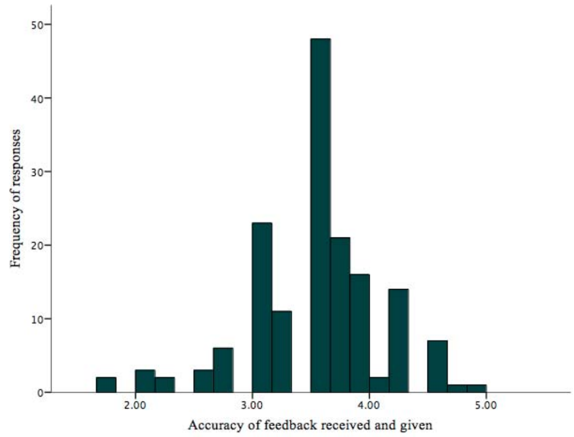

Figure 2. Students' average score on beliefs in the accuracy of the feedback they received and provided, where the y-axis indicates the frequency of that score in the sample.

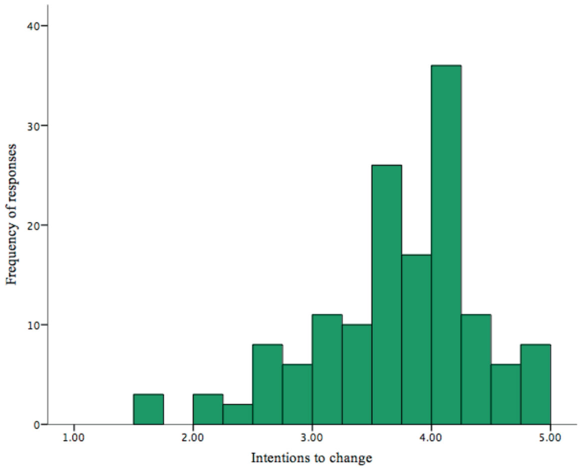

Figure 3. Students’ average score on intentions to change based on the feedback they received, where the y-axis indicates the frequency of that score in the sample.

CONCLUSION

We believe that the Team CARE assessment and peer feedback tool have enormous potential to impact the teamwork capabilities of engineering student teams. First, our platform (www.itpmetrics.com) offers instructors a pedagogical framework and practical tool for supporting the development of student teamwork skills. Second, merely exposing students to the assessment provides them with an understanding of the behaviors that contribute to effective teamwork. Where repeated use, allows students to develop superior soft skills. Additionally, instructors may use the assessments to track cohort changes in teamwork skills as students advance through their education. Taken together, the team dynamics and peer feedback assessments provide instructors with an opportunity to diagnose, develop, and monitor teams and individual students in order to guide them towards effective performance and interpersonal development.

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BIOGRAPHICAL INFORMATION

Nicole Larson. Nicole is first year of her PhD in Industrial Organizational Psychology at the University of Calgary under the supervision of Dr. Thomas O'Neill. Nicole has been working with the Schulich School of Engineering for the past three years. During this period she has been involved in several initiatives such as assessing student learning and engagement, implementing systems for peer evaluations, and leading teamwork-training sessions. She is currently conducting research on team learning processes in engineering student project teams. Additionally, she has co-developed a framework for measuring and interpreting an array of team dynamics. An online assessment tool has been created based on this framework, which allows teams to diagnose and improve the "health" of their team. She is passionate about her area of research and plans to continue conducting research on factors that contribute to effective teamwork.

Julia Smith. Julia is a M.Sc. candidate in Industrial-Organizational Psychology at the University of Calgary, supervised by Dr. Thomas O'Neill. Her research interests include the study of factors impacting teamwork and leadership capabilities.

Genevieve Hoffart is a first year master's student at the University of Calgary focusing on at team dynamics, training, and communication. She has been working with the Schulich School of Engineering for the past four years during which time her focus has been on improving team dynamics and maximizing the student experience. In addition to co-developing a communication training framework that has now been applied to over 5000 students campus wide, Genevieve has personally facilitated many of the training sessions. Her goal is to continue working on developing applicable and universal tools to improve the experience and functioning of student teams in institutions across North America.

Tom O'Neill. Tom is a Professor of Industrial/Organizational Psychology and leading expert in the areas of team dynamics, virtual teams, conflict management, personality, and assessment. He is director of the Individual and Team Performance Lab and the Virtual Team Performance, Innovation, and Collaboration Lab at the University of Calgary, which was built through a $500K Canada Foundation for Innovation Infrastructure Grant. He also holds operating grants of over $300K to conduct leading-edge research on virtual team effectiveness. Over the past 10 years Tom has worked with organizations in numerous industries including oil and gas, healthcare, technology, and venture capitals. He is currently engaged with the Schulich School of Engineering at the University of Calgary to train, develop, and cultivate soft-skill teamwork competencies in order to equip graduates with strong interpersonal and communication capabilities.

Marjan Eggermont. Marjan is the current Associate Dean (Student Affairs) and a Senior Instructor and a faculty member at the University of Calgary in the Mechanical and Manufacturing department of the Schulich School of Engineering, University of Calgary, Canada. She teaches graphical, written and oral communication in their first Engineering Design and Communication course taught to all 650 incoming engineering students. With co editors Tom McKeag (San Francisco) and Norbert Hoeller (Toronto) she co-founded and designs ZQ, an online journal to provide a platform to showcase the nexus of science and design using case studies, news and articles (zqjournal.org). As an instructor, she was one of the recipients of The Allan Blizzard Award, a Canadian national teaching award for collaborative projects that improve student learning in 2004. In 2005, she was one of the recipients of the American Society of Mechanical Engineers Curriculum Innovation Award. She is - as PIC II chair - currently a board member of ASEE.

William Rosehart appointed dean of the school in early 2014 after serving as Interim Dean for the year prior. Before his appointment, he was the head of the Department of Electrical and Computer Engineering. Dr. Rosehart holds a BASc (Electrical Engineering), Master's of Applied Science and PhD from the University of Waterloo and joined the University of Calgary in 2001. He has won many awards including the SSE Service Excellence Award in 2009, the Department of Electrical and Computer Engineering Professor of the Year Award for 2003-04 and the Students' Union Teaching Excellence Award. He has also received awards from the Institute of Electrical and Electronics Engineers (IEEE) and the Association of Professional Engineers and Geoscientists of Alberta (APEGA). He is registered as a Professional Engineer through APEGA, was a member of the Governing Board of the Institute for Electrical and Computer Engineers' (IEEE), Power Energy Society (PES) and was the PES Vice-President, Meetings and Conferences, from 2010 to 2013. A founding member of the Canadian Engineering Education Association (CEEA), he was on the CEEA's Board (2011-2013) and is currently a member of the Petroleum Technology Alliance Canada (PTAC) board.

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REFLECTIVE DIARIES – A TOOL FOR PROMOTING AND PROBING STUDENT LEARNING

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ABSTRACT

For engineering students to be able to effectively solve problems in their future professions, it is essential that they become self-regulated learners and learn to reflect on their own learning using metacognitive strategies. One way to promote this is to introduce reflective diaries as a writing tool for students, and give them weekly prompts to reflect upon. These prompts should stimulate reflections on learning content and learning behavior, in order to help students in becoming self-regulated learners. In addition, reflective diaries allow for in-depth probing of student learning and can be used as a research method to better understand students' learning processes. In this case study, we describe and evaluate the implementation of reflective diaries in a project-based undergraduate course at Chalmers University of Technology, based on diary entries and individual interviews with the students. We explore the potential of reflective diaries for promoting and probing student learning, as well as offer research-based guidelines for implementing reflective diaries in undergraduate courses.

KEYWORDS

Reflective diaries, inquiry-based learning, self-regulated learning, metacognition, case study, Standards: 7,8, 10, and 11

Introduction

Engineering education has been criticized for neglecting to provide students with opportunities to develop skills that are crucial to practicing engineers and prepare them appropriately for the tasks they will face in their work life (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014). One important aspect to achieving this in our knowledge-based society is *lifelong learning*. As problems, contexts, and technologies constantly change and are improved, engineering students need to be able to learn and adapt throughout their whole life (Jonassen, Strobel, & Lee, 2006; Kenny et al., 1998). In order to become lifelong learners, students' ability to engage in *self-regulated learning* is a crucial component (Fabriz, Ewijk, Poarch, & Büttner, 2014). Therefore, learning environments should enable students to own their problems and stimulate them to ask questions like "what do we know?", "how can the problem be approached?", and "where can information be found?". This can be achieved by using *inductive* teaching methods like problem- or project-based learning that place applications and real-life examples first, and encourage students to engage in self-regulated learning (Prince & Felder, 2006). These methods promote an *active learning* process that encourages the students to take a larger responsibility for their own learning compared to traditional teaching, as well as facilitates the students' acquisition of complex skills, like critical thinking, problem solving, and the desire for lifelong learning (Kuh, 2008). These ideas have also been highlighted within the CDIO approach, as pointed out by Crawley et al. (2014): "a contextual learning approach assists students in learning how to monitor their own learning so that they can become self-regulated learners."

Furthermore, self-regulated learning goes beyond the knowledge and skill dimension of student learning. It requires students to link and integrate *cognitive*, *metacognitive*, and *motivational strategies* in appropriate ways (English & Kitsantas, 2013; Fabriz et al., 2014). Metacognition is the awareness of one's own thinking and learning (Flavell, 1979). It enables students to reflect on their own learning, dissect their own thoughts, argue with themselves possible alternatives, and think about how their experiences will shape their future (Gall, Gall, Jacobsen, & Bullock, 1990). There is mounting evidence that metacognition needs to be taught – it is not something that all students automatically engage in (Wedelin & Adawi, 2014). It has therefore been proposed that active learning methods in engineering education should not only encourage students to reflect on the content, but also encourage them to reflect on their own thinking and learning (Vos & de Graaff, 2004). Tanner (2012) gives a good overview of different teaching and learning activities that promote metacognition, one of them being *reflective diaries* (also referred to as learning diaries, learning journals, or log books in the literature).

Reflective diaries can be used in many different forms depending on the purpose. They can be in the form of a public blog or a handwritten book, they can be written everyday, once a month or whenever something significant happens, and they can be structured in different ways (Moon, 2003). The diaries are a writing tool for students that can help the students' reflection process and promote metacognitive skills by providing them with a medium to write down their thoughts (Walker, 2006). Careful prompt design stimulate students to actively reflect upon the learning content and their own learning behavior, therefore facilitating the use of metacognitive strategies and their integration (Fabriz et al., 2014; Jarvis, 2001). In this way, reflective diaries can *promote* students' learning and support students to engage in self-regulated learning and fully benefit from active learning environments (Boekaerts, 1999). However, little is known about the use of reflective diaries in engineering education and the importance of particular disciplinary contexts (Tanner, 2012).

In addition to *promoting* student learning, reflective diaries can also be used for *probing* student learning, which is an important part in order to understand student learning in more depth and make informed decisions to improve engineering education (Lohmann, 2008). Traditionally, there has been a focus in engineering education research on what students have learned at the end of a course or program with a minor emphasis on the pathways students take to reach this final stage (Schmitz & Wiese, 2006). This is mirrored by the data collection methods commonly used: interviews at the end of the course, surveys, and course evaluations (Koro-Ljungberg & Douglas, 2008). In order to understand the processes in student learning, however, it is crucial to look at the pathways they take during their education, what challenges they experience, what motivates them, and what supports their learning. Reflective diaries enable researchers to collect data more continuously (Rieman, 1993), and open up for the possibility to investigate students' pathways in more detail (Jarvis, 2001). In contrast to observational data, that shows how subjects behave and interact, reflective diaries provide information about the students' thoughts and reflections on situations, in some way similar to interviews, but closer to the moment that they occur in. Schmitz and Wiese (2006) summarized two important advantages with reflective diaries as a data collection method: “First, they allow to observe learning over time. Second, learning can be investigated with ecological validity because learners complete the diaries in their natural learning environment.”

In this paper, we: 1) explore the potential of reflective diaries for promoting and probing student learning, and 2) offer research-based guidelines for implementing reflective diaries in undergraduate courses. The case study presented here describes and evaluates the use of reflective diaries in an undergraduate course on tissue engineering at Chalmers University of Technology and illustrates our findings by using extracts from the reflective diaries and individual interviews with the students.

Study context and design

The context for this study is an advanced level course (15 ECTS-credits) on tissue engineering that runs over a five-month period at Chalmers University of Technology. The majority of the students take the course in the first year of their master program. The aim of the course is for students to: 1) gain an overview of the tissue engineering field; 2) understand the fundamental science and technology that form the building blocks of the field; and 3) develop research competencies relevant to the field and a research identity.

The dominant pedagogy underpinning the tissue engineering course is *inquiry-based learning* (Lee, 2012; Prince & Felder, 2006), which belongs to the class of inductive teaching methods. To support students during the difficult and complex inquiry process, *expert guidance* is embedded in different ways, for example through lectures, modelling of skills, coaching during activities, and collaborative problem-solving (Laurillard, 2012). The course consists of lectures, article review sessions and a research project. The research project runs over the entire five-month period of the course and all projects are directly coupled to on-going research at the university. The aim of the project is not only to gain a deeper understanding of the outcome but also to experience research as it is conducted to gain an understanding of the scientific process. For a more detailed description of the course see Wallin, Adawi and Gold (2013, 2015).

In 2014, weekly reflective diaries were used with one of the project groups (four students S1-S4) to promote and probe the students’ learning, as well as evaluate the use of reflective diaries themselves. Individual interviews were conducted in the middle and at the end of the course where students were asked to talk about their perceptions and experiences with the reflective diaries. Student participation in writing the diaries was voluntary, but strongly encouraged. The students were carefully briefed at the beginning of the course about the purpose of the reflective diaries and how they could help the students to learn better and support them during their own project work. No points or formal assessment was based on the diaries, and the person reading the diaries was the project tutor, who was not involved in grading the students at the end of the course. All students gave their informed consent that their diaries could be used as research data.

The students wrote weekly reflective diaries around specific prompts. Figure 1 illustrates the design principles used for the prompts. Topics were selected around different phases the students encounter in their projects, general aspects of working with tissue engineering research, and the students' learning experiences. Through the use of four general categories of questions that encouraged reflections on different levels, specific prompts were designed, exemplified in the figure.

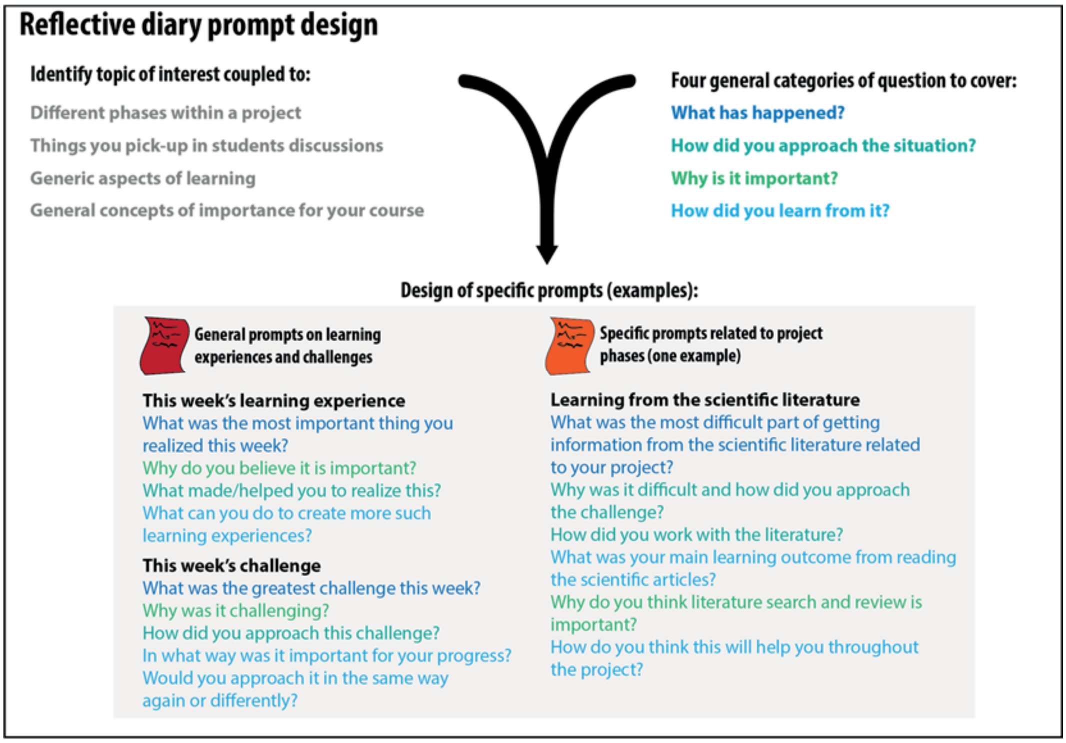

Figure 1. Overview of the general design thoughts behind the reflective diary prompts and examples of specific prompts.

The students received the prompts at the beginning of the week via email and were asked to send their reflections back on Friday afternoon. The prompts alternated between focusing on more general learning experiences in odd weeks and on the different phases of the project in even weeks (Figure 2). By using prompts that were both looking backward and forward, the students needed to reflect upon their planning on upcoming tasks, monitor their actions, and evaluate their performance on completed tasks. On the probing side, this approach allowed us to get process data on the same incident from two different directions or perspectives.

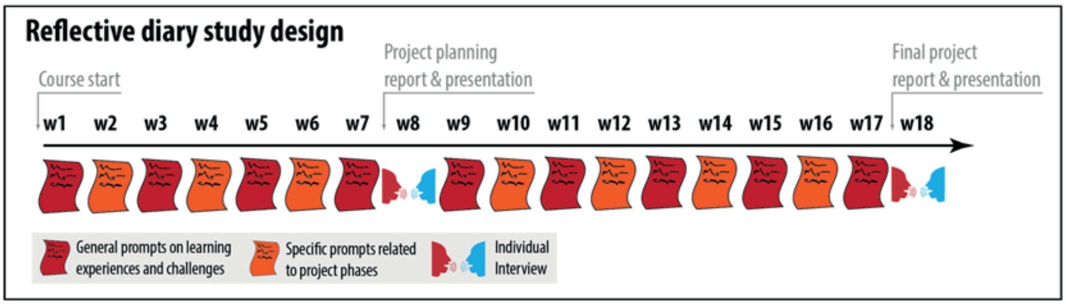

Figure 2. Overall design of the study.

Results

The results for the study presented here are based on two data sources: individual interviews with the students at the middle and end of the course, and the reflective diaries themselves. In order to understand how the students experience writing reflective diaries, we will first take a look at the interview data. In the second part of the results section, we will use excerpts from the reflective diaries to illustrate how reflective diaries help both to promote and probe student learning.

During the interviews, the students were asked to talk about how they experienced writing the reflective diaries. Some students said that it was difficult at the beginning to write the reflective diaries. They did not know what was expected from them and could not fully understand the aim of writing the diaries:

> *I can say at the beginning it was difficult, I did not know what to write, because the questions were so open and I did not know what you did expect us to write (S2).*

One way for the students to avoid this uncertainty and the lack of experience to write reflective diaries is to relate it to tasks that they are more used to and commonly perform at the university, like assignments and writing descriptive text:

> *At the beginning, I thought about it like an assignment and I did not know what to write (S1).*

> *Yes, I agree we are trained to write descriptive text. It is true because we just try to make things very precise and exact all the time (S2).*

This happened despite the fact that the students were carefully introduced to the idea of reflective diaries and their purpose was discussed extensively together with them. The interviews suggest that the problem lies deeper and the students' behaviour cannot be explained by a simple misunderstanding of the task. The students are aware of the task and aims of writing reflective diaries, but they have difficulty doing it:

> *I suppose this is the idea of the reflective diaries that you want to hear what we have in mind, and that there are no rules. But I mean for me it is difficult sometimes to write things like that (S2).*

The students often experience learning at university as a pure cognitive task, where knowledge is transferred from those who know to those who do not yet know, rather than an integrative process where their own experiences and reflections play an important role. They find it difficult to write about their own experiences and feelings, and prefer to write about concrete aspects of their learning, as they are not used to write reflectively:

> *For me, it is difficult to write these kinds of things. For example the questions "what did you feel" and these things, it feels a bit strange to write about them. I prefer to write more specific things. But in the end I think it is good. Maybe it is just that I am not used to do these things (S2).*

It is through continuously writing the reflective diaries that the students that were sceptical at the beginning start to appreciate them more and more. They feel that writing the diaries helps them to sit down and take the time to reflect upon what has happened during the week. By doing so, they experience that the diaries help them to see their own development, learning, and progress:

> *At the beginning, I did not think [the diaries] helped, but later they helped. It is my first time writing something like this. It was good to sit down and think about what I have done during the week… it was really helpful. It really helped me grow and see my own progress (S1).*

> *I think it is good that we are forced to think about things, especially what we learned and also what our working progress has been (S3).*

The diaries are also used as a tool by the students to make their cognitive processes visible to themselves and become aware of their own actions, thoughts, and social interactions within the project group. It helps them to see and reflect upon the challenges that they experience, the approaches they took to overcome them, and possible improvements in the future:

> *The diaries are a really good way to see for yourself and reflect upon challenges you have had and how you got through them. Seeing things you might want to do better next time. And reflect on yourself as a person in a group and a project. I think it is really good to have (S3).*

This positive attitude towards reflective diaries and ability to use them effectively can be seen in all students at the end. This means that while they have different starting positions due to personal and cultural differences, all students were able to use reflections as a metacognitive strategy to think about their own learning by the end of the course. It is important to keep in mind these differences, as it means that the support students need varies between individuals.

In the second part of the results, we will now take a closer look at the reflective diaries themselves and illustrate with selected excerpts how the diaries are promoting student learning and how they can be used to probe student learning. We will focus on the specific topic of working with the scientific literature, which the students engage in throughout the tissue engineering course. Whereas the interviews gave us an idea of how the students experienced writing the reflective diaries, the challenges they encountered, and development over time, the diary excerpts can illustrate how the prompt design and structure can help the students to reflect upon various aspects.

Figure 3 shows selected excerpts from the reflective diaries in the center column, and the analysis along the promoting dimension on the left and the probing dimension on the right. The diary excerpts are grouped around the four categories that the students were prompted to write about in each topic every week: 1) what has happened, 2) how did I approach the situation, 3) why is it important, and 4) how did I learn from it. For promoting students' learning, these four categories translate into: 1) reflecting on their plans and assessing the challenges, 2) identification of appropriate cognitive strategies, 3) evaluation of their approaches and connections between different parts, and 4) ideas of how what they learned can be used in the future. In addition, the excerpts can be viewed from a different angle with a focus on probing student learning. In that case, the four categories can be seen as 1) to raise the teacher's awareness on the challenges students face, 2) to identify what type of scaffolding and support they need, 3) to understand the students' motivation to work in a certain way, and 4) to evaluate if students are able to see transfer possibilities of what they have learned into other contexts.

Promoting	Reflective Diary quotes	Probing
Planning Writing the reflective diaries helps the students to identify and become aware of the challenges they are facing, as they need to think through them and write about them. They need to analyze their current situation, in order to be able to plan their actions.	**"What has happened?"** *One of the biggest challenges when starting a new project is to classify the information, due to the large amount of information that exists on the network, it is important to classify and select the ones that are relevant to our project.* *The most difficult part is to understand the terminology and become familiar with it.*	**Awareness** The reflective diaries can help teachers to become aware of the challenges that students experience during a project. This information can be helpful to design appropiate scaffolding of the students learning process and provide the right support to them.
Cognitive strategies The next step is for the students to find their own solutions to overcome the challenges they are facing. By writing down their own approaches and strategies and reflecting upon them, the students make them tangible and easier to use. Reflection helps students to opertionalize the information and strategies they recieve in class about the structure of scientific articles and see it in connection to the challenges they face.	**"How did I approach it?"** *However, reading all of the articles by whole text seems impossible. The abstract provides a very good view of the content. Also in the introduction part, a basic knowledge background is provided and there are always a few sentences about what others have done previously in this part, as well as their aims, what they want to improve. It is a good way to learn.*	**Support & Scaffolding** The reflective diaries also help teachers to see how the students overcome the challenges that they experience and the strategies that they apply. The students' strategies can either be coupled to formal course activities or other more informal activities e.g. interactions with other students and web searches. In this way, the diaries help to evaluate the effectivness of certain interventions.
Evaluation Another important aspect is that the students through their reflections start to realize why certain elements are important and how they are connected to each other. In this way, the different tasks also become meanigful. Furthermore, they need to think about their approaches with respect to their goals and evaluate the strategies that they have used.	**"Why is it important?"** *One of the best ways to understand the topics related with the project and be aware of the state of the art is to read articles. In this way we can find the latest research in this area and look at the experiences and mistakes from other researchers to create something new or take a step further in the subject.*	**Motivational factors** Teachers might have a very clear idea why certain aspects and phases of a project are important, however this might not be clear to the students. The factors that motivate students to pursue a task can differe greatly, and it is important for teachers to know what stimulates student learning. Reflective diaries provide the teachers access to these factors.
Future use Finally, the reflective diaries encourage students to reflect upon what they have learned from a task. This includes reflections on how the content of what they have learned can be used within their project or in other contexts, as well as how the used strategies can be used in the future.	**"What did I learn from it?"** *By doing literature research one can get a lot of information and tips from other peoples research to get a more successful project outcome, for example by using existing protocols, not having to reinvent the wheel on every step... I have also learned a lot doing the literature searches, about other peoples experiments, setups and evaluations.*	**Transfer** In addition, it is important to see and evaluate how students use their knowledge and findings within the project. Reflective diaries can help to assess how different project phases are linked together and in what ways students transfer information and knowledge from one to another.

Figure 3. Results based on excerpts from the reflective diaries.

Discussion and Recommendations

Based on the results presented here and the empirical findings by others (e.g. Davis, 2000; Fabriz et al., 2014; Ifenthaler, 2012), reflective diaries can promote student learning and support students to become self-regulated learners, as well as being used to probe student learning. However, from our data it becomes clear that students need training and support to develop metacognitive and reflective strategies. We want therefore to highlight two aspects that are important to consider when using reflective diaries for promoting student learning: the design of diary prompts and the process of introducing reflective diaries.

On a more concrete design level, the use of multiple types of question in the diary prompts can stimulate students to reflect at different levels and around different topics. It is through careful prompt design, which focuses on both learning content and learning behavior, that reflections can help students to become aware of their own thought processes and strategies. A first step is to select a relevant topic for the students to reflect upon. Tanner (2012) provides an extensive list with possible questions, which can serve as a starting point, but can also feel overwhelming. In our view, reflection topics should be grounded within the activity the students engage in and be identified by practitioners. It is important for the students to feel that the prompts are coupled to something that they experience and feel is meaningful to reflect upon. We have proposed four categories of diary questions (Figure 1: what has happened? How did you approach the situation? Why is it important? How did you learn from it?) in this study that offer a starting point for educators to design their own prompts around topics relevant for their context. In order to avoid that students get tired of writing the diaries or filling them out mechanically, it is important to have variation within the prompts given to the students each week, while still providing some familiarity each week to facilitate writing (Jarvis, 2001; Moon, 2003).

Using carefully designed prompts is, however, not enough, and the introduction and framing of reflective diaries towards the students is a crucial aspect. It cannot be assumed that students are used to write reflective text and readily know what to do (English & Kitsantas, 2013). Our interview data illustrates how students' previous experiences and their conceptions of knowledge and learning can pose strong obstacles for them to engage in reflective writing. Some students might not see reflective writing as part of their learning experience at the university, as they have never encountered it before and have difficulties to relate to it. These students might hold a view of knowledge being absolute and focus on specific knowledge to be either right or wrong (Felder & Brent, 2004); a view that is difficult to maintain when engaging in reflective practice. The students require the right guidance and support to overcome this internal conflict that they describe during the interviews. It is not enough to provide the students with prompts and tell them the purpose of writing reflective diaries. Based on our own experience and data, one important factor is that the students need the possibility and encouragement to write reflective diaries over a longer period of time to fully appreciate them and benefit from them. The extended engagement in reflective practice also helps the students to get to know the person reading the diaries and developing a trust relationship, which is very important to be able to openly reflect (Walker, 2006). Other important factors that help the students are modeling of reflective thoughts by teachers (Tanner, 2012) and receiving feedback on their text (Moon, 2003; Walker, 2006).

Reflective diaries can also be used for probing student learning, as shown in the results section. For the probing dimension, it is important to consider how the information will be used, which can be roughly divided into: probing for development and probing for research. Probing for development aims at improving a course, project, or activity by helping the teacher to see it from the students' point of view. In this case, the information will stay within the university with limited access for other people. Probing for research, on the other hand, aims at using the reflective diaries to help answer research questions, and the goal is to publish the anonymized data in a research context. This means that research ethics need to be considered (Rieman, 1993), and while rules and guidelines might differ around the world, we feel that it is important to inform the students about the research and ask them for permission to use their accounts before introducing reflective dairies.

In this paper, we have shown the potential of reflective diaries for promoting and probing student learning. From a CDIO standpoint, this is very interesting, as it can support students to become self-regulated learners and fully benefit from active learning environments created within the CDIO syllabus. Reflective diaries can help students to have *integrated learning experiences* (Standard 7: Crawley et al., 2014) by facilitating the integration of disciplinary and personal knowledge and skills, as well as provide an additional aspect to *active learning* (Standard 8: Crawley et al., 2014). Furthermore, the diaries can support the *enhancement of faculty competence* (Standard 10: Crawley et al., 2014) through the ability to probe and study student learning, and could also be used for *learning assessment* (Standard 11: Crawley et al., 2014), especially for formative assessment that support student learning (Moon, 2003). We hope that the research-based guidelines provided in this paper will help practitioners to implement reflective diaries in their own context for promoting and probing student learning.

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BIOGRAPHICAL INFORMATION

Patric Wallin is a Researcher at the Division of Engineering Education Research at Chalmers University of Technology, Gothenburg, Sweden. He holds a Ph. D. degree in Bioscience with a specialization in Educational science. He has tutored projects in the Tissue Engineering course for several years. Patric's research interests in the EER field are focused around personal development, undergraduate research experiences, communities of practice and situated cognition. He is particular interested in the progress and development processes students experience in these learning situations.

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DESIGN SCIENCE RESEARCH AS AN APPROACH FOR ENGINEERING EDUCATION RESEARCH

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ABSTRACT

Design Science Research is a research approach that is widely used in information systems, IS, but also in other areas where the development of an artefact is parallel to the development of a theory or methodology for this development. In our research we have developed the model "the learning of a complex concept", LCC, as a method to analyze learning outcomes, as well intended as experienced by students.

In this paper we will show how this model was developed, and how design science research was used to develop a methodology that may now be used in the iterative design and analysis of learning outcomes. LCC was developed while designing teaching sequences in a course in electrical engineering. The model was derived as a means to analyse videorecordings of students' actions, during lab-sessions in an electric circuit course in the first year of an electrical engineering program.

The model has contributed to the understanding of learning but also to the design of learning materials, and design science research has improved the methodology. Can this become an especially appropriate methodology for analysis of CDIO-projects? What may be learned, and what is actually learned in a CDIO-project? How can "the learning of a complex concept" (LCC) be used in the iterative design process designing a CDIO-project?

KEYWORDS

Learning of a complex concept, design science research, engineering education research, Standards: 1, 2, 3, 4, 5, 6, 7, 8, 10.

INTRODUCTION

In an attempt to study learning in engineering education, we video-recorded students' actions in a lab course on electric circuit theory. Since the amount of data was very large (for the whole course ca 250 hours of videorecordings, and for this particular lab ca 40 hours) we tried to find a way of analyzing students' difficulties by looking at the questions that were raised during the labs. We used the method *Practical Epistemologies* (Wickman, 2004), where the researcher looks for gaps in students' conversations, when they encounter something that is new to them. We represented our findings graphically in a model, where the topics students were talking about were represented by circles (nodes) and switching to another topic by an arrow (link).

Often questions were raised at these points. This model was refined and used both for analysis of students' actions and to design new lab-instructions (Anna-Karin Carstensen, 2013; Anna-Karin Carstensen & Bernhard, 2007). However, modelling is an engineering endeavor often taken for granted, as is also design (Mitcham, 1994), and there was a need to turn this method into a methodology for engineering education research. Since in design science research "the design researcher arrives at an interpretation (understanding) of the phenomenon and the design of the artefact simultaneously" (Vaishnavi & Kuechler, 2008) it seemed fruitful to explore the derivation of the LCC-model by means of design science research. This exploration was presented at the Engineering Education Research Symposium 2015 in Dublin (A-K. Carstensen & Bernhard, 2015). Here we will summarize the exploration and show how the methodology may be used in analysis of learning outcomes in a CDIO project course.

DEVELOPING A METHODOLOGY

One of the strengths of design science research is the iterative process rendering the theory, since the same method is used for development and evaluation. The refinement of the designed artifact is aligned to the development of the theory. The LCC-model can be considered to be a design artifact, and the "evaluation of the artefact then provides information and a better understanding of the problem in order to improve both the quality of the product and the design process" (Hevner, March, Park, & Ram, 2004, p.78).
The methodology most often used in design science research in information technology is the method described by Takeda, Veerkamp, Tomiyama, and Yoshikawa (1990):

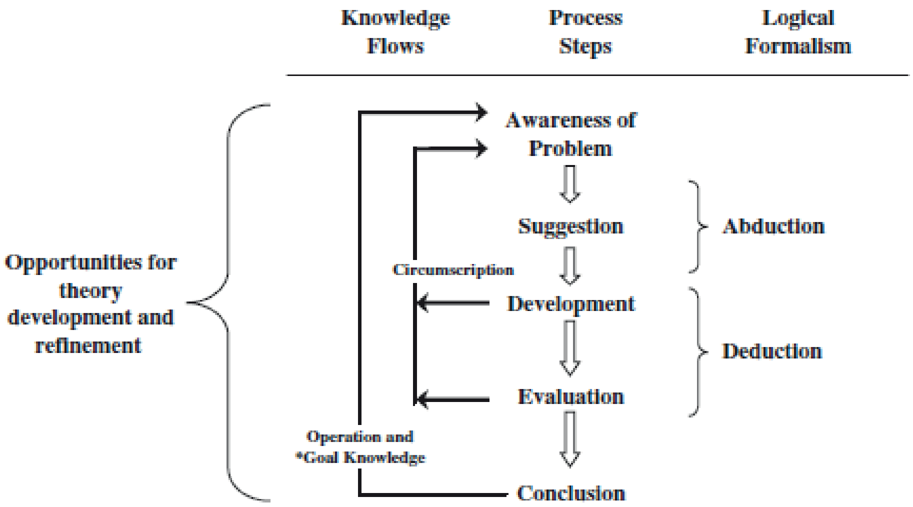

Figure 1: The design cycle originally proposed by Takeda et al. 1990 (as displayed by Kuechler & Vaishnavi, 2008, p. 493)

The iterative process gives opportunities to refine the artefacts, and models, but also for theory development (Kuechler & Vaishnavi, 2008). The theories that inform design science research belong to either of two categories, *descriptive* and *prescriptive*, where the descriptive, also called *kernel theories*, frequently have their origin within other disciplines, and the prescriptive, the *design theories,* are prescriptions of "how to do something".

Typically the design cycle starts with the awareness of a problem (Figure 1), and an analysis of the normally wicked and complex problem. The first suggestions towards a "solution are abductively drawn from the existing knowledge or theory base for the problem area" (Vaishnavi & Kuechler, 2008), often theories from other disciplines, termed *kernel theories*. In our case we used analysis methods from pragmatism in the analysis of students' actions (Wickman, 2004) and from phenomenology in the analysis of "the intended object of learning" (Marton & Tsui, 2004).

A suggestion is then made, in our case the LCC-model was designed, and used to design new teaching sequences. As well the model as the labs were then evaluated, and especially the model has been refined in subsequent design cycles. However the evaluation is not the last step since this is an iterative method, the circumscription is of uttermost value. When designing a car, the prototype is not the last step, there is always a new iteration of the car design starting the moment a prototype is ready to launch.

THE THREE DESIGN CYCLES FROM OUR METASTUDY

(Summary of the metastudy in A-K. Carstensen & Bernhard, 2015)

First design cycle

In the first design cycle we had video-recorded students' actions in a lab course in electric circuit theory. One of the labs concerned "Transient Response". We needed a way to analyze the problems students faced when dealing with this topic, in order to design a new lab-instruction. The amount of data is very large, and thus the need for a method to condense data is necessary. Our first attempt in this was to listen to the students' discussions and look for the occasions students asked questions. We used the method of *Practical Epistemologies* (Wickman, 2004) where the researcher looks for gaps in students' conversations, when they encounter something that is new to them. Analysis of the questions showed that the questions seemed to occur when students were changing topics to discuss. For example the students started to wire up the circuit, and the first questions concerned how to connect the leads for measuring. Thus we started to draw the questions as arrows, and the discussions on a topic as nodes, "islands", which lead us to draw the two circles called "real circuit" and "measured graph", and although we did not write any labels on the arrows, they represented the action where the students connected the circuit to the computer-interface, and started to measure (using a computer interface measurements directly render graphs). Now the next action expected was that the students should try to make the computer draw the calculated graph in the same diagram, by use of the mathematical expression of the time function. In the first course the students were not able to do this without help from the teachers, and thus they asked "Is this good enough for the report", showing that they did not make the links between the topics but only talked about one concept at a time.

Thus we tried to analytically draw what nodes and actions we had expected the students to talk about, what in *the Theory of Variation* is termed the *intended object of learning* (Marton & Tsui, 2004) – and draw the nodes starting with the real circuit, onto the differential equation, further to the Laplace Transform in order to calculate the solution to the differential equation by searching the inverse transform, i.e. the time function. In this first course the arrows were not actions done by the students, rather they were the path of topics in a traditional teaching sequence or text book. The gap between the measured graph and the calculated graph – which was very clear in the video recordings, thus appeared as a gap between what was taught in theory classes and what was expected actions in the lab-sessions.

According to Tiberghien and co-workers (e.g.Vince & Tiberghien, 2002) who consider the learning divide be between the theory/model-world, and the object/event world (rather than between theory and practice) the most problematic steps for students to take are those transcending the two worlds, and by studying the newly drawn model it was obvious that those passages were very small and very few.

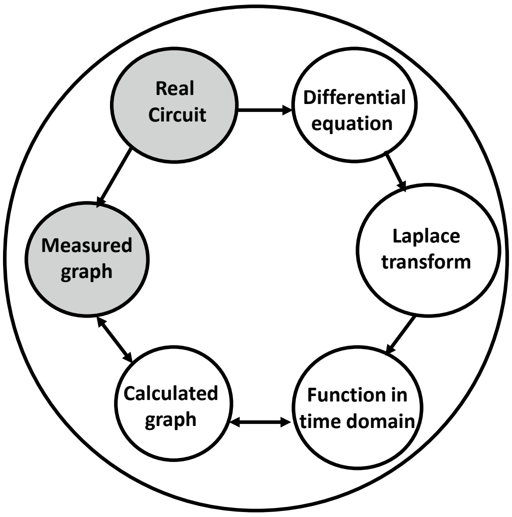

Figure 2: First Design Cycle – Intended object of learning

Our proposition thus became to try to find arrows across the circuit. One of those would be to draw an arrow from the Laplace transform, the transfer function, directly to the calculated graph, something that could be possible to make through simulations of various transfer functions in Matlab-Simulink.

Second Design Cycle

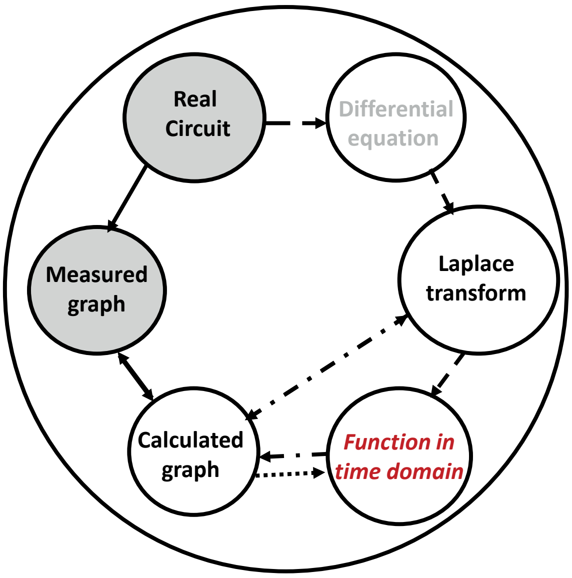

Figure 3: Second Design Cycle – Design of new teaching materials

In figure 3 the dashed arrows are showing the teaching sequence in the lectures, the dash-dotted arrows show the two tasks explicitly asked for in the new course, where problem solving sessions and labs were integrated. The students were now asked to analyze the correlation between the calculated graph and the function in the time domain, the dotted line, in order to realize what parameters in the time-function that rendered differences in the calculated graph. Now the students worked in a totally different way than in the old course: Some students started to do the calculations, and some started to do the simulations, and the new video-recordings from the revised course rendered two different versions of the model:

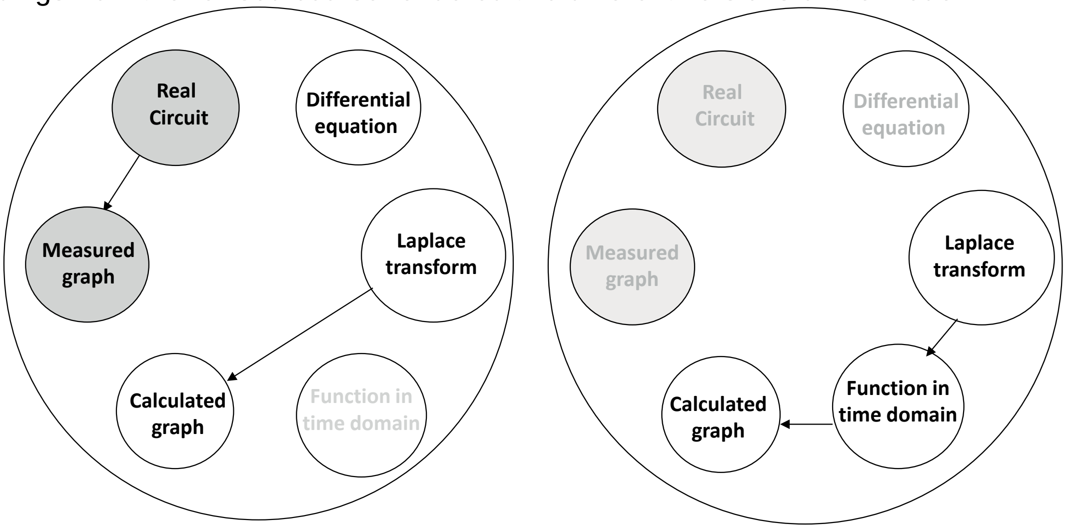

Figure 4: Two different students' paths due to different actions

The student who first measured a couple of graphs, then jumped to the simulation task without any connection to what he had measured, led to the left figure, and the student who started to do calculations made us draw the right figure. At the end of the lab both students had worked the whole lab through and made all the links in figure 5:

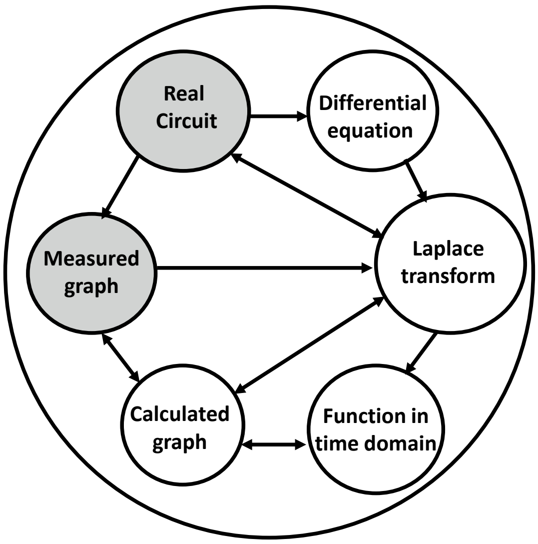

Figure 5: The students' paths at the end of the lab in the new course

In this new course not once was the question "Is this good enough for the report" asked, since now the students had made all the links that were necessary in order to understand the complex concept "transient response".

Third Design Cycle

The two first design cycles were focusing on the analysis and design of the lab instructions. Now it was necessary to start the analysis of what knowledge this designed model could bring to the engineering education research community, the phase that Vaishnavi and Kuechler (2008) call "circumscription". In Figure 6 we can see that two of the nodes have double labels. The first pair of labels were *Laplace transform* and *Function in time domain.* Of course the Transfer function is the Laplace transform of the differential equation, and thus a noun, but the Laplace transform is also the action that has to be taken in order to go from the differential equation to the transfer function. Similarly the Inverse transform is the action that transforms the transfer function into the function in the time domain, i.e. it is not a node but an arrow. The confusion here due to the word transform being as well a verb as a noun, highlighted that all nodes were nouns and all arrows verbs, as in other types of models such as concepts models or concept maps. However it also highlighted that the verbs, the actions were not just rote actions. It was necessary for the students to have both nodes in focal awareness while making the link between them. Thus the links, the arrows are not just there to learn but are actions students need to do in order to make links between concepts, i.e. to learn complex concepts is to do something that connects the islands. Here the analysis of the designed model thus leads to a new learning theory, that to learn complex concepts is to *make links.*

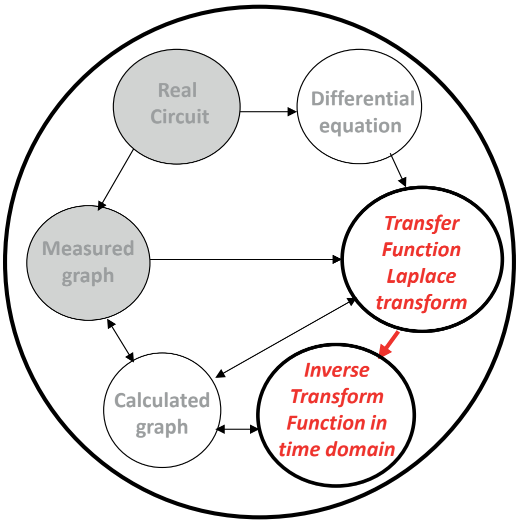

Figure 6: The model "the learning of a complex concept"

In the third cycle also the other links were explored (Anna-Karin Carstensen & Bernhard, 2013), but are omitted in this presentation.

A METHODOLOGY FOR FURTHER RESEARCH - FINDINGS FROM THE DESIGN SCIENCE RESEARCH EXPLORATION

The above presented exploration may be summarised in the figure below:

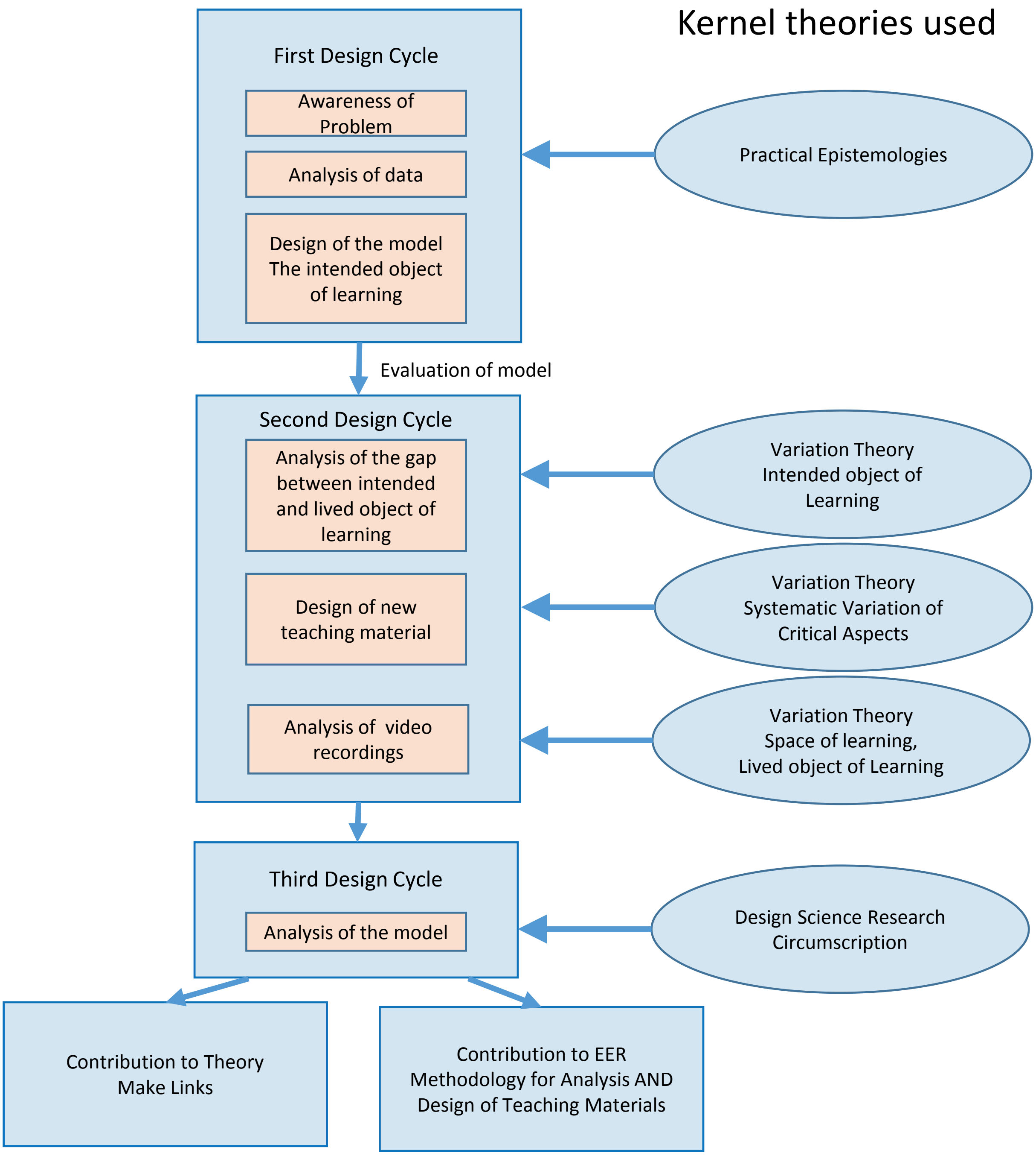

Figure 7: The Design science research process and the resulting contributions to the EER-field adopted from Takeda et al. 1990, with reference to referenced kernel theories from education (A-K. Carstensen & Bernhard, 2015)

EXPLORING LEARNING OUTCOMES IN A CDIO-PROJECT COURSE – A WORK IN PROGRESS

Previous research on learning outcomes in CDIO-project courses have mainly discussed collaborative learning of design processes, and learning to design, but not often what may be learned *through* working in design projects, especially how disciplinary knowledge may be learned through CDIO-projects (see e.g. Bernhard, Edström & Kolmos in this conference). By using the design science approach in figure 6, it seems possible to analyze the learning by analytically separating process knowledge, disciplinary knowledge and collaboration skills.
At our university in Jönköping we offer several opportunities for CDIO-projects. One is through an internship course, NFK, which is a 7 weeks internship, where one of the topics students' report on is to analyze their learning at the internship workplace to the learning in their courses, e.g. which course learning outcomes did you use at the workplace?, and what learning outcomes do you view as inappropriate. In an ongoing study we are analyzing the learning outcomes of this course. We have collected reports from the students, we are in the process of interviewing the students after one semester of courses after the internship. Our preliminary findings show that there is an astonishing shift in the students view of their own knowledge, e.g. one student writes in his report that "I thought I got the worst project of all students", but later he compares the learning outcomes in the course plan with what he actually learned and claims "I never thought I would have enough knowledge, but now I have both learned more and been able to use the knowledge I gained in the previous courses." We have seen the attitude towards studies changed, and also seen the group dynamics change remarkably – one of the most dominant students in the group before the internship course is no longer considered the leader of the group due to his attitudes towards studying. This remark has to be further explored in the interviews, but is still worth mentioning in these preliminary findings. Two previously rather weak students, gained self-confidence from their project and also the company was very satisfied with their accomplishments.

USING THE MODELLING APPROACH TO INVESTIGATE THE LEARNING IN THE INTERNSHIP-COURSE

In order to make these findings analyzable we have started to use the approach in figure 6 to model the learning in this internship course, separating the interpersonal skills, disciplinary knowledge learned, impact on future courses, and so forth and try to see what links between these analytical categories students make. We will use this model to redesign the curriculum and reanalyze the learning outcomes regarding as well explicit learning outcomes as in what way we may facilitate students' learning paths.

First design cycle

Starting with a first cycle – What learning outcomes do the students report on spontaneously in their reports? We have here started to analyze the reports handed in by students in computer science majoring in embedded systems. In the reports the students reflect on their learning in relation to courses they have taken before the internship course, but also on their own expectations.
So far the students have taken around 14 courses of different length and content. The courses that are mentioned as relevant to the internship are Introduction to electronics, Human-machine and electrical interfaces, Microcontrollers, and Operating systems for embedded computers. Some students mention Digital electronics with VHDL and Research methods and communication. Only one student mentions introduction to programming and none of them

mention following programming courses. This raises more questions than can be answered without making interviews with the students. Have the students already chosen to mention the major-specific courses? Or are these the courses they felt less on the track of their expectations? Both questions may have their answers in students' responses to course evaluations. During the electronics courses students have commented on the fact that reading datasheets is a difficult task that they would rather skip but in the reports this is what they mention as one of the most important learning outcomes from these courses. Also the comments regarding choice of programming language in the courses are made in the reports: "I have noticed that this language [C-programming] actually is used in practice. I am glad that I got the opportunity to learn this thoroughly before I started my internship." Another students concludes with the remark: "When out there, you also get a sense of how broad this education really is"

As in figure 6 the second cycle will start with the discrepancies between intended and lived objects of learning: How do the expectations of the studies affect the learning outcomes? And how may curriculum development, including the internship course, facilitate for students becoming engineers. Since the reports show that expectations, fears and self-esteem are important factors that students bring fore in their reports, this will also be modelled into the learning model. These results are in line with previous results on motivation in engineering education (Edström, Törnevik, Engström, & Wiklund, 2003), however, the students reports also show that the motivation may change due to the internship course, and thus this issue is of uttermost importance in making the curriculum design.
As a point of departure, the model from figure 9.1(Crawley, Malmqvist, Östlund, & Edström, 2014, p. 214) where the links between elements of the curriculum, CDIO standards and evaluation of learning are modelled.

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BIOGRAPHICAL INFORMATION

Anna-Karin Carstensen, is a senior lecturer in the department of Computer Engineering and Informatics at the School if Engineering at Jönköping University. Her research in the field of engineering education focuses on the learning of complex concepts in electrical and computer engineering especially how students link theory to practice.

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TEACHING AND LEARNING ACTIVITIES LEADING TO ENGINEERING GRADUATE ATTRIBUTE DEVELOPMENT

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ABSTRACT

Engineering graduate attributes guide educational institutions in the design and development of engineering curricula. However, engineering educators are provided with limited guidance on which teaching, learning, and assessment activities should be used to most effectively develop these graduate attributes. A systematic literature review explored the various teaching and learning activities being used to teach and assess graduate attributes. This literature review encompasses the last five years of data from engineering education journals and conference proceedings. The results provide a breakdown of the most prevalent graduate attributes and the teaching and learning strategies currently employed to foster the growth of those attributes in students. Some graduate attributes, such as teamwork and communication, are highly correlated and many activities are able to teach them simultaneously. Some teaching and learning activities, such as project-based and service-based learning, are able to teach a wide variety of graduate attributes. Certain graduate attributes had very few teaching and learning activities associated with them, and this opens an area for future research. Finally, the strategies to assess graduate attributes consisted mainly of non-validated surveys or analysis of student grades. This highlights that, while assessment is being performed, further work can be done to improve and validate assessment methods.

KEYWORDS

Learning Outcomes, Graduate Attributes, Accreditation, Assessment, Standards 2, 3, 7, & 11.

INTRODUCTION

The work of engineers has a direct impact on many diverse social, economic, and environmental systems. For this reason, the education of engineers and the regulation of the engineering profession are two critical components for safe and efficient societal operation. To this end, many countries have implemented accreditation systems which include a list of desired attributes that graduating engineers should possess. These include the knowledge, skills, and, attitudes that are required for conduct as a practicing engineer in modern-day society. Previous studies have provided insight into the similarities and differences between graduate attributes worldwide (Paul, Hugo, & Falls, 2015; Abdulwahed, Balid, Hasna, & Pokharel, 2013). Consistency among these graduate attributes provides a mechanism for international collaboration, global mobility, and improved unity in the increasingly diverse workplace.

Although engineering attributes are well defined, many institutions continue to explore teaching & learning activities (TLAs) that effectively and efficiently develop these attributes. Additionally, once TLAs have been defined and implemented, the process of assessing these attributes in students remains an area of development. Through a comprehensive and systematic literature review, this paper provides a summary of the most common TLAs and assessment methods used in the development of engineering graduate attributes.

BACKGROUND

Graduate Attributes

Accreditation processes used for the evaluation of engineering programs have been in place for decades, and these processes were traditionally based on accounting methods that quantified the number of instructional contact hours in areas that included math and science, engineering science, and design. Although this accounting-based approach ensured content coverage, it did not include consideration for the actual performance requirements of an engineering graduate in professional practice. In 1996 the document “Desired Attributes of an Engineer” (Boeing, 1996) effectively summarized the needs of industry, demonstrating that the performance requirements of a professional engineer extended well beyond technical knowledge.

Starting in 2000 with ABET’s EC2000, engineering accreditation bodies worldwide have been shifting their focus from input measures to output measures, expecting graduates from engineering programs to have a specific set of skills indicative of an appropriate level of practice (IEA, 2014), referred to as graduate attributes. Graduate attributes (GAs) are also called competency guidelines or programme outcomes. These attributes are mandated, regulated, and updated by national accreditation bodies, and they direct institutions towards the expected outcomes for their respective engineering curricula.

Outcomes-based education has been a strong catalyst for curricular change and improvement in engineering education (Maranville, Neill, & Plumb, 2012). GAs provide learning outcomes that communicate the goals of engineering programs to both the students and the instructors (Crawley, Malmqvist, Östlund, & Brodeur, 2014). The structure provided by the GAs facilitates the curricular continuous improvement process and provides a systematic method for the design, development, and assessment of curriculum.

A 2015 study analyzed the GAs of 17 countries within the Washington Accord as part of the International Engineering Alliance (Paul et al., 2015). Using a content analysis methodology, Paul et al. (2015) summarized and grouped the main themes and categories of GAs observed across the 17 countries. Figure 1 below shows the category proportional frequencies of the attributes.

Teaching and Learning Activities

Given the complexities of the global economy, students need more than technical knowledge to solve multi-dimensional problems. Engineers need to be skilled in understanding the contexts in which their knowledge is useful (Litzinger et al., 2011) . Traditionally, engineering education focused on the presentation of knowledge. Instead, , the contextual application focuses on the “concept of integration of knowledge” (Mohammad Yusof, Aliah Phang, Hamzah, Ismail, & Isa, 2012). Conceptual knowledge not only increases student motivation, but it also provides students with application-oriented topics, integration of diverse knowledge, and skills to solve real-world problems.

The majority of engineering researchers and educators have limited experience with theories and practices from education (Borrego & Henderson, 2014; Borrego & Bernhard, 2011). Therefore, the practical implementation of graduates attributes in classrooms is often ineffective, and there is a gap between research and practice (Finelli, Daly, & Richardson, 2014). Instructors worldwide use a variety teaching and learning activities (TLAs); however, it is unclear which TLAs effectively foster the desired attributes. This paper seeks to determine which teaching and learning activities are most commonly used to foster each of the engineering graduate attributes, and as will be mentioned next, how these TLAs are assessed to measure to effectiveness.

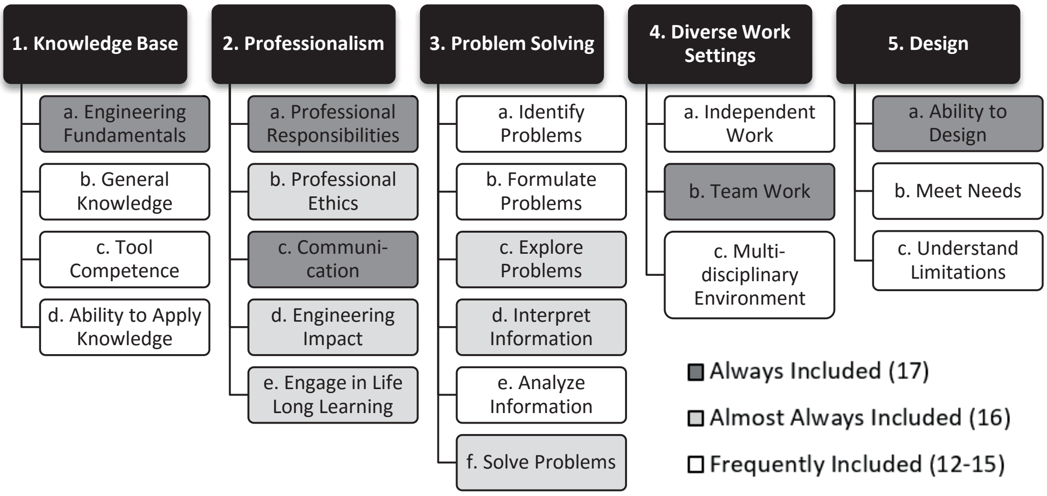

Figure 1. Attribute Category Proportional Frequencies (the number of countries in which the category appeared) (Paul et al., 2015)

Assessment Methods

Alongside the challenge of determining effective TLAs for graduate attributes, instructors are faced with the challenge of assessment. Shuman, Besterfield-Sacre, and McGourty (2005) discuss three hurdles that educators face in assessing how students have learned and understood the professional outcomes. Firstly, there exists a lack of consensus on definitions for graduate attributes. Secondly, there is difficulty in assessment with scope (Shuman et al., 2005). While technical information can be learned through lectures and assignments, professional outcomes are typically learned in settings that extend beyond traditional coursework. Finally, the nature of the professional outcomes increases the difficulty of their assessment (Shuman et al., 2005). Many attributes are concerned with students' awareness and being able to demonstrate the use of a particular attribute, which affects their aims, attitudes, and values (Shuman et al., 2005). While there have been efforts in the engineering education community to discover better assessment methods, there is still much work to be done.

LITERATURE REVIEW METHOD

A systematic literature review was undertaken (Lopes, Fialho, Cunha, & Niveiros, 2013) to determine which TLAS are used to teach graduate attributes. The search spanned five years, and included two databases as the field of Engineering Education is interdisciplinary and does not perfectly fit into one field. Table 1 lists a summary of the search criteria and search terms.

Table 1. Summary of the Literature Search Terms and Databases

Database	Date	Title	Subject/Title/Abstract	# of Results
Compendex *(engineering village.com)*	2011-current	Capability OR attribute OR skill OR competence	[develop OR development OR "teaching and learning"] AND [“graduate attribute" OR CDIO OR abet]	85
Scopus *(scopus.com)*	2011-current	Engineering	[capability OR attribute OR skill OR competence OR develop OR development OR "teaching and learning"] AND ["graduate attribute" OR CDIO OR abet]	136 *(27 duplicates of Compendex search)*

Selection Criteria and Process

The following criteria were used to determine which articles would be included in the review: 1) accessible from the databases available at the University of Calgary; 2) published in English; 3) in reference to undergraduate engineering; 4) within the Scholarship of Application (Boyer, 1990); and 5) focused on the development of one to four specific attribute(s), including a discussion on the associated teaching and learning activities.

Criteria 1-3 allowed for quick acceptance or rejection of articles outside of scope. In total, 51 articles were rejected, mostly due to references to other groups, such as non-engineering students, graduate students, or professionals.

Boyer’s Model of Scholarship (1990) refers to four main categories of scholarship, and this was used for criterion 4. The *Scholarship of Discovery* refers to the building of new knowledge and is typically associated with ‘traditional’ research (Boyer, 1990). *Scholarship of Integration* takes this new knowledge and interprets it in an interdisciplinary way to bring new insight (Boyer, 1990). *Scholarship of Application* is defined as “service activities [which] must be tied directly to one’s special field of knowledge and relate to, and flow directly out of, this professional activity.” (Boyer, 1990, p. 22) Finally, *Scholarship of Teaching* uses teaching models and new practices to improve learning (Boyer, 1990).

This literature review considers the application of teaching and learning activities in classrooms to teach graduate attributes, which aligns most closely with the *Scholarship of Application*. There were 32 articles rejected based on criterion 4.

Lastly, 31 articles were rejected based on criterion 5. Most of these articles included a teaching and learning activity which was fostering “ABET” or “CDIO” attributes. Although these provided interesting insight, they discussed several attributes and did not focus on a select few. In total, 35 papers were accepted for the detailed analysis.

Selection of Attributes

The terminology used to describe graduate attributes varies across countries, institutions, and even across departments within institutions. Recently, a special report in the *Journal of Engineering Education* highlighted this challenge and the need for a common language in engineering education research (Finelli, Borrego, & Rasoulifar, 2015). For the purpose of this study, it was necessary to choose the graduate attributes that would serve as a framework for grouping the papers.

An analysis and discussion of engineering graduate attributes was completed in a previous paper titled *International Expectations of Engineering Graduate Attributes* (Paul et al., 2015). The graduate attributes guidelines were obtained from 17 engineering regulatory bodies worldwide and analyzed using content analysis. The result was five overall themes and 21 categories (Paul et al., 2015), with the category frequency shown above in Figure 1. Of the 21 categories identified, the 11 categories that were always, or almost always, included serve as the framework for this literature review.

Attribute Mapping

After the attributes were freely identified for each paper, they were mapped to the 11 attributes. Attributes which could not be mapped directly were grouped with an attribute that covered a similar idea. This was completed as a collaborative process involving more than one person to ensure validation during the mapping process.

Global issues, global perspectives, contemporary issues, and sustainability and environmental issues were all mapped to *Engineering Impact*. Creativity was observed in two papers with a focus on divergent thinking; therefore, these papers were grouped into *Explore Problems.* Project management and agile development were mentioned in a few papers; however, they were not the main attribute and therefore these attributes were discarded. There were also three attributes which were the main topic of papers however, they did not map within the 11 specified categories. Therefore, it was agreed these would be included independently. These three attributes were as follows: tools, entrepreneurship, and leadership.

RESULTS

The following section discusses specific examples of TLAs in the context of teaching each attribute. Figure 2 shows a visual summary of the frequency of TLAs which were associated with each graduate attribute. From this figure, it is evident that Project Based Learning and Inquiry Based Learning were observed across the majority of the attributes, often with a high frequency. Service Learning was also a popular TLA, observed being used to teach 50% of the attributes.

Looking at the distribution across the graduate attributes in Figure 2, it is evident as to which graduate attributes were discussed most frequently in the literature (communication, teamwork, ability to design) and which were discussed the least (tools and solve problems). Entrepreneurship and leadership were also observed infrequently, however these were additional attributes added.

The teaching and learning activities (TLAs) observed for each graduate attribute are summarized in Table 2 below, along with any observations and specific examples for each attribute. Information on assessment methods used is also included, with particular mention of any validated assessment tools used.

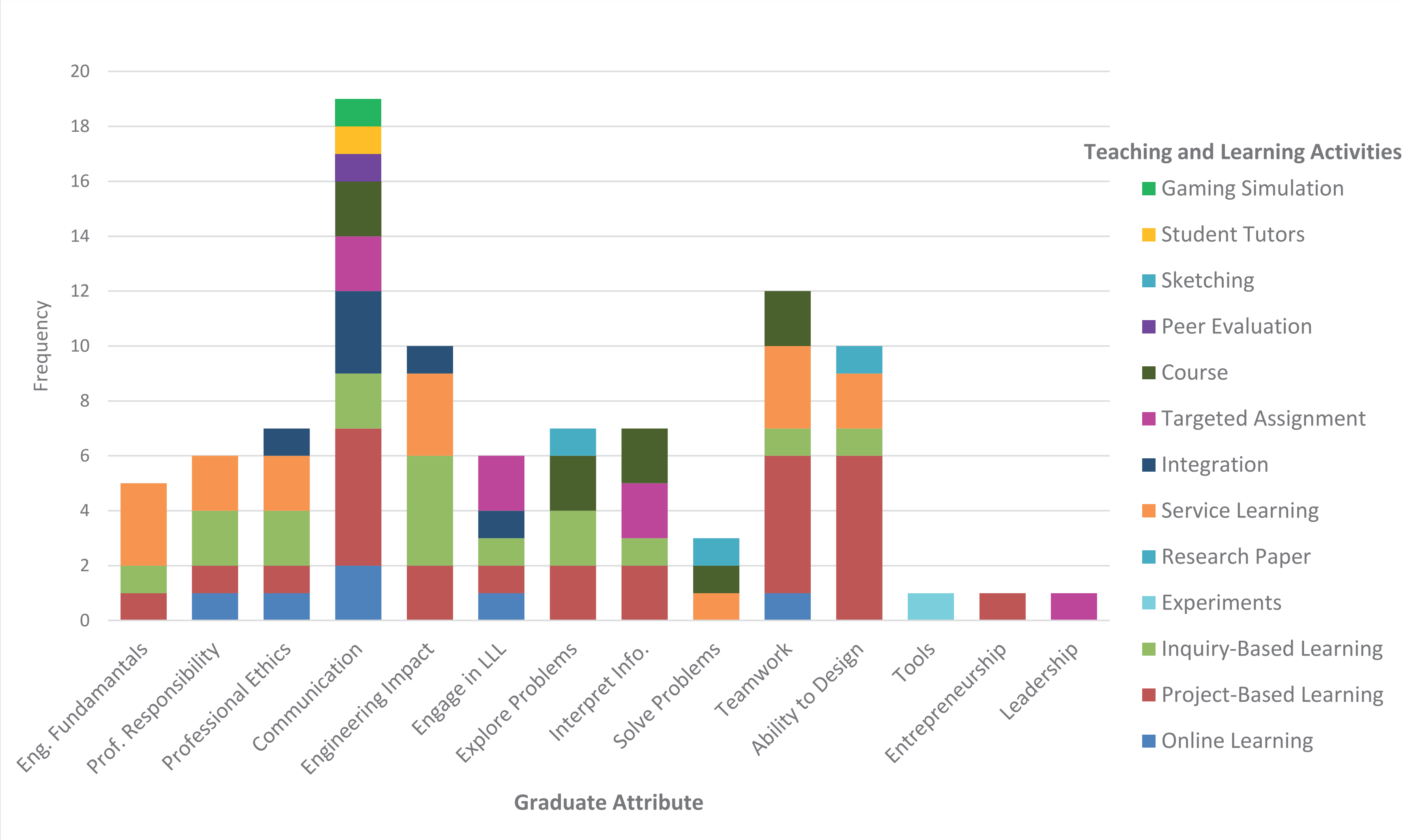

Figure 2. Frequency of attribute mapping to teaching and learning activities.

Table 2. Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Engineering Fundamentals	-Few papers specifically mentioned engineering fundamentals -Service learning to increase confidence in technical abilities	-Service learning project within leadership module increased confidence of women in engineering skills[1] -Service learning project increased student interest and recognition and relevance within specific technical engineering[2]	-Grades, exams
Professional Responsibilities	-Multiple TLAs -Service learning, project-based learning, model-eliciting activities, multi-modal assignments, online modules -Similar to those for professional ethics	-Service learning projects with social and environmental impact[3] or projects abroad[4] -PjBL with discussion of technical content and professional responsibilities and ethics[5] -Research, case studies, and presentations on professional responsibility topics[6] -Online modules with professional responsibility in context of professionalism, economics, and project management[7]	-Student surveys -Grades
Professional Ethics	-Often main or secondary attribute in a paper -TLAs varied -Similar to those for professional ethics -Model-eliciting activities, PjBL, online modules, textbook companion	-Project including ethics and sustainability[8] -Capstone projects involving service learning and sustainability[3] -5 of 19 online modules specifically targeting ethics[7] -Textbook companion to explore ethics in relation to thermodynamics topics[9]	-Student surveys -Grades
Communication	-Main TLA was PjBL -Taught directly in courses -Digital media initiatives -Student tutors -65% of papers fostering teamwork also mentioned communication	-Entrepreneurship projects or capstone projects[10] -K-12 outreach activities[11] -Online modules during co-op work terms[7] -Gaming simulation to explore communication behavior of cultures[12] -Tutors from non-engineering majors[13]	-Student feedback surveys -Grades -Faculty assessment -Industry expert assessment[10]

[1](Wang, Patten, Shelby, Ansari, & Pruitt, 2012)
[2](Sevier, Callahan, Schrader, Chyung, & Schrader, 2012)
[3](Lathem, Neumann, & Hayden, 2011)
[4](Budny & Gradoville, 2011)
[5](Bursic, Shuman, & Besterfield-Sacre, 2011)
[6](St. Clair, Riley, Thaemert, & Lindgren, 2011)
[7](Barakat & Plouff, 2014)
[8](Jollands & Parthasarathy, 2013)
[9](Riley, 2011)
[10](Kiefer & Kuchnicki, 2013)
[11](Pruitt, 2011)
[12](Ekaterina, Anastasya, & Ksenya, 2015)
[13](Weissbach & Pflueger, 2013)

Table 2 (continued). Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Engineering Impact	-Most common TLA was open-ended problem solving -Three papers that used service learning -Includes multi-modal assignments[6], model-eliciting activities[5], and problem-based learning[14]	-Water supply system project in Ecuador[4] -One-on-one interviews with professionals in the field, both private and public[6]	-Validated: Concept inventories to measure the gain[5] -Validated: Student Attitude survey[3]
Engage in Life-Long Learning	-Only main focus of one paper -TLAs includes research projects, independent study, and case studies	-Open-ended problems in a fluid mechanics course[15] -Information literacy projects requiring students to conduct research, design projects, and write reports[16]	-Measured enthusiasm, perception of skills for life-long learning[15] -Self-assessment of activity impact on ability to "learn how to learn"[15]
Explore Problems	-Seven papers overall -Three discussed PjBL -Discussion of structure of overall courses	-Article that had students use sketching to encourage them to engage more deeply in problem exploration and idea generation[17]	-Self-developed surveys -Observations -Student grades
Interpret Information	-Two papers specifically discussed information literacy -Four used PjBL	-Information literacy, which is the ability to identify a need for information and effectively apply that information to a problem[16]	-Skill assessment - SAILS[16] -Surveys -Peer evaluations -Grades
Solve Problems	-Observed least frequently of all specified 11 attributes -Never primary topic -Main theme of problem solving is divided into: explore problems, interpret information, solve problems -Papers primarily focused on process rather than solution	-Using sketching to help students explore product design and practice a visual method of the problem solving process[17] -Capstone design projects focused on team-based engineering problems to be solved[18]	-Recommendation Reports -Self-assessment

[3](Lathem et al., 2011)
[4](Budny & Gradoville, 2011)
[5](Bursic et al., 2011)
[6](St. Clair et al., 2011)
[14](Pierce et al., 2014)
[15](Vasko et al., 2011)
[16](Naz & Casto, 2013)
[17](De Vere, Melles, & Kapoor, 2012)
[18](Mohammed & Dimmitt, 2012)

Table 2 (continued). Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Teamwork	-Discussed in 14 of the 35 papers -Main TLAs were PjBL (6 papers) and service learning (3 papers) -Mainly taught in classroom, but also online	-Entire courses on teamwork and communication[18,19] -Aeronautical engineering student teams to build an Unmanned Aerial System[20] -Student teams to design tabletop devices to extract juice from apples[10] -Water project in Ecuador[4] -Development of a K-12 project with a local science centre[1] -Web-based collaboration[21]	-Student self-assessments -Peer assessments -Small number of papers considered grades
Ability to Design	-Discussed in 11 papers, of which 5 papers included as main attribute -Main TLA was PjBL (6 papers)	-Air pollution study with experiments, design considerations, and report[11] -Real world projects from industry[10]	-Peer feedback -Faculty & industry judges[10]
Tools	-One paper -Extensively discussed graduates' abilities to use techniques, skills, and modern engineering tools	-Use of smartphones as mobile computing devices, using their position, velocity, and acceleration sensors to calculate acceleration values and learn how to handle noisy experimental data[22]	-Student survey
Entrepreneurship	-One paper -PjBL	-Students came up with an entrepreneurial project idea and pitched it to their classmates[23]	-Student survey to measure student interest in the design projects
Leadership	-Service learning project	-Students use engineering knowledge to develop science and engineering activities for K-12 students at a local science centre[11]	-Survey -Self-assessment

[1](Wang et al., 2012)
[4](Budny & Gradoville, 2011)
[10](Kiefer & Kuchnicki, 2013)
[11](Pruitt, 2011)
[17](De Vere et al., 2012)
[18](Mohammed & Dimmitt, 2012)
[19](Dimmitt, Mohammed, & Moore, 2012)
[20](Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, & Rodriguez-Sevillano, 2012)
[21](Lingard & Barkataki, 2011)
[22](Bevill & Bevill, 2015)
[23](Dahm & Riddell, 2011)

DISCUSSION

Graduate Attributes

All eleven graduate attributes were observed in the literature review. This suggests that research and implementation of TLAs is being done to promote the need for defining attributes required to be a successful engineer.

Teamwork was observed to have a high correlation with communication, approximately 65% of the papers with TLAs which fostered teamwork also mentioning communication. This is not surprising, as working in a team involves a high level of communication between team members. Team projects also typically have communication-focussed deliverables such as written reports and oral presentations. Although teamwork is dependent on communication, communication was observed to exist separately from teamwork in the form of individual assignments such as independent research projects and resume building.

There were five papers which discussed TLAs for both professional responsibilities and professional ethics. These two attributes were also intertwined. It could be argued that professional responsibilities include ethics, yet the terminology was not consistent across the literature. Therefore, it was difficult to distinguish which attribute authors were discussing.

Problem Solving

In Figure 1, it can be seen that "Problem Solving" is an overall theme that included the following attributes: explore problems, interpret information, and solve problems. Within the original study (Paul et al., 2015), the attribute *explore problems* included experimentation, investigation, and the ability to conduct research. *Interpret information* included synthesis of information and the ability to interpret data. Whereas the attribute *solve problems* was in reference to the ability to solve engineering problems by selecting the appropriate analysis to reach valid conclusions. The distinction can be seen in that the emphasis of *explore problems* and *interpret information* is not on solving the problem but rather going through the problem solving process.

The results of the literature review show the attribute *solve problems* was observed the least, with no paper focusing on this topic. Edström & Kolmos (2014) define problem-based learning as "a broad philosophy of teaching and learning focusing exclusively on the *learning process*, that is, *how* students should learn, and not on *what* they should learn." Consequently, it follows that the papers and TLAs tended to focus on attributes on the process of problem solving (explore problems and interpret information) rather than the end result (solve problems).

Problem solving is covered throughout the conceive-design-implement-operate framework. Using TLAs which support this approach helps students to first engage in the process, and then understand how to apply the technical theory to the problem solving and engineering practice (Crawley et al., 2014). While all elements of problem solving are important, "learning to learn" is an illustration of the idea of improving engineering problem solving skills rather than simply providing students with a technical base of knowledge (Crawley et al., 2014). Within the education system, it is more important that students are exposed to undefined problems that involve new ways of combining problems, rather than they reach a predetermined solution.

Teaching and Learning Activities

Although not always directly mentioned, active learning (any instructional method that engages students in the learning process) was an overarching theme observed and is central to TLAs such as project-based learning, model-eliciting activities, and service learning. Evidence has shown that active learning strategies support an effective learning environment (Prince, 2004), and therefore evidence of its implementation is encouraging. However, it is important to clarify a successful implementation of a TLA does not imply that any single experience can lead to the complete development of an attribute. Instead, the aim is that each experience contributes as much as possible towards student growth (Litzinger et al., 2011).

Project-Based Learning

Project-based learning (PjBL) was the most commonly observed TLAs in the literature. More specific types of PjBL included experiments, team-based learning, cooperative learning, product archeology, inquiry-based learning, problem-based learning, multi-modal assignments, and open-ended problems. All of these were grouped within the TLA of "project-based learning;" however, it is evident that a more consistent terminology is required to distinguish between these activities (Finelli et al., 2015).

All but one of the attribute categories were associated with PjBL teaching and learning activities (see Table 2). These results suggest that PjBL is a TLA which is very common in engineering education, as well being effective at providing students with the variety of necessary engineering skills and attitudes. The most common attributes associated with the use of PjBL were *teamwork*, *communication,* and the *ability to design*.

Within CDIO, the use of PjBL is central, where the learning experiences are "based on pedagogical theories of how students, especially engineering students, learn and develop cognitive skills" (Crawley et al., 2014, p.157) . Although PjBL is rated to be highly successful by instructors, one limitation of this TLA is that inexperienced instructors find the transition to a project-based course to be extremely challenging and demanding.

Service Learning

The central purpose of engineering is to provide solutions (products, processes, and systems) that directly or indirectly serve society. Therefore, within CDIO there is an emphasis on the skills and the attitudes conveying that conceiving-designing-implementing-operating is the role of engineers in their service to society (Crawley et al., 2014). Service learning could be considered a subset of PjBL, where the project is specifically targeted towards the service of others. However, as its own independent TLA it was still the second most commonly observed. Service learning was also associated with many attributes: 7 of the 11 categories used in this analysis. The main focus was typically to provide students with an understanding of the professional responsibilities, ethics, and the impact of engineering on society. Overall, these projects help to widen students' perspectives.

Assessment Methods

The main assessment method was surveys written by the instructors and completed by students. While many surveys asked similar questions, very few validated their instruments or used an already validated tool. This raises questions of whether or not these instructors can academically prove the success of their chosen TLA in teaching a particular attribute. Another popular assessment method was looking at students' grades and comparing these to previous years. This method can point out that the students had a similar level of understanding for a particular attribute, but it fails to capture any qualitative differences in that understanding. This shortcoming was addressed in many papers by also including the opportunity for students to give feedback on the activities and assess their own work, their peers' work, and occasionally that of their instructors. Less common assessment methods included observations and anecdotal feedback from professors.

CONCLUSION

Engineering education institutions worldwide are adopting new teaching and learning activities that promote the variety of attributes and skills engineers require to succeed in the 21st century. A systematic literature review explored the various teaching and learning activities being used to teach and assess graduate attributes.

Communication and *teamwork* were the most commonly discussed attributes, and these were often discussed together. The differences between *professional responsibilities* and *professional ethics* were not always identified. *Solve problems* was the least commonly discussed attribute perhaps given that it is a process including the attributes *explore problems* and *interpret information.* The most common TLA was project-based learning activities such as open-ended problems, team-based learning, and service learning which were used to simultaneously develop a number of graduate attributes in engineering students. Other unique approaches included sketching, student tutors, and gaming simulations.

One limitation of the implementation of all of the TLAs was the assessment methods used to measure their success in fostering the intended attribute. Most investigations used student grades, qualitative observations, and self-developed surveys, of which few authors provided their validation methods. Future work could include a literature review with search terms targeted towards assessment methods.

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BIOGRAPHICAL INFORMATION

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STUDENT STUDY HABITS AS INFERRED FROM ON-LINE WATCH DATA

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ABSTRACT

This paper examines on-line watch data for three different Mechanical Engineering courses. The results indicate that positive benefits can be derived from flipped delivery if newly available lecture time is used to increase the amount of formative assessment in the course. Students are found to study more often in the afternoon and evening than they are in the morning, a trend that exists for both weekdays as well as weekends. Evidence of prioritization is given where students are able to adjust content viewing and study time in relation to the demands placed on them by all of the courses that they are taking in a given semester.

KEYWORDS

Blended Learning, On-line Delivery, CDIO Standards 10 and 11

INTRODUCTION

The general concept of distance learning and video lectures is not new: for example, the Open University (McAndrew and Scanlon, 2013) has been using this approach for the past 50 years. However, recent advances in video and on-line technology, along with the decreasing cost of this technology, have made this approach much more accessible to teaching faculty. The most well-known contribution to this area in recent years has been the “massive open on-line course” or MOOC (Pappano, 2012), whereby students view relatively traditional lectures by a prestigious professor through an on-line forum (an example of this approach is Harvard’s introductory computer science course: CS 50).

Although on-line delivery has generated much interest in higher education, institutions still struggle with its implementation (Bates, 2010). In particular, there is a growing consensus that on-line learning in isolation can be problematic with respect to student completion and student assessment (Dutton et al., 2011). However, when on-line modules are combined with in-class activities, the resulting hybrid approach has been shown to greatly enhance student learning (Peercy and Cramer, 2011; U.S. Department of Education, 2011). As a result, there has been interest in hybrid learning techniques such as “flipped” learning (Al-Zahrani, 2015) where on-line lectures are used to open up time for more meaningful activities during the in-person sessions (e.g., discussions, case studies, projects, problem-solving sessions, etc.). Care must be taken with the flipped approach though, especially when implemented across multiple courses where there is the risk of overloading students with outside-of-class video lectures (Khanova et al., 2015).

The use of on-line delivery for flipped or blended learning offers a number of opportunities to explore student study habits in ways not readily available when using traditional live lecture delivery. Given the nature by which data is recorded, on-line learning platforms provide an ability to collect data that is more objective in comparison to methods such as interviews (Oosterbeek, 1995), personal journals (Juster and Stafford, 1991; Kember et al., 1995), or end-of-semester course evaluations (Zuriff, 2003). The ability to monitor the number of times, duration, and time of day when students view content in relation to the date that homework is due or that exams are held can provide new insight into how students structure their study time. Further insight can be derived from extending this data collection to include the dates of assessment activities in other courses taken by students during a single semester.

This paper will explore student on-line watch data collected during the delivery of three different blended learning courses: Mechanical Engineering Thermodynamics taken by third-year students; Introductory Fluid Mechanics taken by second-year students; and Heat Transfer taken by third-year students. Each course offering involved different assessment schedules, making it possible to examine how student study habits vary in relation to the differing schedules. Both Mechanical Engineering Thermodynamics and Heat Transfer were taught over a 13-week-long semester with most students enrolled in 5 to 6 courses at a time. Introductory Fluid Mechanics was taught over 6 weeks during a Summer session with most students taking only one course during the Summer term. Given the varying lengths of academic semesters, the differences in assessment schedules, and the differing course loads, it becomes possible to examine how student study habits change in response to these parameters. Through an analysis of student watch data, the intent is to also suggest that the process of developing and refining a flipped-delivery course can facilitate the following: increased faculty teaching competence (Standard 10); more diverse assessment of disciplinary knowledge (Standard 11); and increased time for alternative learning methods (Standard 8) and, as a result, improved student learning experiences.

METHODS

This section discusses the nature of the student sample, the instruments and measures used, and the procedures by which the instruments and measures were used to collect the data analyzed in this paper.

***Sample*:**

The first year for students in the Schulich School of Engineering is experienced as a common-core year. At the conclusion of the first year, they select their programs. Placement in programs is highly competitive and based on the students' first-year GPA (Grade Point Average). Mechanical Engineering is a popular program choice for students, and the first-year cut-off GPA for the Mechanical Engineering program has averaged between 2.6 and 2.8 on a 4-point scale.

Data from three Mechanical Engineering courses are examined in this paper: one a second year Fluid Mechanics course (ME341) and the other two third-year courses – Thermodynamics (ME485) and Heat Transfer (ME471). The Fluid Mechanics and Heat Transfer courses were taught only once, whereas the Thermodynamics course was taught twice. Given that the first author had previously taught all three courses in a face-to-face manner, these same courses were selected in order to reduce the time required to develop the on-line content. Data for all four course offerings are presented in Table 1.

Table 1: Course Information

Course Number	Course Title	Semester Taught	# of Students	# of Weeks	# of Term Exams	Final Exam
ME485F	Thermodynamics	Fall ‘13	92	13	2	Yes
ME485W	Thermodynamics	Winter ‘14	94	13	2	Yes
ME341	Fluid Mechanics	Summer ‘15	59	6	4	Yes
ME471	Heat Transfer	Fall ‘15	94	13	6	No

All three of the courses involved lectures and laboratories. The Fluid Mechanics course (ME341) also involved a tutorial. The laboratories in the Thermodynamics and Heat Transfer courses were of the scripted variety, where students followed an explicit procedure from a laboratory manual while performing the experiment. Written laboratory reports were due one week after the conclusion of the experiment, and reports were submitted in groups.

The laboratories in the Fluid Mechanics course were not scripted but rather followed an Inquiry-Based Learning approach where each experiment was described to the students; they were provided with equipment; and then they were told to construct the experiment and formulate a test plan. Four types of group reporting were assessed: a short technical report, a technical poster, a 10-minute video presentation, and an oral presentation.

All four courses had homework assignments; however, only in the Fall 2013 offering of Thermodynamics was the homework graded, as shown in Table 2. The Winter 2014 offering of the same course required that homework be submitted, but it was not graded. Active Tutorials were given in all four courses. Both electronic personal response systems and Mazur’s peer instruction technique (Mazur, 1997) were applied during the active tutorials.

Table 2: Teaching & Learning Activities and Assessment Weight

Course Number	Homework (Assigned / Due)	Homework Qty / %	Lab Reports Qty / %	Active Tutorial Qty / %	Semester Exams Qty / %	Final Exam
ME485F	Yes / Yes	8 / 10%	2 / 10%	10 / 10%	2 / 30%	40%
ME485W	Yes / Yes	8 / 0%	2 / 10%	9 / 10%	2 / 30%	50%
ME341	Yes / No	5 / 0%	5 / 25%	5 / 5%	4 / 40%	30%
ME471	Yes / No	6 / 0%	4 / 20%	6 / 5%	6 / 75%	--

Instruments and Measures:

1) YouTube Analytics Data – Canadian Watch Minutes

With the on-line content delivered through YouTube, it was possible to use the Analytics package within YouTube to examine and compare viewing statistics. It should be mentioned that watch data for Canada is reported in aggregate for the entire country, and consequently it is possible that some of the reported watch data includes students who were not registered in the course, such as students at another university. Electronic communications received by the course instructor from students at other Canadian universities confirmed that this is indeed the case. A second source of ambiguity can be attributed to students downloading the YouTube videos and watching them offline, as reported to the course instructor by a number of registered students. These two sources of ambiguity would tend to cancel one another out, especially in cases where the course was offered for the first time.

It should be mentioned that given that this was the first time that three of the four courses were offered via YouTube (i.e. the availability of these YouTube lectures was in its infancy and potentially not discovered by other Canadian students), it is assumed that the Canadian watch data is primarily attributed to University of Calgary students.

2) YouTube Analytics Data – Real-time Report

Starting in September 2014, YouTube began providing content creators with the ability to monitor their YouTube watch data hourly. As a result, estimated views from the last five published videos can be monitored. Additional videos can be monitored by creating groups of up to five videos per group and then monitoring the hourly watch data for each of these groupings. It is not possible to filter the views by country or region. Real-time data has a lifespan of 48 hours, and consequently if data is not downloaded within 48 hours, it is lost.

3) Instructor Survey

Course instructors teaching the cohort of students who were taking Heat Transfer during the Fall 2015 semester were asked to complete a survey of course assessment activities. Instructors were asked to report, by week, when assignments, quizzes, midterms, laboratories, projects, or other activities were either held or due and the assessed weight of the activity.

Procedures:

Canadian watch minute data was downloaded weekly while each course was being offered. The data was stored but not analyzed until after course grades had been awarded. Real-time data was only collected for courses offered after September 2014 (Fluid Mechanics and Heat Transfer). Data was collected for one or more weeks before examinations were held in order to develop an understanding for when students viewed the content in preparation for an exam.

RESULTS AND DISCUSSION

Data provided by on-line learning platforms is relatively new to the engineering education community and consequently it is important to begin by examining methods for visualizing these data sets. YouTube Analytics provides a variety of data sets that includes watch time, audience retention, demographics, playback locations, traffic sources, devices, and so on. Of interest to this paper is watch time data by video that is restricted to Canada. The watch time data is cumulative, and is reported by video in decreasing number of cumulative views. In order to gain insight into how students watch content over the duration of a course, the daily watch minute reports first need to be extracted from each daily report, then sorted by video, and finally concatenated into a single file that quantifies cumulative watch minutes by video by day. The result of this process, when plotted in the form of a contour plot, is shown on the left in Figure 1. In this figure, the horizontal axis represents time from the start to the end of the course. The vertical axis represents lecture video segment going from the content covered at the start of the course to content covered at the end of the course. Finally, each colour contour denotes the number of cumulative watch minutes. Visually this plot provides an indication of which videos students are watching and when.

A second method of viewing this same data set is to compute the difference in cumulative watch minutes or, more specifically, the total number of minutes watched per video per day. This data set is presented to the right in Figure 1. Viewing the data in this manner reveals a light blue band that tracks student progression through the course, starting on Day 8 and ending on Day 100. Comparing both the cumulative (left) and the daily (right) contours, the daily contour is seen to be the more effective method for highlighting when video segments are being watched. Consequently it was decided to use this form of data representation for the remainder of this paper.

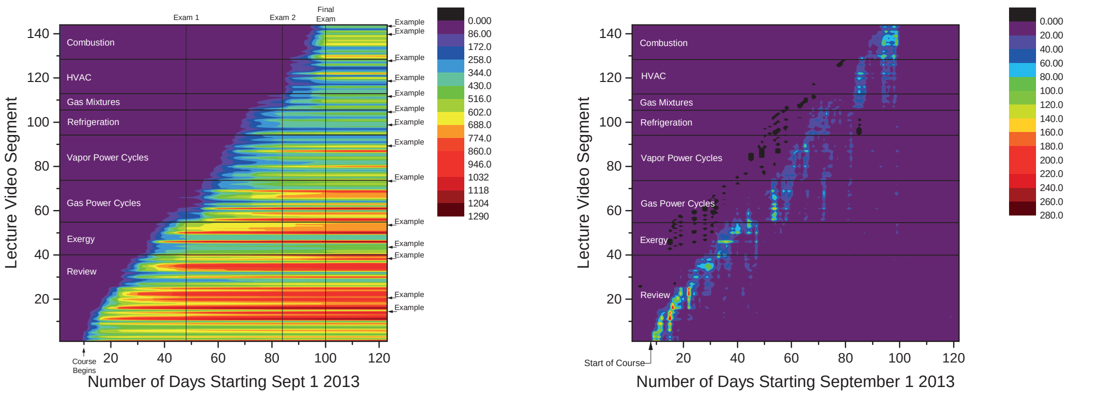

Figure 1: Canadian Watch Minutes – ME485F – Fall 2013 – Cumulative (left); Daily (right)

As shown in Table 1, the Mechanical Engineering Thermodynamics course (ME485) was taught twice, first in Fall 2013 and a second time in Winter 2014. Watch minute data collected from both of these courses was compiled and the resulting contour plots are compared in Figure 2. Visual inspection of both contour plots reveals a light blue band that runs from the lower left (start of the course) to the upper right (end of the course). The data set on the right in Figure 2 includes a feature not observed in the plot on the left, specifically a band of light blue that extends horizontally across the bottom of the contour plot. This horizontal band covers video segments from the first four lectures of the course. It also covers introductory course material that reviews topics normally found in an Introductory Thermodynamics course. It is believed that this content was being watched throughout the duration of Winter 2014 by other Canadian students who were not registered in the course. Thus given that these views negatively impact the quality of data collected during the Winter 2014 semester, it was decided not to examine this data further in this investigation.

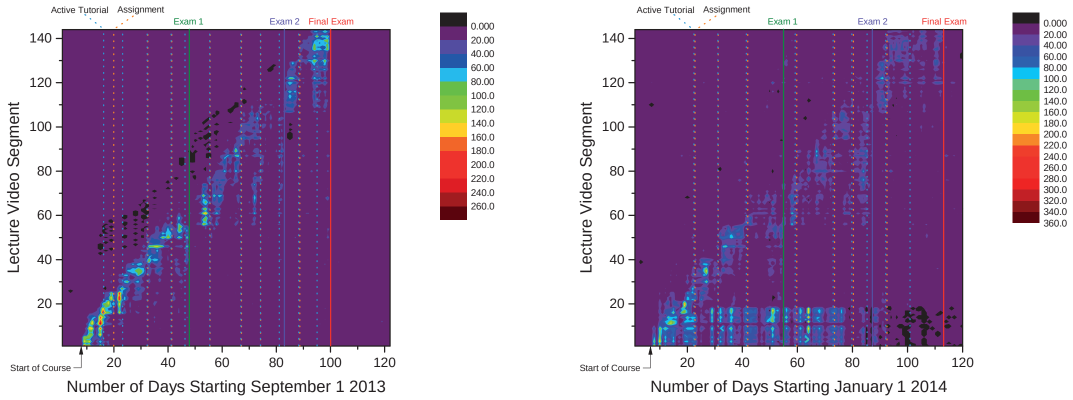

Figure 2: Canadian Daily Watch Minutes - ME485 - Fall 2013 (left); Winter 2014 (right)

Daily Watch Minutes

Daily watch minute data for ME485F, ME341, and ME471 are presented in Figure 3 through to Figure 5. Vertical lines superimposed on each contour plot denote teaching and learning activities within each course that include active tutorials, assignments, and exams. In examining the watch minutes both before and after Exam 1 (green vertical line on Day 48) for Figure 3 for ME485 more closely, it is noted that students watch little content after that content has been assessed. Of particular note is the void in watch data to the right of the green vertical line and below Lecture Segment 55. A similar pattern is observed to the right of Exam 2 (purple vertical line on Day 83) and between Lecture Segments 55 and 108. The only exception to this is the viewing which occurs immediately prior (to the left of) the Final Exam, as indicated by the red vertical line on Day 100. Figure 3 also reveals some evidence of increased viewing prior to when either an active tutorial is held or when an assignment is due, as reflected by vertical bands of watch data to the left of a dashed vertical line (prior to Day 55, for example).

Figure 4 shows the contour plot for watch minutes during the Summer 2015 offering of Fluid Mechanics (ME341). At a little over six weeks, the duration of this course was roughly half that of either the Fall or Winter semester courses. Although students were given assignments in this course, they were not required to be submitted. Instead students were given weekly exams, and an active tutorial preceded each exam and served the purpose of motivating students to study material (and do homework assignments) prior to each exam. Comparing the data in Figure 3 with that in Figure 4, it immediately becomes apparent that weekly exams result in more concentrated student watch minutes. Again, as observed in Figure 3, it is evident that students review content from different sections of the course in preparation for the final exam. In the case of ME341 in Figure 3, lecture segments 30 and 50 were reviewed by students prior to the final exam, indicating that students believed this material would be covered in the final exam. Given that not all lecture content was reviewed prior to the final exam, it can be surmised that students *gamble* in deciding what course material to study in advance of the final exam. In the case of ME341, it was noted that students focused on course content that had not been asked in previous examinations.

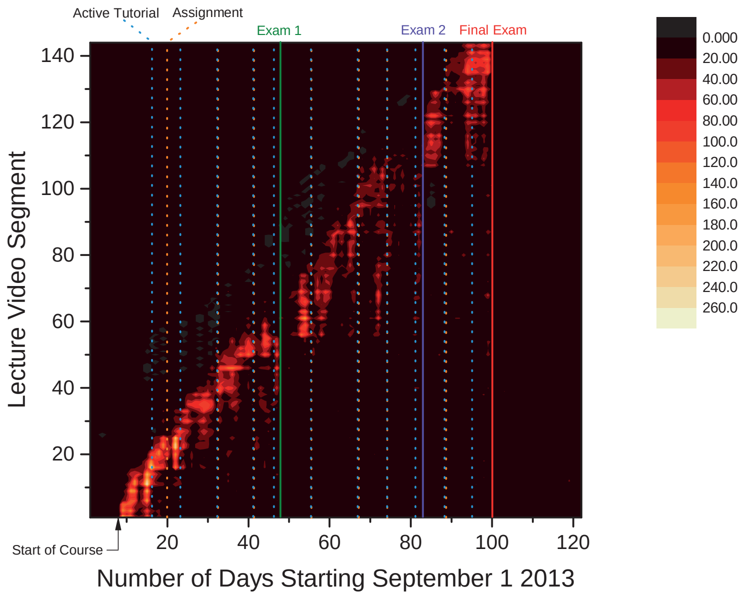

Figure 3: Canadian Daily Watch Minutes – ME485 – Fall 2013

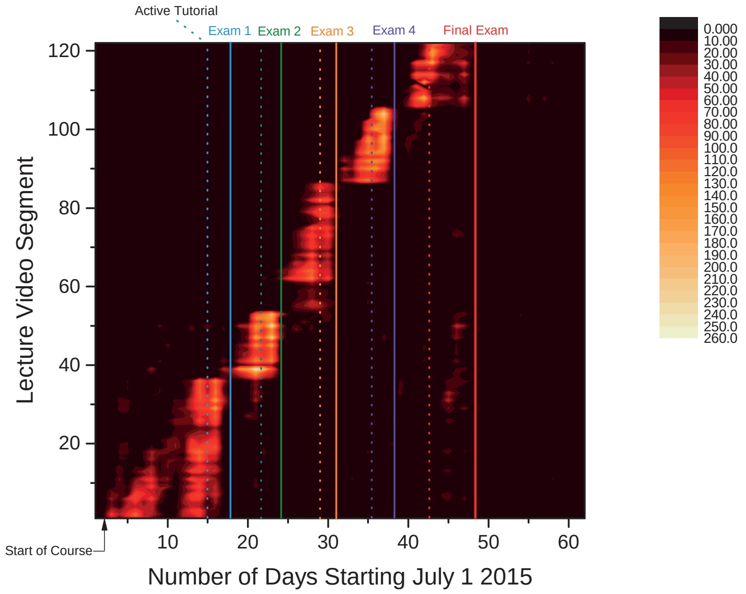

Figure 4: Canadian Daily Watch Minutes – ME341 – Summer 2015

Figure 5 illustrates the watch minute data for Heat Transfer (ME471) which was offered during Fall 2015. This course was structured with six semester exams and no final exam. Each semester exam was preceded by an active tutorial held during the lecture period prior to the exam. In Figure 5, active tutorials are denoted by dashed lines, and exams are denoted by solid lines. Again, as with ME341 shown in Figure 4, content was viewed both before and after each active tutorial and the watch minutes were found to be tightly clustered in advance of each semester exam.

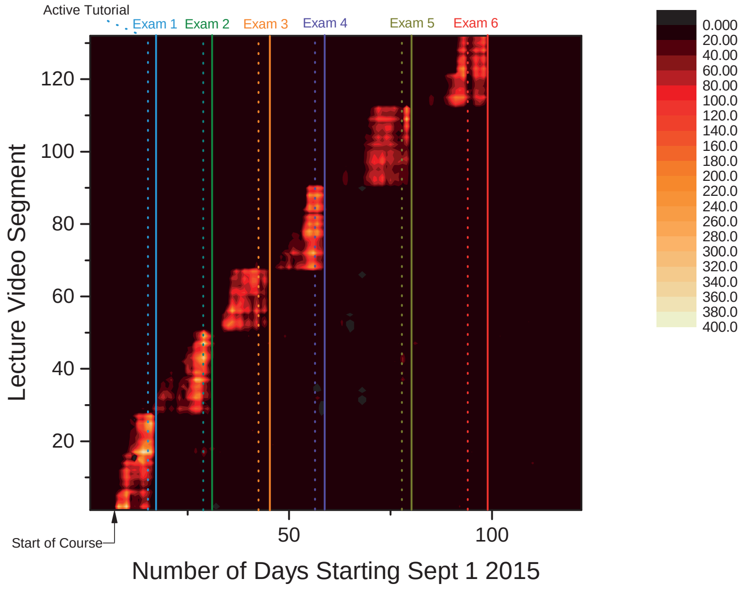

Figure 5: Canadian Daily Watch Minutes – ME471– Fall 2015

Weekly Viewing Patterns

Real-time watch data was used to examine how students would watch content on an hour-by-hour basis. Figure 6 shows data that was collected for more than one week prior to Exam 5 (held on a Thursday) and Exam 6 (held on a Tuesday). Overlaid on the contour plot are yellow boxes indicating scheduled lectures for the five courses taken by the cohort of students taking ME471 during the Fall 2015 semester. These students had three scheduled courses held on Monday, Wednesday, and Friday along with two scheduled courses held on Tuesday and Thursday. The yellow box with yellow crosshatching denotes the time that the ME471 lectures were scheduled. The data indicates that students tend not to watch the on-line content during the time allocated for ME471 traditional lectures (Tuesday and Thursday, 8:00-9:15AM), but rather they watch content starting at around noon and extending into late night. Content viewing is greatest on days preceding exams (Monday and Wednesday) and lowest on Thursday and Friday. Some content viewing is noted at times when other lectures are being held. It is also noted that on weekends the students do not start viewing content until the afternoon, and on Saturdays content viewing is greater in the afternoon than in the evening while on Sundays content viewing is greater in the evening than in the afternoon.

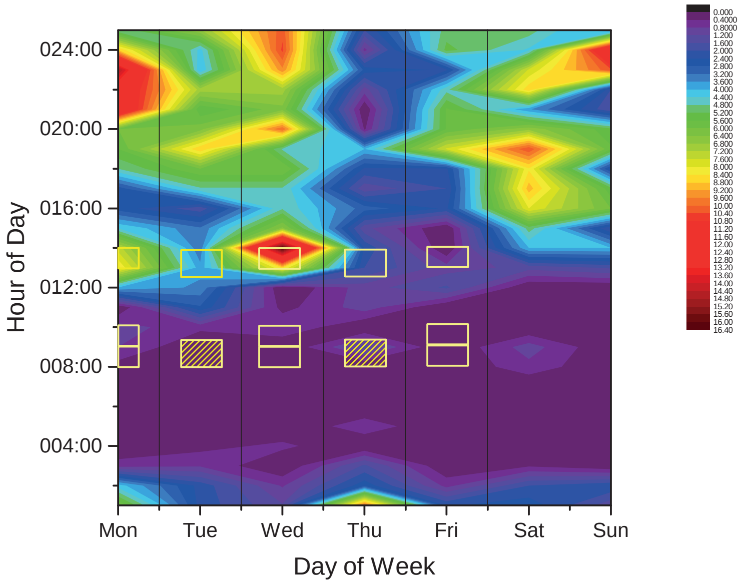

Figure 6: Real-time Watch Data by Day of Week - ME471 - Fall 2015
[yellow boxes represent lecture times; cross-hatched box denotes ME471]

Student Prioritization

The instructors of all five courses taken by the cohort of students during the Fall 2015 semester were surveyed and asked to specify when students were assessed and to specify the weight of that assessment. Figure 7 shows the daily watch minutes for ME471 during Fall 2015, and inset in the contour plot is a bar graph showing the total assessment by week for all five courses. With this information it is possible to examine how students choose to adjust their content viewing in relation to assessment activities in their courses. Comparing Weeks 4 and 5, it is noted that more content is viewed during Week 4 when the total assessment is 7.5% as compared to Week 5 when the total assessment is 50%. Week 8 offers another example where the total assessment was 27.8%, and consequently students opted to defer their viewing until Week 9. Weeks 11 and 12 again offer another example: with the total assessment in Week 11 being 43.3%, students elected to defer their viewing until Week 12 when the total assessment was much lower at 11%.

It is important to note that students *do* prioritize their watch time (and consequently study time) in relation to when assessment activities are taking place in all of the courses that they are taking in a given semester. The results in Figure 7 clearly indicate that students do not watch content consistently on a week-to-week basis but rather adjust according to the amount of work that they have in all of their courses. This indicates that one advantage to the flipped delivery model is that it enables students to adjust their viewing schedules in response to the overall demands that are being placed on them.

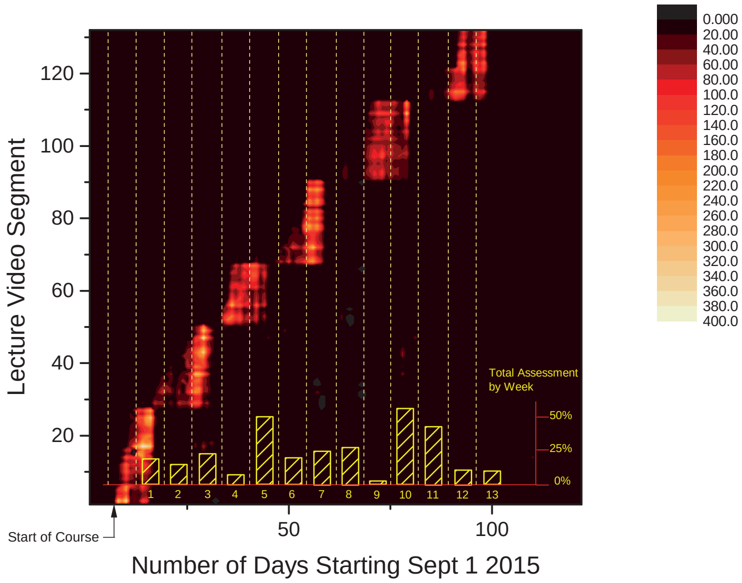

Figure 7: ME471 – Fall 2015 - Total Assessment for All Courses (inset) by Week

On-line Attendance

An on-line version of “attendance” is presented in Figure 8 where, for each course, the Canadian view minutes over a certain period are divided by the number of content minutes posted for that same period multiplied by the number of students in the course. If all students watched all of the content provided, this number would be 100%. When the course instructor taught face-to-face lecture-based courses from 2000 to 2005, the average class attendance was 65.8% as indicated by student participation in the USRI. In Figure 8, it is interesting to note that for ME485F the on-line attendance for the entire course was 66.4%; for ME341 it was 64.3%; and for ME471 it was 78.7%.

These results indicate that the lecture content viewing for the on-line courses examined in this investigation is similar to lecture attendance in face-to-face courses. The results also indicate that on-line attendance (or content viewing) is seen to increase by administering more and frequently scheduled exams. Although ME341 also had regularly scheduled semester exams, the shortened summer session and the increased load due to the Inquiry-Based Learning laboratories made it more challenging for the students to view the content as compared to the watch patterns observed with ME471 where the semester was longer and the laboratories were of the more traditional scripted variety.

The increased on-line attendance in ME471 with an increased number of term exams implies an increase in student motivation. This result is in agreement with Wankat & Oreovicz (1992) who indicate that an increased number of tests have positive benefit on student learning. One of the drawbacks that they identify, however, is that an increased number of tests will reduce the amount of lecture time that can used to cover content. One advantage of the flipped-delivery model is that this drawback is eliminated, thereby enabling the benefit of increased testing to be realized, as found in this investigation.

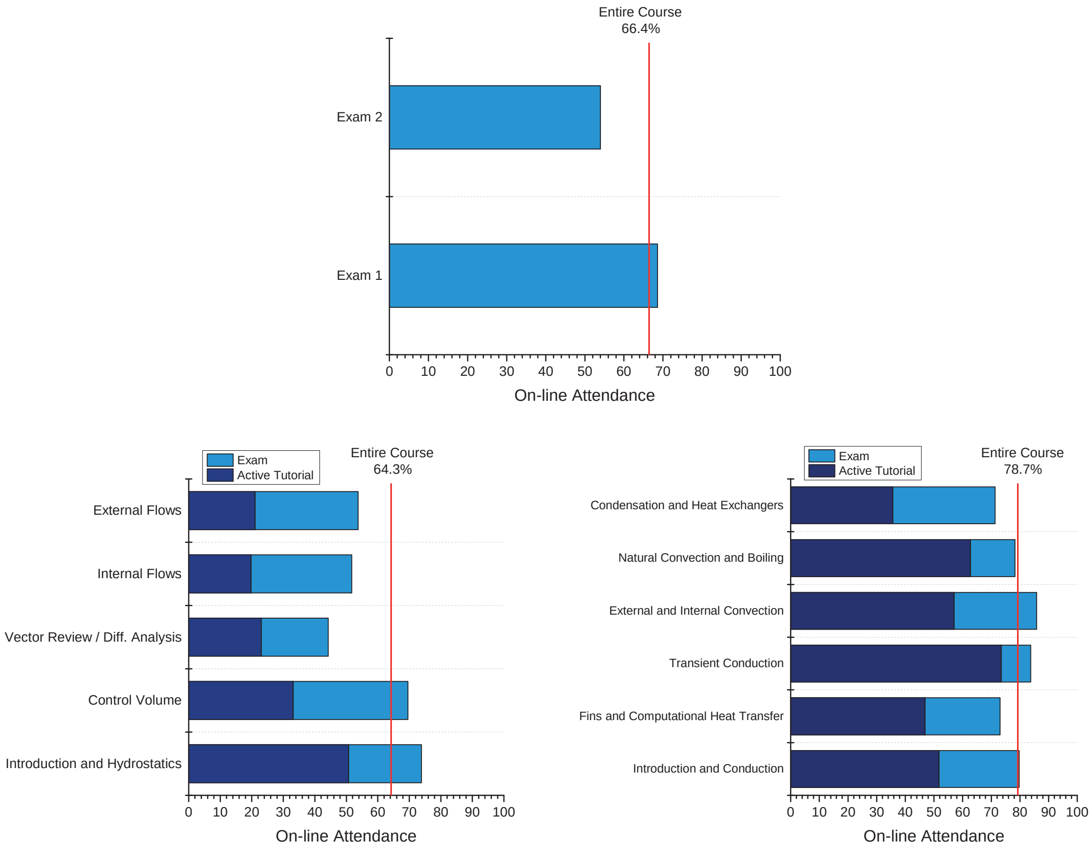

Figure 8: On-line Attendance by Course
[ME485F upper middle;
ME341 lower left; ME471 lower right]

CONCLUSIONS

This paper has examined student watch data from three different on-line courses taught over the span of two years. Daily watch data was found to be an effective method of conceptualizing and visually representing when students watch content and what content they are watching. It was also found that students studied more in the afternoon and evenings than they did in the morning. Students were noted to study less on Thursday and Friday than they did on other days of the week. Evidence of time prioritization in response to the amount of assessment (and hence workload) in all of the courses taken by a single cohort of students was also examined.

From an analysis of the data, it was found that administering a larger number of examinations with smaller assessed value was more effective at motivating students to study than offering fewer exams with greater assessed value. Therefore, future flipped-delivery course offerings will be taught using more frequent assessment. Given that the flipped-delivery format frees up lecture time, this newly available free time can be used to increase the amount of formative assessment and/or to introduce other CDIO-related activities (e.g. active learning). These changes would impact course design and the ways in which students engage in learning.

Overall, the paper offers a glimpse into the type of information that can be derived from the use of on-line watch data. While many of the results obtained in this paper are somewhat intuitive, the significance is in having access to quantitative data that confirms this intuition.

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BIOGRAPHICAL INFORMATION

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IMPACT OF GLOBAL FORCES AND EMPOWERING SITUATIONS ON ENGINEERING EDUCATION IN 2030

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ABSTRACT

Over the last couple of decades the world around us has changed at a dizzying pace by the globalisation and digitalisation, the horizontalisation of the socio-economic world, and the blending of technical, economical and societal cultures. The ways we communicate, work, play, travel and do business have changed dramatically, and are expected to change at an even faster pace in the future. We have entered an era where higher engineering education has to move from content coverage to content mastery. Are our programmes good enough to absorb the changes in the world 10 to 15 years from now?

This paper discusses the results of an exploration by a Think Tank of academic staff about "what future engineers should learn in higher engineering education in 2030". Key issues are the embedding of personal development in a meaningful way - the teaching of the "whole engineer", the creation of purposeful engineering profiles for society, keeping them specific enough to create in-depth learning.

KEYWORDS

Engineering education, 2030, profile, engineering language, hub, CDIO Standards 1 (Context), 3 (Integrated Curriculum), 7 (Integrated Learning Experiences).

INTRODUCTION

Although Moore's law of exponential growth in electronic devices is challenged today, technological innovations have not slowed down. According to Brynjolfsson and McAfee an extraordinary re-invention of our lives and economy will take place driven by digital technology. It is expected that much labour force will be supported or replaced by intelligent assistants, cognitive computing systems, who will come to know their controller through continuous interaction. These robots will complete more and more non-routine cognitive tasks and develop broad abilities in pattern recognition in big data, complex communication and other domains that used to be exclusively human (Brynjolsson & McAfee, 2014). Although the future scenario is full of uncertainty, engineers will be better off when they master the usage of multipurpose tools and methods, master common languages in engineering such as mathematics, programming, visualisation, have learnt to use their imagination and intuition, and have agile and resilient abilities. They have to be prepared for practice to learn about the kinds of practical questions that engineering scientists and professionals in their domain repeatedly face. Vivak Whadwa states we should encourage our students to develop a love for learning as they will have to reinvent themselves many times over the course of their life time. This will include technology, reading, writing and mathematics as much as the more human empathetic skills coming from non-engineering fields.

Table 1 Shifting attributes of engineering graduates (based on Kamp, 2014)

Current MSc graduate profile	Shifting needs
Mono-disciplinary thinking	Multi- and interdisciplinary thinking
Reductionism	Integration
Convergent thinking	Creativity (divergent – convergent)
Independence	Collaboration
Techno-scientific base	Socio-economic context
Understanding certainty	Handling ambiguity and failure
Rounded expert	Employability, lifelong learning
Rational problem solving	Complex problem solving

The landscape of the challenges in society, technology and engineering and the research topics in the National Scientific Agenda (NWA) of the Dutch government differs dramatically from the past because of the many deep interconnections. Solving these challenges requires innovative solutions that balance technological innovation, economic competitiveness, environmental protection and social flourishing. Today's problems are already of such complexity that they can no longer be solved in siloed engineering disciplines. Solutions ask for multi- and interdisciplinary approaches where specialised knowledge of several disciplines in engineering and humanities and social sciences are integrated into relevant solutions supported by technological advances (Kamp, 2014). But the reality is that many engineering programmes have marginally changed over the past 30 to 40 years. Whilst recruiters in engineering business emphasise that the arguments why they offer a person a job and create opportunities for successful careers is only marginally tied to knowledge, and which will even be more so in the future. More elusive factors like ambition, creativity, patience, perseverance, international orientation, organisational sensitivity and social intelligence gain importance.

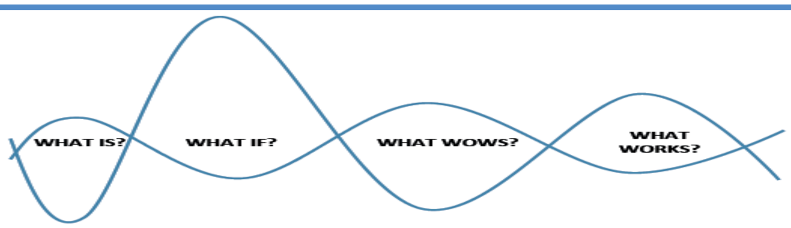
METHOD

In spring 2015 a "Free Spirits" Think Tank has been set up as a joint initiative of the Dutch 3TU.Centre for Engineering Education and TU Delft's Directors of Education. Its aim was to look ahead to the year 2030 and revaluate what students' capacities should be, without losing their current core strengths. In five dedicated workshops with in total 12 full, associate and assistant professors, senior lecturers, programme directors, members of the valorisation centre and student bodies from all disciplines of the institution, the Think Tank challenged the following key questions:

- What type of students does TU Delft want to educate?
- What are the major changes our students will face in 2030?
- What is the added value TU Delft can deliver in terms of educational content?
- Which learning processes help to sustain preparation of the future engineer?

The Think Tank explored these questions via the method of Design Thinking, known for its effective creation of out-of-the-box solutions for new ways of working. The method is known to be effective to address complex, human centred problems with many unknowns and little objective data (Jeanne Liedtka, 2010). The Think Tank explored current trends in engineering and society, established the greatest needs in engineering capabilities, developed ideas based on possible future worlds and built concepts that addressed the "What" question. The workshops were supported by survey data on trends in science, numerous small informal workshops, ad-hoc student interviews on the campus pavements, and a "Free Spirits" Facebook page on which progress was shared with the academic community of TU Delft.

Figure 1 gives an overview of the activity flow. The steps throughout the process can be viewed in detail at https://www.youtube.com/channel/UCO3lrxZICd5ID6TmN481DFA/videos.



Critical Questioning Journey Map Insight questions Dillema's/ SWOT Survey response on scientific trends Design Challenge Mind Maps	Building World Scenarios Profiles and added value Pockets of knowledge lego exploration	Profiles Hubs Languages	Pilot testing Validating stakeholders Policy discussions

What is: Exploring present trends and innovations in engineering education, defining the problems and reframing the questions.
What if: Generating new concepts for on campus Engineering Education
What Wows: Identifying the best opportunity
What Works/Manifests: Define rapid prototyping options/Create a Manifest- Results of previous sessions and the way it will be disseminated

Figure 1 The Design Thinking flow with activities followed by the "Free Spirits" Think Tank

REFRAMING THE PROBLEM

One of the first activities of the Think Tank was to make a SWOT (Strengths-Weaknesses-Opportunities-Threats) analyses. It created the boundary conditions for whatever it might be we would create as a solution to the Why and What questions, as proposed at the start of the Think Tank initiative.

Type of students we want to educate

Career deliberation should start at the very beginning of higher engineering education, at admission and during the Bachelor's study programme. We, the institution, should be looking for motivated students who can deal with freedom of choice, are able to excel in key scientific areas, are focused on personal development, are able to create multiple perspectives towards subject matter, take initiatives and are self-regulatory in behaviour (engagement of students with the learning environment). Our students have a talent for realising change, having plenty analytic and creative skills. They are not afraid of getting a taste and test of success and failure to become resilient in the face of obstacles.

Learning path in our engineering programmes

To facilitate the students we may need a differentiation in learning paths towards the acquisition of knowledge, skills and attitudes that intrinsically motivate students. Play, passion and purpose in education should be the key values to create education based on exciting real-life cases, wherever possible embedded in (global) societal and engineering challenges (CDIO Standards 1, 3 and 7). Authentic cases, projects and research which allow for failure and experimentation; collaborative learning and plenty of links to the outside world are leading in learning. Recent initiatives in Delft such as the building of the Holland Particle Therapy Centre in collaboration with Dutch medical centres, the Smart Industry Digital Factory Composites Fieldlab in collaboration with knowledge institutions, government and industries, the YES!Delft High-tech Incubator centre, and an Open Innovation Centre on or nearby the campus have to be stimulated. They will create the visionaries we need and allows for building up early relations with the professional market in engineering business. TU Delft has numerous of small and larger scale initiatives that create strong bridges between research, education and industry.

Main strengths of TU Delft

The strong points of TU Delft are its (mono)disciplinary engineering programmes, with emphasis on application and creative workable solutions for the societal and engineering problems. Future innovations are especially expected at the fringes of mono-disciplines. If we are to stand out in the world, a stronger student preparation for innovation should make the institution more future-proof. It will be a stimulus to work with foreign partners, increase contacts with external regional partners, and create involvement and collaboration between truly diverse bodies of expertise in education. The students and specialists, educated or developed in disciplinary fields of expertise, should then be trained in multi- and interdisciplinary collaborative projects, in networks with extensive and diverse research and industrial platforms.

THE DESIGN CHALLENGE

A design challenge is always based on what is presently needed and holds promise for the future. It is framed in a How question, yet leads to Why and What answers as intended. The design challenges, reframed from the original Think Tank questions and the SWOT analysis were:

- How to create an engineering educational programme in which personal development plays a key role, and is acceptable to accreditation bodies?
- How to create more specific profiles and programmes that will be recognised as coherent tracks?
- How to create purposeful profiles or programmes with added value to the future society?

IDEATION

After the above framework for the design challenge was established, the Think Tank went on to explore possible future worlds, based on realistic trends in science and engineering (Figure 2), the so-called pockets of knowledge. A number of hypothetical extreme scenarios were “invented” for combinations of these future worlds (such as a world of Scarcity of Resources combined with Big Data – Smart Data, or a world of Design beyond Nature combined with Robotisation). Then backward engineering was conducted to unravel the capabilities and knowledge the future engineer in such extreme world scenarios would need to create a life and create added value to that world. The future engineers in these different hypothetical worlds could not be cast into one image and thus a number of different engineering profiles were established.

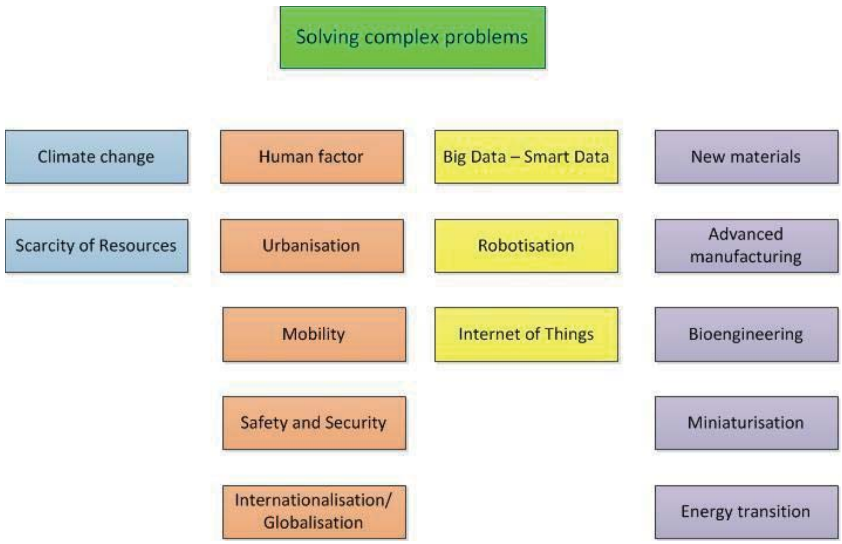


Figure 2 Megatrends in society and engineering

With these profiles the Think Tank went back to the design criteria: flexibility for personal development, keeping purposeful and specific profiles that are meaningful to the institution, society and industry. Nowadays' educational programmes are traditionally shaped in disciplinary curricula. The future requires flexible and resilient engineers, with profiles that differentiate beyond knowledge alone, and beyond engineering, science and design. Profiles that are linked to different roles one may have to play as an engineer in future society, irrespective of it being in academia, governmental organisations, industry, or as an entrepreneur. The flexibility has to enable students to become the engineering professional, i.e. operative industrial engineer, researcher, designer they want to be. Rigidly structured disciplinary curricula will no longer fit to an engineering programme. The engineering curricula will need another dimension that links the disciplinary content to the role(s) a graduate may play in his future job as an academic researcher, a professional engineer, an entrepreneurial innovator, or any other professional job. Also in future, the students in engineering programmes will remain to build a solid level of fundamental knowledge and skills in a disciplinary domain, as one cannot contribute without a broad and deep working knowledge base in one or two particular domains. Yet, within their disciplinary domain they will differentiate, learning one or more specific engineering profiles.

THE RESULT THAT WOWS; A TRIPARTITE CONCEPT

Three idea's emerged from the Think Tank:

1. Profiles, denominating engineering roles in particular contexts that may provide opportunity for specialisation.
2. Hubs in which interdisciplinary learning takes place in an engineering or research environment that focuses on a specific pocket of knowledge.
3. Common engineering languages that are essential for communication across disciplinary boundaries and allow for problem definition, analysis, conceptualisation, visualisation (Goldberg, 2008). These ideas are elaborated upon below:

Profiles (1)

The Think Tank ideation about future worlds yielded four profiles: the Specialist, the System Integrator, the Front-end Innovator and the Contextual Engineer. They partly overlap the professional engineering career tracks that are implicitly identified in Figure 3.6 of the CDIO Syllabus (Crawly, Malmqvist, 2007). A complete description is available in the Appendix or digitally available from http://issuu.com/danielleceulemans2/docs/future_proof_profiles_digital.

These types of engineers tend to play a different role in projects and work environments, as they start with a different heuristic question:

- Specialist: How can we advance and optimize technology for innovations and better performance using scientific knowledge?
- System Integrator: How can we bring together disciplines, products or subsystems into a functioning whole that meets the needs of the customer?
- Front-end Innovator: How can we advance and apply knowledge and use technology to develop new products for the benefit of people?
- Contextual Engineer: How can we exploit diversity-in-thought to advance and apply knowledge and use technology in different realms to develop products and processes for the benefit of people in different cultures and context?

Each profile cannot realise a technological solution without the other and is needed to realise integrated solutions for complex problems.

SPECIALIST - R&D for innovation in science and industry

The role of the Specialist is advancing knowledge in fundamental science, design or engineering research fields or R&D. In industries specialists support innovation and the development of complex systems, products or services with their state-of-the-art expertise. When embarking on an academic career, most scientific staff members develop into disciplinary specialists. In the industrial environment, specialists collaborate with non-specialists with many different disciplinary backgrounds. They need a more holistic engineering mind-set to understand the impact of the interfacing levels and innovate at the fringes of their specialism. Also for a specialist, engineering is not only about mastering a fixed and known body of deep knowledge, but is about the integration of that knowledge into system and product development. The future viable profile for the specialist is therefore oriented towards a specialist with a broader orientation, a T-shaped specialist in a certain branch of engineering. The prime idea is that specialists are educated within the disciplinary department or faculty, while a broadening of their skills can be trained and practiced in multidisciplinary projects such as the Big Data or Scarcity-of-Resources type of Hubs at interfaculty level that will be discussed later.

SYSTEM INTEGRATOR – Connector

System Integrators are system oriented. They have a helicopter view of a wide scope of technological fields and work from the system level back to components. They collaborate in a team of T-shaped specialists, engineers and managers and are therefore socially skilled and aware of ethical aspects in engineering. To design systems or processes that can perform as components of large-scale complex enterprises, future System Integrators must have learnt to look beyond the technical system, and consider the characteristic of the enterprise in which the system will operate and the context in which the system is developed. System Integrators will transform from the architect who guides engineering projects for clients from concept toward strategic goals, to a leader who is capable of balancing his technological skills with the demands of restricted budgets, regulatory frameworks, collaboration complexity, public safety impact and public understanding. The major idea is that T-shaped System Integrators are educated within the disciplinary department or faculty, and that their disciplinary broadening and development of interdisciplinary and interpersonal skills will take place in multidisciplinary projects that will be produced in interfaculty Hubs.

FRONT-END INNOVATOR

Front-end Innovators are entrepreneurial design engineers with a broad education in engineering and socio-economic factors. They are customer oriented and focus on trends in engineering and the world. They have learnt to work in horizontal flat organisations and work in small teams of T-shaped Specialists, System Integrators, design engineers, business managers, customers and end-users. They are capable solving complex adaptive problems and feel comfortable to follow agile methodologies with cross-functional team work, rapid iterations, rapid prototyping, continuous user involvement.

Students who enrol in this profile are independent participants with an entrepreneurial attitude. They have a good understanding of the engineering context and an awareness of the user and client environment. They have good social and empathetic listening skills to talk with a wide variety of people, including specialists and customers or end-users. They have to be creative enough to translate market needs to technological innovation. Their education emphasises the engineering domain, and addresses the interdisciplinary context that will be available in the interfaculty Hubs. The innovation and business component may be inserted into the Hubs by involving students in humanities or social sciences.

CONTEXTUAL ENGINEER

The National Academy of Engineering (NAE) envisions the workplace of the near future as one of dynamic technological change that requires engineers to understand complex societal, cultural, global, and professional contexts. Multinational companies and their development teams make use of the diversity in cultures and socio-economic environments for the benefit of technological innovation, product design and engineering business. Teams of different cultures, with different perceptions of ethical responsibility and risk, collaborate for customer-centred innovations.

By 2030 multinationals from emerging countries might own enterprises with a Western origin, and vice versa. The investors, president and leaders import their beliefs, norms and values and habits into the enterprise culture and expect their employees not only to respect but also behave accordingly and exploit the differences in cultures and socio-economic environments for the benefit of technological innovation, product design and business. Strong intercultural communication and collaboration skills and attitudes will be necessary to be successful in these enterprises. Employees have to be open-minded to learn how to operate in such different realms, not only technical but also cultural. This is where the Contextual Engineer profile comes in. These engineers require much more contextual knowledge to work effectively with other cultures and get things done and influence strategic decisions.

Contextual Engineers are technically adept and understand the contextual constraints and consequences from discipline, policy, judicial and ethical perspective. They are a leader in realising technological innovations in political contexts. They have a helicopter view, are open minded, work in interdisciplinary settings, are agile and patient but are always focused on results. They understand how differences in disciplinary backgrounds, cultures and socio-economic environments can be an enrichment.

Pocket of Knowledge becomes a Hub (2)

Students will spend part of their study in a Hub, in which they collaborate in multidisciplinary teams on engineering and societal challenges together with industrial business partners and customers (CDIO Standard 7). A Hub is a physical location on campus that is flexibly organised around (families of) high-tech innovative “hot topics” like “Driverless cars”, “Developing a 5-million inhabitant city from scratch”, “Energy transition”, “Advanced manufacturing”. It is a flexible engineering research and learning space in which expertise from different disciplines (engineering, humanities, social sciences) and different stakeholders from within and outside the university is bundled, based on the pocket of knowledge to create immediate scientific and educational synergy.

A Hub may be provided by already existing initiatives like the interdisciplinary Delft Infrastructures & Mobility Initiative, the TU Delft Space Institute or the Sports Engineering Institute, or be instigated by one or more faculties around a hot topic that is relevant and of common interest, interdisciplinary and challenging for research, technology development and innovation at the intersections of disciplinary knowledge, across the faculty boundaries. For educational purposes the complex societal and research problems will have to be reframed into engineering cases for authentic interdisciplinary learning.

The specific approach in a Hub depends on the problem definition, complexity and problem solving derived from the available expertise and engineering discipline, the level of the students. In the Bachelor programme the students may explore the different profiles, orientate and discover their personal strengths in “Foundry Hubs” by adopting a profile and solving real-life problems in interdisciplinary and intercultural teams while building onto fundamental engineering knowledge they have attained in their disciplinary fields. In the Master’s the students will no longer only specialise in their field of expertise but also develop a profile of their choice. Probably the role of Specialist can still be developed at the faculties, as usual. The role of System Integrator, Frond-end Innovator and Contextual Engineer will be developed by partaking in design and research projects in Hubs.

Languages (3)

All students, irrespective of their engineering discipline, need to be master a set of universal engineering languages to meet the needs of the future working context. In the end it is these professional skills that make the difference of being well prepared for the job market of the future.

- Mathematics
- Digital literacy (data analytics, programming)
- Design skills
- Academic communication
- Engineering ethics.
- Collaborative and interdisciplinary teamwork

The idea is that Bachelor students have to master these languages at graduation to a basic level, so that each engineering student of whatever engineering discipline will understand another engineering student and is able to work effectively in multiple collaborative contexts, as he or she will be required to do in future professional life.

OPTIONS FOR IMPLEMENTATION

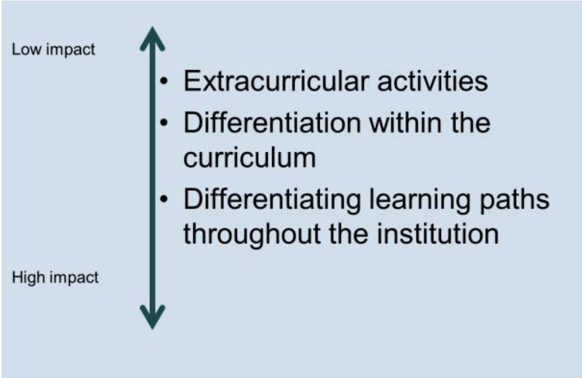


Figure 3 How to get there?

In final interview sessions we discussed options for implementation (Figure 3). Low impact options are extracurricular projects in which students work on their profiles in a Hub-type project organisation linked to already existing research institutes, living labs or other existing structures. Such option is low cost and allows for prototyping, testing and validating the conceptual philosophy. A more permanent solution would be to free up space in the Bachelor curricula for projects linked to the profiles that are complemented by obligatory courses or trainings in the “common engineering language” skills. In the Master’s larger sized projects coupled to engineering or research institutes, such as the TU Delft Sports Engineering Institute, Space Institute or the research-based initiatives in health, energy, globalization and infrastructures & mobility could be aimed for, which would be complementary to the thesis in the final year of the disciplinary Master’s, where the common engineering languages could be practiced and further developed.

Another possibility would be to create (for credit) verticals within a disciplinary faculty on cross-disciplinary themes. Verticals are teams of scientific professionals – full professors, associate and assistant professors, PhD students and talented Master students – working in a horizontal working relationship on particular societal and technological problems. The vertical is embedded in the curriculum for the entire study period. Students participate for credit on a theme or subject of their choice. The profiles are embedded and an interaction with industry is essential. The project may be shaped as a sort of apprenticeship with a narrow focus.

The highest impact option would be to label the courses of the study programme based on profiles and disciplines, allowing the students to develop a flexible learning path, while guided by a coach. The students would then obtain a truly personalised profile with a high level of intrinsic motivation.

THE WAY FORWARD

The results of the Free Spirits Think Tank are a start, based on an innovation initiative for the vision of TU Delft’s engineering education. The process has revealed available engineering projects and initiatives at TU Delft with structures available for experimentation with the Think Tank concepts. Some of the concepts will be prototyped and tested within existing extracurricular initiatives. Additionally the ideas and prototype outcomes will be validated amongst industrial and entrepreneurial stakeholders of multinationals in engineering like the Airbus Group, small and medium-sized enterprises (SMEs), engineering and consultancy business and young entrepreneurs. A policy working group has started to develop TU Delft's future vision on engineering education, among others on the basis of the outcome of the Think Tank, which will be followed by an implementation strategy from 2017 onwards.

CONCLUSION

TU Delft wants to educate intrinsically motivated students, who excel in their key discipline yet go beyond their studies and their discipline and are self regulatory in behaviour, taking initiative, open to multiple perspectives, sociable and open to experimentation. The Think Tank expects that our students in 2030 will face many changes. They will be challenged during their studies to go out in the world and bring back the problems to education that need to be solved. Not while they have rounded off their education, but during their education, as integrated learning experiences.

The added value of research universities like TU Delft remains the thorough foundation in engineering basics. More than nowadays, individual or monodisciplinary projects and courses on specialist subject matter will be complemented by flexible and diverse interdisciplinary research and engineering projects, in collaboration with third parties from industrial companies, research institutes and society. They offer a playing field for experimentation with the roles that can be played in areas at the front end of scientific advancement and innovation.

The learning process is one of passion (intrinsic motivation), peer (working collaboratively), purpose (contributing to the solution of societal challenges or on-the-edge research) and play (a culture of experimentation) to move forward the state-of-the-art knowledge as it is today towards unknown and horizons to be explored.

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Biographical information

Aldert Kamp the Director of Education for the Faculty of Aerospace Engineering at TU Delft, the Netherlands since 2007. He is deeply involved in the rethinking of engineering education at university level with a horizon of 2030, as a response to the rapidly changing world. More than 20 years of industrial experience in space systems engineering and 10 years of academic experience have given him the insight in the capabilities tomorrow's engineers need in the future world of work. Aldert has been involved in university-level education policy development, renovations of engineering curricula and audits of Dutch and international academic programmes. He is a member of the Council of the CDIO Initiative, the global innovative education framework for producing the next generation of engineers, and is TU Delft Leader of the Dutch 3TU Centre of Engineering Education (3TU.CEE) that will facilitate innovations in higher engineering educational programmes within and outside the Netherlands.

Renate Klaassen is an educational consultant, working at the TU Delft Educational Centre of expertise on Education "FOCUS". She has been heavily involved in educational advising on the innovation of the BSc in Aerospace Engineering, and various other curriculum reforms at TU Delft. She is TU Delft Coordinator of the Dutch 3TU.CEE. Other consultancy activities include assessment (policy, quality and professionalization), internationalisation of university education and design education. Area of research interest pertain to content, language integrated learning in higher education, English language proficiency and coaching in design education.

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APPENDIX: FUTURE-PROOF PROFILES 2030

Specialist

Role in field of work

In industries the specialist supports innovation and development of complex systems, products or services with its experts knowledge. It is even more important that the specialist can collaborate in multidisciplinary teams with non-experts and people without an engineering background. The specialist visits international conferences to gain knowledge and to meet other experts from university or industry. During its professional career the specialist becomes an expert in its field.

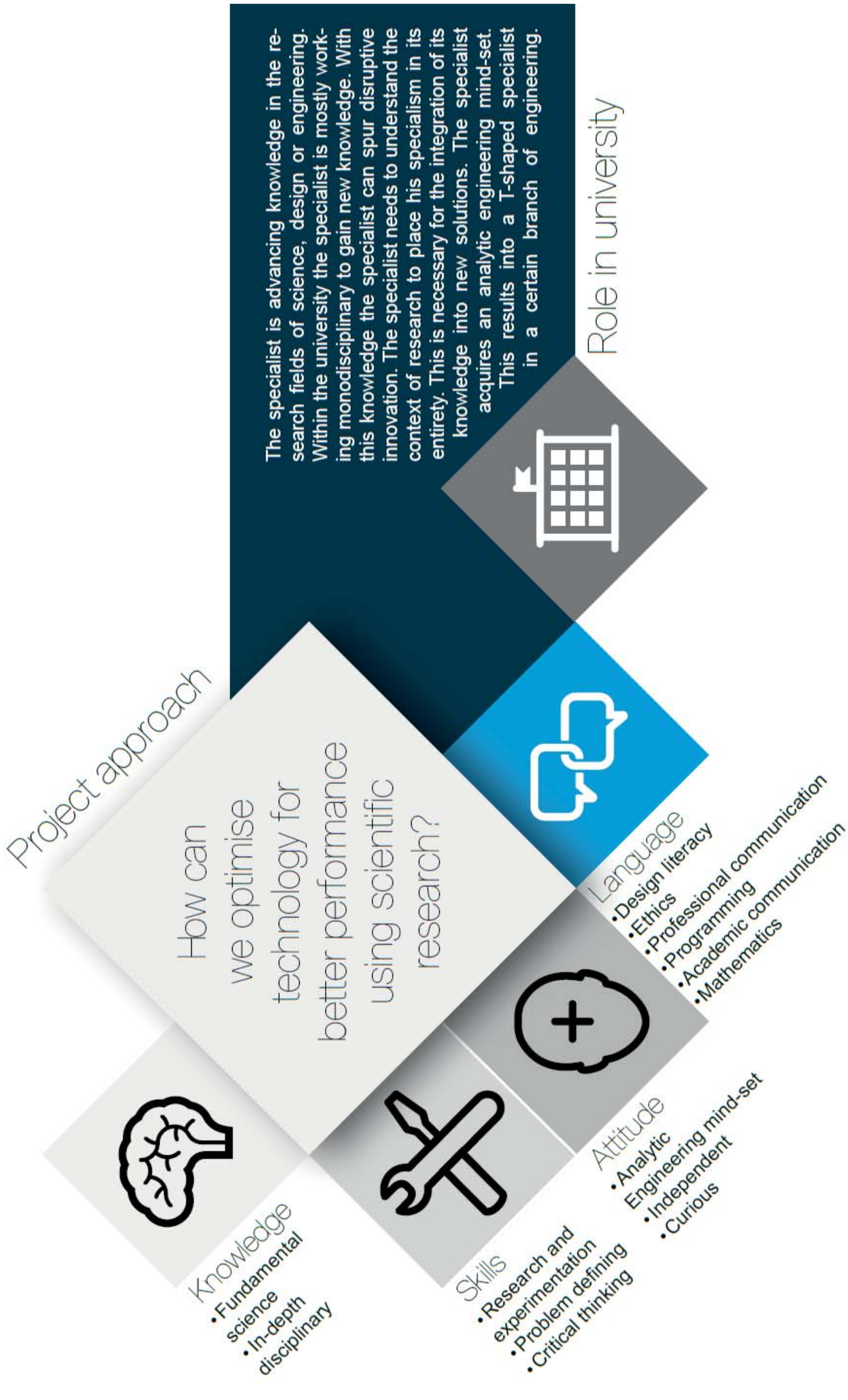
Goals and believes

My goal is to become an expert in my field and use and share my knowledge in science and industry. I believe I can change the world with incremental innovation.

Pain and frustration

I think it is difficult when there is a language gap with non-experts. I have less experience in business or entrepreneurship and I think it is hard to make compromises with the system integrators or other specialists of different disciplines.

TUDelft



Role in university
The specialist is advancing knowledge in the research fields of science, design or engineering. Within the university the specialist is mostly working monodisciplinary to gain new knowledge. With this knowledge the specialist can spur disruptive innovation. The specialist needs to understand the context of research to place his specialism in its entirety. This is necessary for the integration of its knowledge into new solutions. The specialist acquires an analytic engineering mind-set. This results into a T-shaped specialist in a certain branch of engineering.
Project approach
How can we optimise technology for better performance using scientific research?
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Analytic
Engineering mind-set
•Independent
•Curious
Skills
•Research and experimentation
•Problem defining
•Critical thinking
Knowledge
•Fundamental science
•In-depth disciplinary

System integrator

Role in field of work

The system integrator collaborates in interdisciplinary teams with different departments, clients and stakeholders. For solid communication the system integrator needs to understand the management team and the specialists. System integrators develop end-to-end solutions from technical to business level. They also focus on schedule constrains, cost savings and risk reduction. The system integrator is employed at a company that works on close to the market products or services. They coordinate test runs to make sure the integrated system works perfectly prior to implementation.

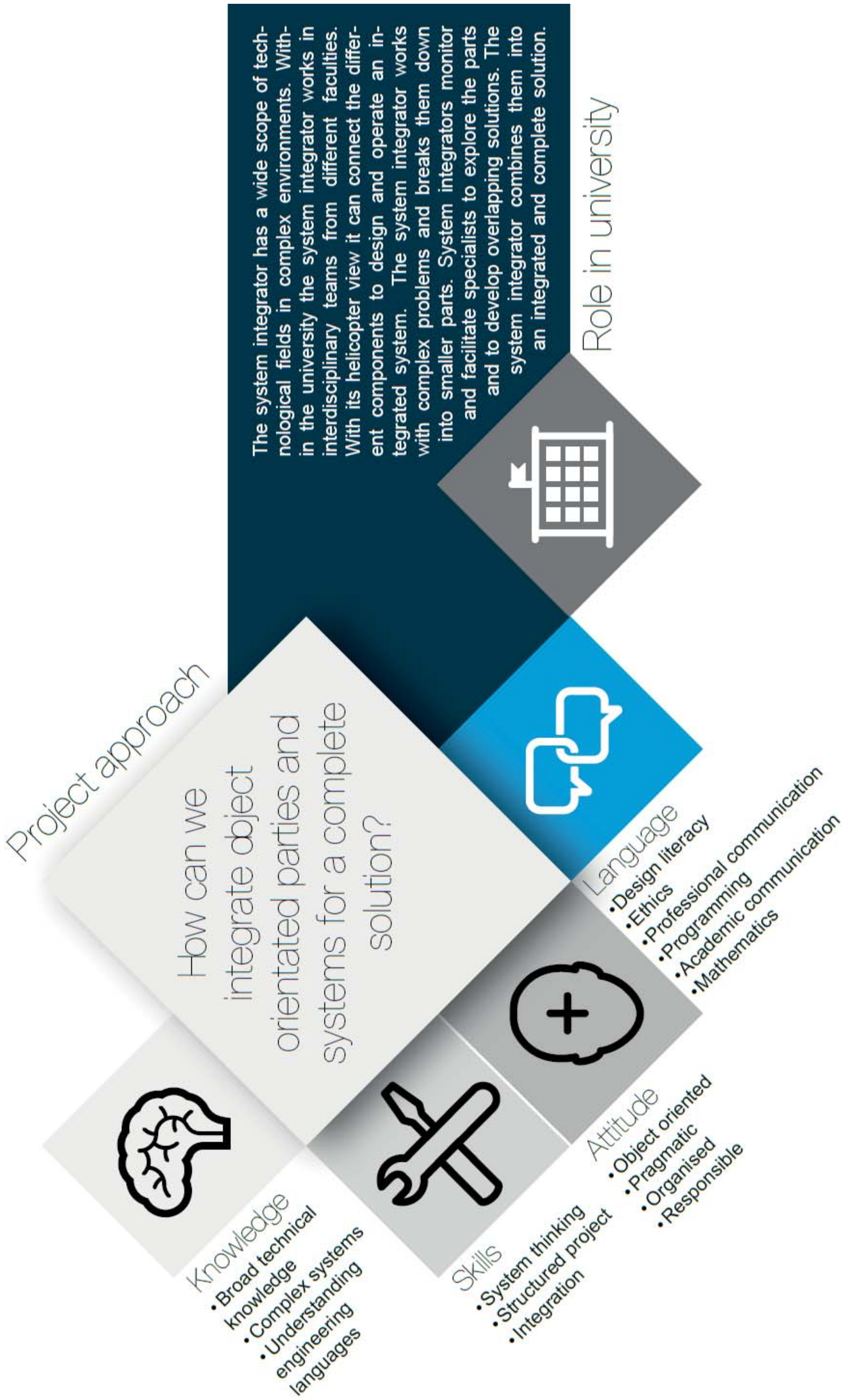
Goals and believes

My goal is to develop complete and integrated solutions that meet the needs of the customer. I like to work efficient and with fewer errors for a proper implementation.

Pain and frustration

I think it is very frustrating if the specialists in my team cannot think systematically and not see their project in its entirety. If they cannot look beyond their horizon it is hard to create a solid and reliable integrated system.

TUDelft



The system integrator has a wide scope of technological fields in complex environments. Within the university the system integrator works in interdisciplinary teams from different faculties. With its helicopter view it can connect the different components to design and operate an integrated system. The system integrator works with complex problems and breaks them down into smaller parts. System integrators monitor and facilitate specialists to explore the parts and to develop overlapping solutions. The system integrator combines them into an integrated and complete solution.
Role in university
Project approach
How can we integrate object orientated parties and systems for a complete solution?
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Object oriented
•Pragmatic
•Organised
•Responsible
Skills
•System thinking
•Structured project
•Integration
Knowledge
•Broad technical knowledge
•Complex systems
•Understanding engineering languages

Front-end innovator

Role in field of work

The front end innovator works in different industries because their methods can be implemented in various complex problems. They focus on trends in engineering, society and industry to meet the market needs and even create new markets. The front end innovator develops concepts within transdisciplinary teams using user insights or co-creation to increase the chance of acceptance. Companies employ front end innovators as designers and entrepreneurs in open-innovation labs or start-ups to generate more innovations for the company.

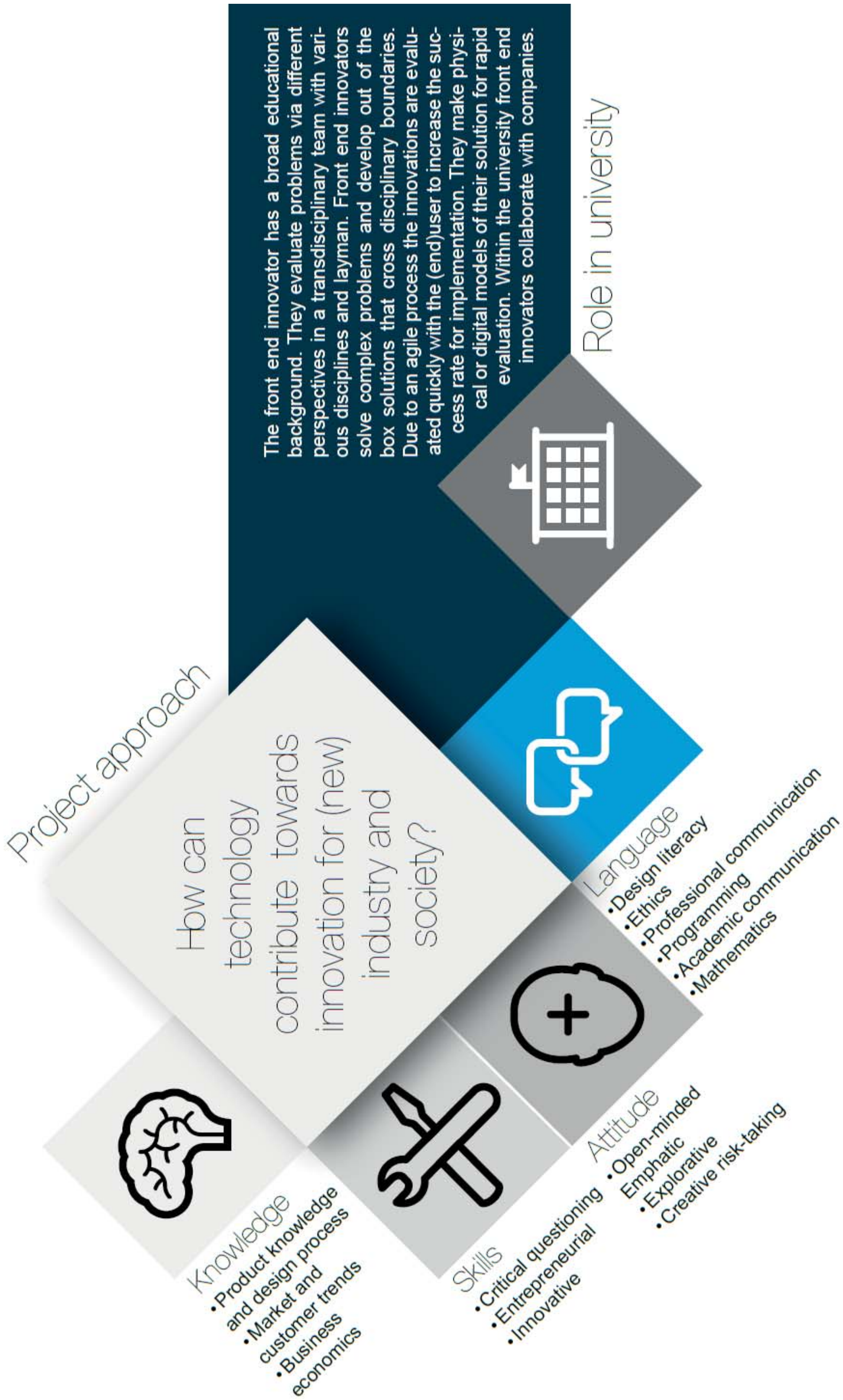
Goals and believes

My goal is to develop new solutions that meet the demands of the complex changing world. I believe that user-insights, rapid prototyping and open labs can help make the innovations become successful in performance and time.

Pain and frustration

Intellectual property rights slow down my innovation process. On the contrary, without intellectual properties I think it is hard to make fast choices due to the rapid innovation of competitors.

TU Delft


The front end innovator has a broad educational background. They evaluate problems via different perspectives in a transdisciplinary team with various disciplines and layman. Front end innovators solve complex problems and develop out of the box solutions that cross disciplinary boundaries. Due to an agile process the innovations are evaluated quickly with the (end)user to increase the success rate for implementation. They make physical or digital models of their solution for rapid evaluation. Within the university front end innovators collaborate with companies.
Role in university
Project approach
How can technology contribute towards innovation for (new) industry and society?
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Open-minded
Emphatic
•Explorative
•Creative risk-taking
Skills
•Critical questioning
•Entrepreneurial
•Innovative
Knowledge
•Product knowledge and design process
•Market and customer trends
•Business economics

Contextual engineer

Role in field of work

The contextual engineer easily communicates and solves contextual problems with foreign and diverse colleagues. They develop solutions that are acceptable within the different realms of culture and environment. The contextual engineer is prepared to travel and explore international opportunities for the company. Being aware of the cultural, ethical and political elements they assure a successful implementation. They are also able to translate and adapt the company's current solutions for other environments and cultures that have similar problems.

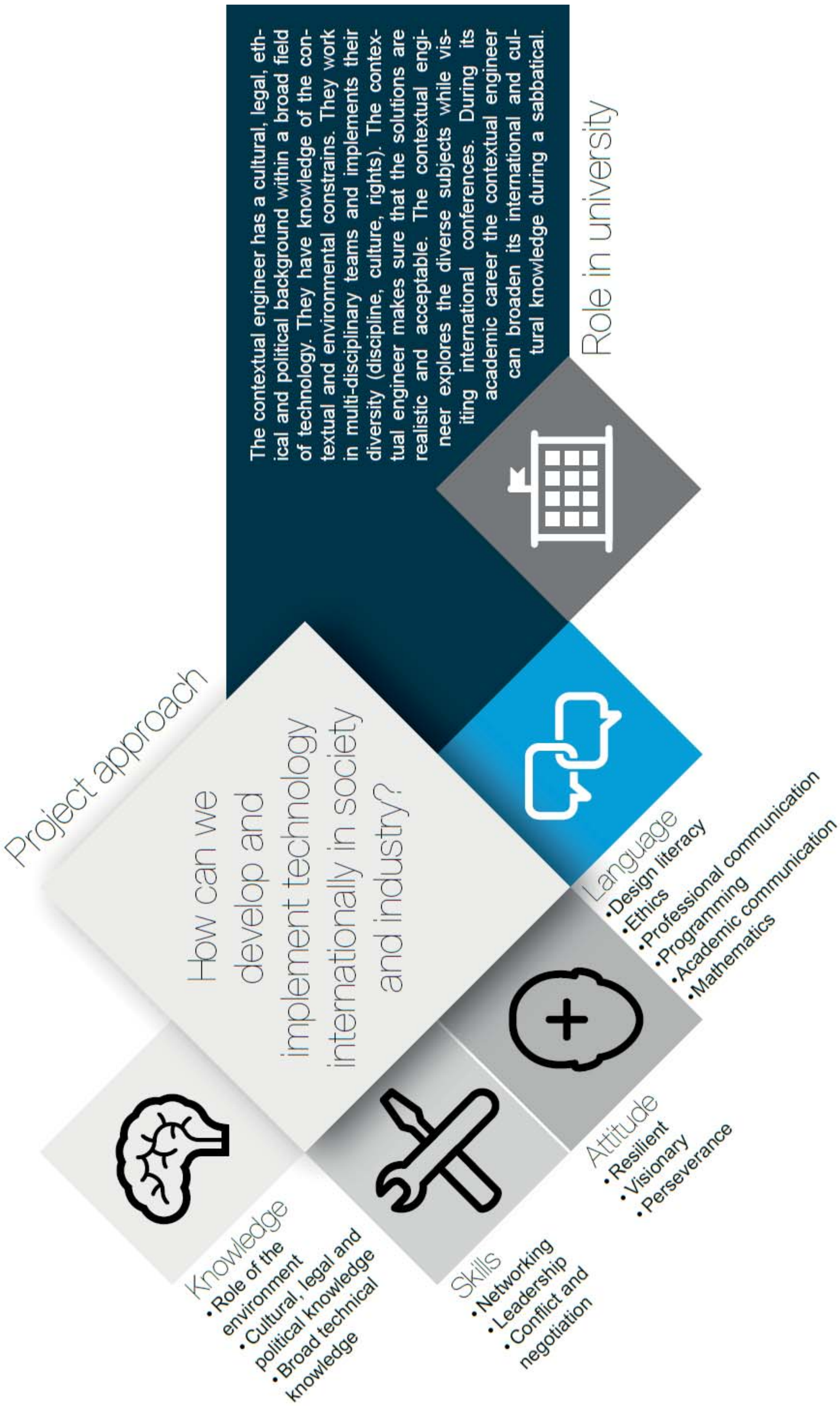
Goals and believes

It is my goal to make borders disappear and come to a whole solution that is in line with the context. I believe that the durability of innovations can be extended when the contextual constrains are taken into account.

Pain and frustration

International differences in values, norms, beliefs and regulations limits extending the international success of the solution. This requires a lot of perseverance and maneuvering from me.

TUDelft


Project approach
How can we develop and implement technology internationally in society and industry?
Role in university
The contextual engineer has a cultural, legal, ethical and political background within a broad field of technology. They have knowledge of the contextual and environmental constrains. They work in multi-disciplinary teams and implements their diversity (discipline, culture, rights). The contextual engineer makes sure that the solutions are realistic and acceptable. The contextual engineer explores the diverse subjects while visiting international conferences. During its academic career the contextual engineer can broaden its international and cultural knowledge during a sabbatical.
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Resilient
•Visionary
•Perseverance
Skills
•Networking
•Leadership
•Conflict and negotiation
Knowledge
•Role of the environment
•Cultural, legal and political knowledge
•Broad technical knowledge

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