CHALLENGES FOR TEACHING AND LEARNING ACTIVITIES (TLA) AT ENGINEERING EDUCATION

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Abstract

In the knowledge-based society, the legacy education system does not provide the needed skills for creative engineers especially enhancing student innovation and entrepreneurship capacity. Triple-helix model is a concept that aims to bond universities, industry and government in a bid to create innovations. In Europe, integrating research, education, and innovation together in a comprehensive manner has been the major driving force for local and European university development, as example in the form of European Institute innovation Technology (EIT). At KTH, there are activities that alien the Teaching and Learning Activities (TLA) with different task group with the aim of creating a mutual innovation capacity to contribute solutions for major social challenges. Some of these task groups are Cross-Cultural Faculty Development for Challenge Driven Education, Global learning and digital platform and open innovation platform for learning. The progress and the success are measured by the number of joint student teams and their skills, knowledge development with the follow-up workshop, and the ongoing research and results of the socio-oriented projects. To enhance TLA and the teaching and learning practices, we have developed new curriculums (MSc. and PhD) for our partners to spark innovation and entrepreneurship where the students interact with Open Lab activities. The assessments show that the enrolled students have gained creative skills in dealing with engineering problem and consolidate their knowledge to improve the future TLA and the Intended Learning Outcome (ILO).

Keywords: Teaching and Learning Activities, Engineering Education, Digital platform Innovation, technology, research projects,

1 INTRODUCTION

In order to overcome from the Engineering Education (EE) TLA challenges, the Engineering Education teachers must take into account what they can understand about how students learn by their choice of teaching and assessment methods. The teachers need to take in to account and considering the make-up of our student intake, rather than depending on the infrastructure or resource constraints or inflexible requirements. The EE students must be able to ‘learn how to learn’ and the teachers need to have skills and commitment to support students. To facilitate the higher education teaching-learning process, teachers have to come up with methods and teaching techniques. The teacher’s knowledge on the relationship between teaching-learning should be complete and this gains the students and the teachers’ attitudes and actions with a positive outcome that will usually be helpful in enabling learning to happen. Student learning in EE depends largely on teacher's motivation and continues assessment of the learning outcome.

On the other hand, teachers or Instructors should always make sure the students have got the learning and teaching activities to meet with the ILO by following the assessment methods to correspond according to the ILO [1].

1.1 Innovation in the context of engineering education

The word innovation was coined in the early 20th century but the literature on innovation ecosystems dates from early 2000s. The ‘Triple Helix model’ by Etkowitz [2] was introduced the year 2003 and it represents a triangle, in which university, industry and government interact in order to achieve innovations. Different from [2] in [3], the model presented below, the university's role is seen as the educator not as a research institution. Following [2], [4] defined 'Embedded Innovation' as a process that builds upon 'Open innovation' introduced by [2]. Also known as "Quadruple Helix model", embedded innovation adds a fourth helix to the Triple helix. The fourth helix stands for the civil society in terms of co-creators, consumers, NGO´s, and citizens at large. This is seen to comprise an even more holistic innovation ecosystem framework [4] and has been the one of the guidelines for the EIT [5].

Figure 1 presents the innovation hierarchy in education based on [3]. Higher education policies are built on local, national and international level and on high-level and long-term bases. High-level policies translate into to university-, programme- and teaching team level development goals. Based on [6][, work this takes typically 5 to 15 years. The ultimate goal in the whole process is the students' learning.

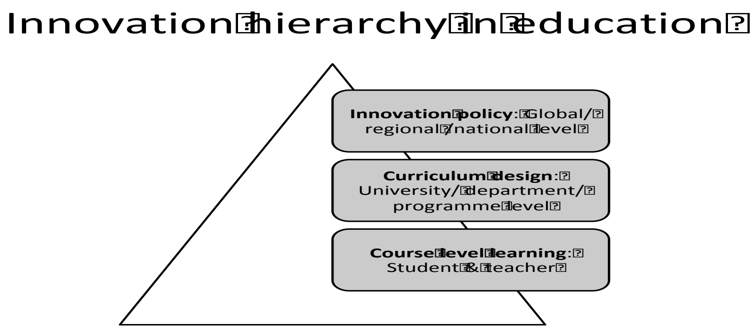

Figure 1. The innovation hierarchy in higher education modified from [3].

In the figure the top of the pyramid presents the innovation policy level that leads to university and programme level and finally to the course level. The successful alignment of the process sets a path for educational innovations and most importantly, it is seen to increase innovation abilities of the students [3].

1.2 Challenge Driven Education in the context of engineering education

One of the possible learning approaches to achieve the above mentioned innovation goals is challenge-driven education (CDE) [7], which is aimed to strengthen transferable working life skills such as co-creation, critical thinking, communication, team work and problem solving skills [4], [8]. The rationale for focusing on these skills is the fact that engineering challenges both in the industry and in the societies are becoming more and more complex. Basic and natural sciences based engineering skills are still the foundation for engineering problem solving yet not enough. CDE is based on iterative learning cycles with the focus on the challenges of the global society [7]. Conceptual understanding sets the basis for CDE approach. The ability to improve knowledge base, skills and competencies is achieved through a process where students are working in a co-creative set-up and solving real-life, open-ended problems.

At KTH, there are courses that is given within the framework of Open Lab, a learning domain allowing students and teachers Karolinska Institute, KTH Royal Institute of Technology, Stockholm University and Sodertorn's University work with department and employer from The City of Stockholm, Stockholm County Council and The Stockholm County Administrative Board.

The rest of the paper is organized as follows. In Section 2, we discuss related work. Section 3 describes the case study used to improve the Engineering Education TLA and Section 4, indicates the assessment results and Section 5 describes the conclusions.

2 RELATED WORK

The rapid advances in technology coupled with increasing competitions in high-tech industry are believed to be the main forces to change the engineering education in the 21st century. As pointed out in [9] engineering education has undergone the following five giant steps: (1) analytic approach and mathematical modeling, (2) outcome based-accreditation, (3) design-oriented education, (4) learning-outcomes and student engagements, and (5) technology-based education [10].

CDIO (conceive-design-implement-operate) is an active innovative education framework that started in 2000 [11]. The three major goals of the CDIO are to produce engineers with the following skills (1) master the fundamentals of engineering (2) conceive and operate innovative products, services, systems, etc., and (3) be conscious of the socio-economic impact of the technology [11].

Challenge-driven education, CDE, is a project based course in which students are confronted to solve engineering problems in an authenticate project [12]. The design of the course project undergoes the following steps: firstly, the project task has to be identified, secondly, teams have to be built, and finally, the assessments of the project have to be detailed. Challenge driven education has been assessed in a three-day workshop at the University of Dar es Salaam [13]. Physical co-location, open science and challenge driven education have been used to create new training approach [14]. Challenge driven education in low-income countries has been adopted as a way to foster innovation and technology transfer between industry and academia [15].

Living lab is a concept pioneered at MIT by Professor Bill Mitchel. The chief idea behind living lab is the enrolment of users, citizens, and consumer in the innovation process. Living lab has been well applied in teaching ICT as well as basic engineering education. In the context smart city, living labs, as an open innovation ecosystem, have been promoted by the IEEE smart city initiative. The European Union has created a platform, European Network of Living Labs or ENoLL for short, with the aim to facilitate the establishment and experiments of a new business model using quadruple helix model. Figure 2 shows the essential elements of a living lab [16].

Figure 2: Essential elements in a living lab

3 CASE STUDY BASED ON ENGINEERING EDUCATION

EE concept is related to the design and successful result evaluated by outcome the research and findings that can be used for the society development through the path of academic work [17]. Students Learning in EE consist of interactions between individuals and interactions between individuals and the materials that being studied. It includes teaching in theory and teaching professionals through research to further or extend discipline consideration for the use of the society through stakeholders [17]. The education book [18] listed some key points to promote EE TLA, including how a positive learning environment can improve the student’s motivation and engagement during the TLA. One of the key concept for EE is to set up the working procedure with preconceptions and a cognitive conflict leads after discussions to clear and carefully chosen outcomes. EE is largely based on the constructive alignment involves the TLA to students to achieve the learning outcomes. It is important that each teacher decides what wants to achieve, to have a firm foundation of choices, and able to explain the students and other interested parties in order to align the ILO with the TLA.

Many suggestions of how the EE TLA can be developed were provided in [18] such as the important of team assignment and project to cultivate team working skills. Active learning system, peer assessments are also part of the TLA of EE. Different projects have been implemented and others are still ongoing for the purpose of solving engineering challenges and hence provide education to the society.

KTH is committed to contribute to the solution for societal challenges through its education, research and cooperation, as underlined in the KTH vision 2027 [7] via different projects to promote the Engineering education according the CDIO principle. The Mutual Innovation Capacity (MIC). Challenge Driven Education for Global impact is one of a project which started in 2016 with initial plan to end 2019 is a mutual Engineering education program between KTH and university of Dar es Salaam. MIC project is supported by STINT (The Swedish Foundation for International Cooperation in Research and Higher

Education). This financial support helps to use the challenge driven project courses in Dar es Salaam and both university students have become beneficial. A jointly established STINT project work group leaders are working on the challenge driven Education Methodology [7] to overcome the problems associated on the Engineering Education teaching and learning activities challenges through MIC [16] concepts. In order to discuss and solve the challenges associated with EE and CDE, several workshops were done as described [7] and summarized below.

The first CDE workshop was held on 18th October, 2016 in Kijitonyma, CoICT, Dar es Salaam. The workshop focused on brainstorming on how to engage with CDE. Students, Instructors and Stakeholders from TANESCO are the key source in this workshop who make a number of 26 participants. The main task was to elaborate the approach and the process on how to involve in CDE design approach, what kind of the problems to solve, how the course will be conducted, number of students groups and the meetings to conduct in a regular based.

The second workshop was held on 7th January, 2017 and the workshop intended to focus on discussions regarding problems to be solved. It included stakeholders from Ministry of Energy and Minerals (MEM), TANESCO, tutors and students who made the 33 participants. The core objective was to link academia and industry towards solving problems for the benefits of the society specifically in energy sectors and hence linking academia and industry toward solving problems for the benefit of the society. After the workshop, the students were supposed to go and visit the TANESCO (Tanzania Electric Supply and Company) and come up with crucial problems both in user sides and distribution sides.

The third workshop was held on 18th February, 2017 and it involved 44 participants. The Workshop involves PhD and MSc students, Instructors and stakeholders from TANESCO and KTH members to explore the problems facing the electric sector. The results of this workshop aimed at shortlisting the problems which are important and that will be solved by the students after they have visited the distribution section at TANESCO. The idea/approach on solving the problem were also addressed, for both PhD and MSc students, each having its own component towards accomplishing the large project (challenge).

The fourth workshop was held on 13th May, 2017 and concerning on the following up activities and work done by students. Each students got 15 minutes time to present and explain his/her progress towards its work and how he/she is expecting to finish it. The comments were also presented from stakeholders and other members from the meeting. In this case the final results were expected based on the comments adhered in this meeting. Later, the final workshop was held and students presented goo results and output obtained in their projects as well as the feedback on the CDE course approach.

The fifth meeting was held in Sweden in 21-25th August, 2017. The workshop involved the following aspects: (i) CDE approach, (ii) Project methodology-Design thinking, impact management and assessment, (iii) Sustainable Development Goals (SDG), (iv) The goal was to apply tools for the EE challenge-driven project courses and output was developing challenge-driven project courses for SDG.

4 RESULT

During the workshops arranged by the MIC (STINT) projects assessment of the project was addressed by interviewing the participants and a survey is distributed and the following result have been achieved on the outcome of the EE using CDE:

The participants were able to experience the CDE methodology and learn its differences from the traditional learning methodology. One area of comparison was in the learning outcome. CDE focuses on developing general problem solving skills for students by tackling real world problems. In the traditional method, students are fed facts and knowledge, which they are expected to remember. There is little emphasis in the application of knowledge. After going through the CDE process, participants in general felt their skills and knowledge has improved significantly compared to the traditional method.

The interaction between stakeholders, teachers and students has increased. It was observed that students became more interested in the projects and communicate more with their teachers. They asked them more questions and looked for clarifications on confusing issues. In the process of finding solutions for the challenges, they also approached related stakeholders in order to find out the current state of the art solutions. On the other hand, stakeholders also became more involved because the challenges being solved were relevant to their day-to-day activities.

The development of curriculum for PhD and MSc students at UDSM was also involve the CDE methodology and EE project, iGrid which focused on improving the Electricity supply reliability in

Tanzania is one of the challenge for students in regards of controlling and monitoring the home electric usages to reduce the overall electric consumption in Tanzania. The iGrid project is still on going and the more information is available at [19].

Moreover, another approach of EE can be addressed in the form of Open access platform. An example was on Sci-GaIA project [20], whereby the iGrid and TTA (Technology Transfer Alliance) teams were able to successfully implement science gateways for their respective projects. Using the CDE approach, the teams were tasked with finding technical solutions for facilitating coordination and collaboration of research activities. With the collaboration of industry stakeholders and experts, the teams were able to implement two custom science gateways that are being used up to this day.

5 CONCLUSIONS

This work-in-progress study looked into the partly local and partly multicultural educational innovations created in collaboration with the faculty and students of both northern European (Sweden) and East African (Tanzania) universities. The theory part elaborated how learning and teaching development is approached in the Swedish university with the intent of facilitating industrial innovation through university, industry and governmental collaboration. This model was seen to possibly catalyse also the innovation activities in the Tanzanian university when integrated into the curriculum with cultural awareness.

The results show that the participating faculty on the EE where able to make out the difference between CDE and the traditional learning methodology and that their perceived teaching ability was enhanced compared to the traditional method. In addition, the interaction between students and the faculty was increased and this was seen as a positive signal from both parties. However, the alignment of the courses within the curriculum needs more attention and planning since the courses added extra weight on already busy students and faculty.

As described in the beginning this is a work-in-progress study showing only preliminary results from the collaboration and co-creation. Future research will focus on both broadening and deepening the data set through new workshops and courses. In addition to the existing focus groups such as students, faculty and faculty management also the industry and entrepreneurial stakeholders will be added to the research data set.

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6 REFERENCES

[1] V. Taajamaa, A.-M. Majanoja, A.Bagiati, X.Guo and V. Leppänen, " University Education as a Pathway to Innovation: Perspective on Building Students Innovation Capabilities in Sino-European Education Set-up," *Journal of European Higher Education Area,* 2017.

[2] H. Etzkowitz, "Innovation in Innovation: The Triple Helix of University-Industry-Government Relations," *Social Science Information,* vol. 42, no. 3, 2003.

[3] A. Bagiati, X. Guo, V. Leppänen, A.-M. Majanoja and V. Taajamaa, "University Education as a Pathway to Innovation: Perspective on Building Students Innovation Capabilities in Sino-European Education Set-up," *Journal of European Higher Education Area,* 2017.

[4] J. Hafkesbrink and M. Schroll, "Innovation 3.0: embedding into community knowledge - collaborative organizational learning beyond open innovation," *Journal of Innovation Economics & Management,* no. 7, pp. 55 - 92, 2011.

[5] EU, "European Institute of Innovation & Technology," [Online]. Available: https://eit.europa.eu/. [Accessed 16 1 2018].

[6] S. Graham, D. McKeown, S. Kiuhara and K. R. Harris, "A Meta-Analysis of Writing Instruction for Students in the Elementary Grades," *Journal of Educational Psychology,* vol. 104, no. 4, pp. 879-896 , 2012.

[7] M. Magnell and A.-K. Högfeldt, *Guide to Challenge Driven Education,* Stockholm: Editabobergs, 2014.

[8] B. A. Karanian, M. Eskandari, A. Aggarwal, F. Pincheira, R. Rose, R. R. Krauthamer and G. Kress, "Open Process for Entrepreneuring Team Collaboration: Story Parallels from an Academic Design," in *American Society for Engineering Education*, 2012.

[9] J. E. Froyd, "Five Major Shifts in 100 Years of Engineering Education," *Proceedings of the IEEE,* vol. 100, no. Special Centennial , pp. 1344-1360, 2012.

[10] V. Taajamaa, "O-CDIO, Engineering education framework with embedded design thinking methods," TUCS, Turku, Finland, 2017.

[11] Worldwide CDIO initiative, "http://www.cdio.org/," CHALMERS UNIVERSITY OF TECHNOLOGY. [Online].

[12] E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur and K. Edström, Rethinking Engineering Education: The CDIO Approach, 2nd edition, Springer, 2014.

[13] V. Taajamaa, D. Rwegasira, A. Kelati, A. Kondoro, N. Mvungi, H. Tenhunen, I. B. Dhaou and S. Naiman, "Challenge driven education in the context of Internet of Things," in *International Conference on Education and New Learning Technologies*, Barcelona, Spain, 2017.

[14] A. Kondoro, D. Rwegasira, I. B. Dhaou, A. Kelati, S. Naiman, H. Tenhunen, N. Mvungi and V. Taajamaa, "Training the future ICT innovators on open science platform," in *9th International Conference on Education and New Learning* , Barcelona, Spain, 2017.

[15] K. Ibwe, E. Kalinga, N. Mvungi, A. Kelati, H. Tenhunen and I. B. Dhaou, "The role of challenge driven learning in activating industry-academia cooperation in low-income countries," in *10th International Conference of Education, Research and Innovation*, Seville, Spain, 2017.

[16] EU Open Living Labs, "Open Living Labs," [Online]. Available: http://www.openlivinglabs.eu/. [Accessed 15 01 2018].

[17] K. Edström, "Exploring the dual nature of engineering education: Opportunities and challenges in integrating the academic and professional aspects in the curriculum," KTH Royal Institute of Technology, Stockholm, Sweden, 2017.

[18] M. Elmgren and A.-S. Henriksson, Academic Teaching, Studentlitteratur AB, 2014.

[19] KTH, "IGRID project," KTH, [Online]. Available: http://igrid.proj.kth.se/. [Accessed 16 1 2018].

[20] EU, "Energising Scientific Endeavour through Science Gateways and e-Infrastructures in Africa," EU, [Online]. Available: http://www.sci-gaia.eu. [Accessed 16 1 2018].