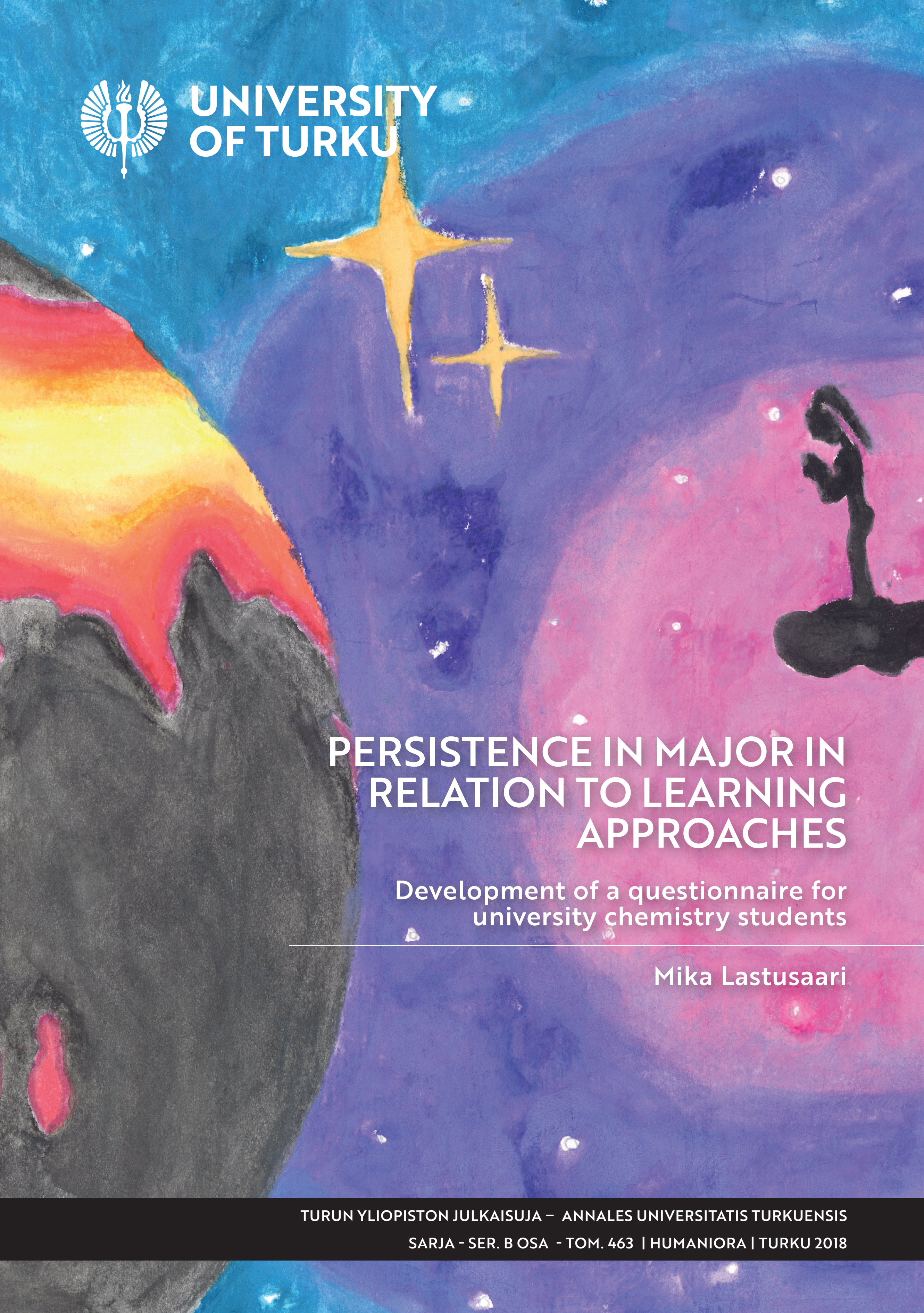

UNIVERSITY OF TURKU

PERSISTENCE IN MAJOR IN RELATION TO LEARNING APPROACHES

Development of a questionnaire for university chemistry students

Mika Lastusaari

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
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LASTUSAARI, MIKA: Persistence in major in relation to learning approaches – Development of a questionnaire for university chemistry students

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ABSTRACT

Increasing persistence in university level studies is a major concern worldwide. For example, in the United States an average of 70 % of students drop out from university studies, whereas in Europe the average drop-out rate is ca. 40 %. In Finland, university level chemistry education shows also a drop-out rate of ca. 40 %, and a half of this number consists of students who change their major subject. The major changers thus constitute an important part of the Finnish drop-out student population. With such high drop-out rates, it is of utmost importance to find ways for the early identification of students at risk of dropping completely or changing their major. The ultimate aim of this dissertation was to develop an instrument that could be used for the prediction of students at risk. This instrument, the ChemApproach questionnaire, was designed in such a way that it probes the learning approach features of chemistry students. As an additional feature in comparison with traditional learning approach instruments, ChemApproach also takes into account approaches to laboratory work. The results obtained during this thesis work indicate that the degree of the presence of certain learning approach features, namely the submissive surface and the practical deep approach features, strongly predict the students' persistence, drop-out and change of major subject. It was confirmed that these features even override the initial intention of wanting to change major subject. The high impact of the practical deep approach highlights the high importance laboratory work in persistence and it serves as an indication of the good functionality of the ChemApproach questionnaire. As a consequence of the present thesis work, it was possible to propose institutional and teaching practices that can be used to decrease the level of the submissive surface approach and increase the level of the practical deep approach and thus increase persistence in chemistry studies.

Keywords: Learning approach; higher education; chemistry education; chemistry learning; science learning; persistence; student retention; drop-out; major changing

TURUN YLIOPISTO
Opettajankoulutuslaitos, Turku

LASTUSAARI, MIKA: Pääaineessa pysyminen ja lähestymistavat oppimiseen – Kyselylomakkeen kehitys kemian yliopisto-opiskelijoita varten

Väitöskirja, 95 s.
Kasvatustiede
Lokakuu 2018

TIIVISTELMÄ

Yliopistotason opintojen keskeyttäminen on maailmanlaajuinen huolenaihe. Esimerkiksi Yhdysvalloissa keskimäärin 70 % opiskelijoista keskeyttää yliopisto-opinnot ja Euroopassa näin käy keskimäärin 40 prosentille. Suomessa yliopistotason kemian opetuksen keskeyttäneiden osuus on myös luokkaa 40 % ja puolet tästä määrästä aiheutuu siitä, että opiskelijat vaihtavat pääainettaan. Pääaineen vaihtajien määrä on siis Suomen kemianopetuksen kannalta merkittävän suuri. Koska opintojen keskeyttäjien määrä on suuri, on tärkeää löytää välineitä, joilla voidaan tunnistaa keskeyttämis- ja vaihtamisvaarassa olevat opiskelijat mahdollisimman ajoissa. Tämän väitöskirjatyön päätavoite olikin kehittää työkalu, jonka avulla voitaisiin tunnistaa juuri nämä keskeyttämis- ja vaihtamisvaarassa olevat opiskelijat. Työssä kehitetty työkalu, ChemApproach-kyselykaavake, lähestyy asiaa opiskelijoiden oppimisen lähestymistapojen kautta. Perinteisiin lähestymistapaa kartoittaviin kaavakkeisiin nähden ChemApproach sisältää lisäksi osion, joka ottaa huomioon laboratoriotyöskentelyssä oppimisen. Tässä työssä saadut tulokset osoittavat selvästi, että tiettyjen lähestymistapojen piirteiden voimakkuus on vahvasti kytköksissä opintojen keskeyttämiseen ja pääaineen vaihtamiseen. Nämä piirteet, alistuvan pintaoppimsen ja käytännöllisen syväoppimisen piirteet, osoittautuivat merkittävämmiksi kuin opiskelijan ilmoittama halu vaihtaa pääainetta. Käytännöllisen syväsuuntautumisen merkityksen suuruus osoittaa laboratoriotyöskentelyn suuren merkityksen kemian oppimisessa, ja se myös osoittaa että ChemApproach on hyvin toimiva kemian opiskelijoiden tutkimuksessa. Tämän työn tuloksien ansiosta voitiin ehdottaa institutionaalisia sekä opetuksellisia käytänteitä, joiden avulla voitaisiin saada alistuneen pintasuuntautumisen määrää vähennettyä ja käytännöllisen syväoppimisen määrää lisättyä. Näiden käytänteiden avulla voidaan mahdollisesti lisätä kemian opintojaan jatkavien määrää.

Asiasanat: Lähestymistapa oppimiseen; korkeakoulutus; kemian opetus; kemian oppiminen; tieteen oppiminen; opinnoissa pysyminen; opintojen keskeyttäminen; pääaineen vaihtaminen

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This thesis work has been a very interesting expedition starting from laying down a questionnaire with questions whose answers could give interesting information for myself as a teacher of chemistry at university. With time, the questionnaire would develop to a validated instrument that can give much more broadly usable information for chemistry educators. Along the way, the process of developing the questionnaire transformed into a PhD thesis work. Who would have believed…

There are a great number of people, who have contributed to the outcome of this work.

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Turku, October 10th 2018,

Mika Lastusaari

LIST OF ORIGINAL PUBLICATIONS INCLUDED IN THE THESIS

Study I

Lastusaari, M. and Murtonen, M. (2013) 'University chemistry students' learning approaches and willingness to change major', *Chemistry Education Research and Practice*, 14(4), pp. 496–506.

ML devised the questionnaire, organized the data collection, collected the data, carried out preliminary analyses and wrote the first version of the manuscript. MM contributed to the study concept and design as well as the final analyses and interpretation of the data. Both authors critically revised the manuscript and approved the final version for publication.

Study II

Lastusaari, M., Laakkonen, E. and Murtonen, M. (2016) 'ChemApproach: validation of a questionnaire to assess the learning approaches of chemistry students', *Chemistry Education Research and Practice*, 17, pp. 723–730.

ML revised the questionnaire and organized the data collection. ML and MM executed the preliminary analyses and wrote the first version of the manuscript. EL carried out the final statistical analyses and the SEM calculations. All authors contributed to the study concept and design as well as interpretation of the data. All authors critically revised the manuscript and approved the final version for publication.

Study III

Lastusaari, M., Laakkonen, E. and Murtonen, M. (2018) 'Persistence in Studies in Relation to Learning Approaches and First Year Grades: A Study of University Chemistry Students in Finland', *Scandinavian Journal of Educational Research*, under review.

ML organized the data collection, carried out analyses and wrote the first version of the manuscript. EL carried out the SEM calculations. MM contributed to the study concept and design as well as interpretation of the data. All authors critically revised the manuscript and approved the final version for publication.

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1. INTRODUCTION

This work stems from my about 20 years of experience as a teacher of chemistry at university level in Finland. While many things have changed during those years, one aspect remains: a considerable amount of students who start studying chemistry, will not come back for the second year. This is typical in all universities in Finland that offer chemistry education. For example, the student magazine "Ylioppilaslehti" of the University of Helsinki (the university with the highest QS ranking in Finland) wrote in 2010 that it is essential to take about 100 % more students that can be educated, because after the first year many of the students will vanish. In fact, more than 50 % of chemistry freshmen in University of Helsinki replied "no" when asked if studying chemistry was their primary goal. Most of those students would like to be medical doctors instead (Ruuska, 2010). Since university education is free in Finland and since the admission tests to medical training require knowledge of chemistry, it has been said that departments of chemistry offer the best free training for admission to medical departments (Nykänen, 2013). For example in 2011, at University of Turku, the admission rate to the Department of Medicine was ca. 15 % for all students, whereas for students who already had been studying chemistry, physics or biochemistry at University of Turku the rate was ca. 33 % (University of Turku, 2012). This indicates that the chances of getting in would be more or less doubled by taking such a "training course".

Chemistry is not the only discipline in Finland suffering from these major changers. However, if we look at statistics between 2007 and 2015 (Table 1), it is clear that chemistry is, together with physics and mathematics, a major subject that suffers the highest major changing rate. Furthermore, these same three major subjects together with information technology have the highest drop-out rates, as well. All in all, chemistry will lose on average 36.5 % of the total 2147 students annually (Table 1), which means that every year ca. 784 students will not persist with chemistry. With such high non-persistence rate and the use as a springboard towards medicine, university chemistry education in Finland is both a unique setting and also a setting where means of increasing persistence need to be studied.

Table 1. *Averages of numbers of students and their persistence between 2007 and 2015 in Finnish universities divided to different major subjects.*

Original major	*Number of students*	*Changed major / %*	*Quit at university / %*	*Quit all studies / %*
Biology	3451.3	10.9	5.6	4.2
Chemical and Materials Technology	3010.6	10.2	5.9	4.7
Chemistry	**2146.6**	**21.2**	**9.0**	**6.3**
Dentistry	773.6	3.5	1.3	1.3
Educational Sciences and Psychology	6372.3	9.2	5.8	5.2
Geography	1014.8	6.0	4.2	3.3
Geosciences and Astronomy	725.6	9.5	6.8	5.3
History and Archaeology	2846.9	7.2	5.1	4.3
Information Technology	7388.5	15.1	12.4	10.5
Language Sciences	11340.3	10.1	7.3	6.0
Law	3980.8	3.1	2.5	2.3
Mathematics	3297.8	18.0	9.5	7.3
Medicine	4074.8	1.3	1.0	1.0
Pharmacy	1594.4	5.0	3.1	2.5
Philosophy	929.4	11.4	7.7	6.9
Physics	2277.9	20.8	9.8	7.1
Political Sciences	2772.6	8.9	6.4	5.9
Social Sciences	5357.5	8.1	6.2	5.5
Teacher Education	7746.8	6.0	4.6	4.0
Theology	2403.8	7.0	5.4	4.7
Veterinary Medicine	433.9	1.3	1.1	1.1

Albeit students willing to become medical doctors have a high benefit from utilizing chemistry or physics teaching to reach their goal, there are also losers in that equation. Generally speaking, universities are highly interested in increasing persistence in studies, since the teaching resources directed towards students who do not persist may be considered as wasted money. Finnish universities get funding from the government according to their performance, and one affecting criterion is the number of graduated students. The money coming from the government is distributed inside the university to its faculties and on the faculty level to their departments. Also this is done by taking into account the performance criteria of each unit. Thus, the annual number of graduated students has a very direct influence on the money available for a given department in a given faculty at a given university. Therefore, considering the case of chemistry departments in Finland, already small increases of persistence could help their survival. Furthermore, Ost points out that drop-outs decrease the global competitiveness of a country (Ost, 2010). It is thus obvious that institutions strive towards maximizing persistence.

Because of the factors introduced above, it is essential to find ways of recognizing students at risk of not persisting in major as well as studying which properties are connected to persistence. In the present work, it is assumed that learning approaches play a crucial role in students' persistence (Haarala-Muhonen *et al.*, 2017). The next three chapters will introduce the reader to the theoretical basis on what chemistry is like as a subject of study (chapter 1.1.), what is already known about persistence (chapter 1.2.) and what learning approaches are (chapter 1.3.).

1.1. Chemistry as a subject of study

Imagine that everything based on chemistry would be removed from the universe. What would be left then? Nothing. One can say that absolutely everything is made of chemical compounds that have been formed from chemical reactions. The air that we breathe contains chemical compounds as does the food we eat and all that we drink. The way that these affect us by giving more energy or satisfactory sensations is based on chemistry. Even what we think of as life is a series of chemical reactions and interactions. In the future, there will be an increased need of experts in chemistry: According to a report published by the Royal Society of Chemistry in 2016 (Palermo, 2016) "Chemical sciences will likely be increasingly required to solve challenges in health, energy and climate change, water and food production". Moreover, a basic knowledge of chemistry is required in many other fields (Lewis and Lewis, 2007). So, why wouldn't everyone want to study chemistry?

Regardless of the true omnipresence of chemistry and the probable demands of the future, the interest towards chemistry seems to be going down since the number of students interested in studying chemistry at the university level is decreasing in many industrial countries (Johnstone, 2000a; Chittleborough, 2014; Broman and Simon, 2015). There are two main reasons, both of which can be thought to be caused by the very nature of chemistry as a subject of study, considered to be the cause of this decline. They will be discussed below in chapters 1.1.1. and 1.1.2.

1.1.1. Relevance of chemistry

The first factor that is thought to contribute to the decline of the number of new chemistry students is the feeling of irrelevance: it seems that young people are not able to see the relevance of chemistry, i.e. they fail to grasp the connection of chemistry taught in school and everyday life, or they do not feel that knowledge of chemistry is something that they would need in the modern society (Bennett *et al.*, 2005; Bulte *et al.*, 2006; Murtonen *et al.*, 2008; Broman *et al.*, 2011; Stuckey *et al.*, 2013; Chittleborough, 2014). One aspect of this may be that it is not clear what chemistry includes. For example, things such as atoms and molecules may not appear to be interesting, whereas health and diseases are very much so (Broman *et al.*, 2011). The latter two, of course, rely very much on chemistry. Chemistry may also seem an undesired subject of study, because it is thought as the origin of bad things such as global warming and depletion of ozone (Sjøberg and Schreiner, 2005).

Yet another uninspiring factor is that the students may possess negative prototypical images of chemists' work or the chemists as workers (Hannover and Kessels, 2004). One example is that if a student perceives himself as not being logical, meticulous or intelligent enough, he will not want to pursue a career in science (McPherson, Park and Ito, 2018). In addition, the stereotypical image of a scientist, i.e. a lab-coated man with a beard and spectacles alone in a laboratory with a multitude of beakers everywhere, seems to persist from childhood to past high-school (McPherson, Park and Ito, 2018). There seems to be quite a lot of power in this stereotype, because it is very typical that women are less interested in becoming scientists than men (Sjøberg and Schreiner, 2005; Buschor *et al.*, 2014; Händel *et al.*, 2014). Furthermore, this stereotypy may extend even to looks: women who do not look like a scientist, i.e. seem to be too feminine, are considered less likely to be scientists (Banchefsky *et al.*, 2016). However, regardless of the many reports on the effects or possible effects of negative prototypical images, there are also reports that indicate that there is little connection between such images and actual study subject choices (Andersen, Krogh and Lykkegaard, 2014).

As is apparent from the discussion above, this lack of interest for studying is not affecting only chemistry but also other areas of science and technology. It seems, however, that the degree of interest is in a strong relationship with the Human Development Index of a country. That is, even if young people in e.g. Africa, Asia and Europe seem to have a positive view of science and technology, only in the developing counties becoming a scientist is considered desirable (Sjøberg and Schreiner, 2005). This may be linked to the fact that the developing countries strive towards growth that can be achieved only with the help of science and technology, whereas the developed countries are already well past that point. Thus, it seems that in the developed countries, more attention must be paid to make the relevance of chemistry apparent for the students (Hofstein, Eilks and Bybee, 2011; Stuckey *et al.*, 2013)

1.1.2. Multi-faceted nature – the difficulty of chemistry

The second key reason for the decrease of the number of people interested in studying chemistry is that chemistry seems to be too difficult to learn. (Bennett *et al.*, 2005; Bulte *et al.*, 2006; Broman *et al.*, 2011; Chittleborough, 2014). Imagine that you have a glass of water and a spoon full of sugar. If you pour that sugar into the water and stir for a while, the sugar disappears. Maybe it is because the water is so wet that it makes the sugar disappear? If you then pour a spoonful of white sand to the water, it does not disappear no matter how long you wait. The spoon does not disappear, either, or the glass around the water. Maybe it is because those are quite hard materials while sugar isn't? If you then put some soft daisy petals to the glass of water, they will not disappear. How can one understand these observations, when it seems like there is no connection between the tangible features of the materials and how they behave? It is problems like this that make learning chemistry difficult. Clearly, chemistry is more than meets the eye.

In 1986, Andersson defined chemistry as having the macroscopic and atomic worlds (Andersson, 1986). After that, other researchers like Gabel et al. (1987) and Johnstone (1991) proposed models with three components, where they had added a third dimension, a symbolic one. This is needed in order to be able to describe why different substances have different chemical behaviors as well as to describe these behaviors. The model of Johnstone (1991, 2000a), i.e. "the chemistry triangle", seems to have gained the widest attention. In that model, the corners of the chemistry triangle (Figure 1) are the following:

1) macro,

2) submicro and

3) representational.

Macro is the level that can be seen as well as touched, i.e. this is the level that people are used to in their daily life. However, to be able gain full understanding of chemistry, it must be described with regard to the unseen. That unseen is the atomic, submicro, level. Finally, the submicro level needs to be recorded in a representational system, *e.g.* symbols, formulas and graphs. All these three levels are complementary to each another with no one of them being superior (Johnstone, 2000b). This model contains the idea that while the representational level is not real (it is just a representation of reality) both the macro and submicro levels are real, even if the latter cannot really be observed. The reality of submicro level may be difficult to believe, because there are no direct ways of visualizing any smaller units than atoms, and even for the visualization of atoms microscopes with high enough resolution (also called nanoscopes) are very expensive and thus scarce. For example, there is only one of them in Finland. Furthermore, even if it is possible to visualize atoms with such microscopes, it is not really possible to identify which elements are in question. Because of such lack of direct evidence of the events taking place in the submicro level, one has to rely on theories, and it is nearly always so that the explanations of chemical events are in this theoretical part of the submicro level (Chittleborough, 2014).

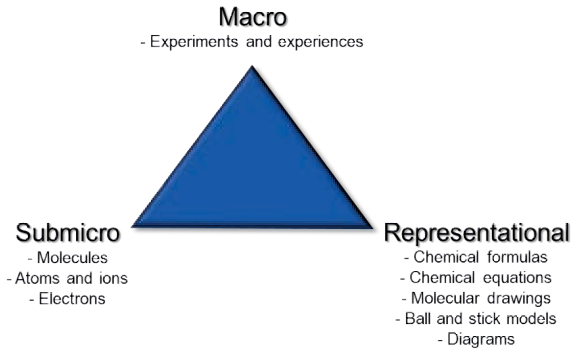

Figure 1. *The chemistry triangle (redrawn from Johnstone, 2000a; Chittleborough, 2014).*

The three-faceted nature of chemistry itself does not make chemistry difficult, but the feeling of difficulty may be caused by factors such as high level of unfamiliarity, abstractness and complexity (Murtonen and Lehtinen, in press). It is thus evident that when chemistry is taught, including all three levels simultaneously will cause problems for the students (Johnstone, 2000a). This is because it will cause a high cognitive load, i.e. overburdening of working memory while doing a cognitive task (Van Merriënboer and Sweller, 2005; Johnstone, 2006). This triangle model describes rather well the learning of chemistry, but because of human factors (such as cognitive load) that are very important when chemistry is taught Mahaffy has proposed the addition the human element as a fourth dimension to the chemistry triangle thus making it a tetrahedron model for chemistry education (Mahaffy, 2004).

1.2. Persistence, retention and drop-out

In a broad definition, persistence means that a student, after enrolment, continues studies until completing a degree. This can proceed through three different pathways: 1) a student is enrolled to a program in one university and graduates within that same program, 2) a student is enrolled to a program from which he transfers to another program in the same university and graduates, or 3) the student graduates in another university than where he started the studies (Leppel, 2001). If a student does not follow any of these points, but leaves the education system, he drops out. Retention is an institutional term used for expressing continuing studies. It is usually given as a percentage of students continuing from one enrolment period to another. Attrition is defined the opposite of retention, i.e. discontinuation of studies (Habley, Bloom and Robbins, 2012).

Persistence in studies is of high interest among universities and their faculties everywhere, because the teaching given for the dropouts may be regarded as wasted money. According to a report of the European Union for the completion rate of bachelor degrees, the overall drop-out rate in European universities is around 30 % (Vossensteyn *et al.*, 2015; Higher Education Statistics Agency (UK), 2018) (Table 2). In the United States, the average drop-out rate in bachelor studies is as high as 70 % varying between the 40 % in for-profit institutions and 80 % in public institutions (National Center for Educational Statistics (USA), 2018). In Finland, the overall drop-out rate in universities is only 5.3 % (Statistics Finland, 2018), but for chemistry education it is around 20 % (see Table 1). A general feature of dropping out is that about 50 % of it takes place during or just after the first study year (Willcoxson, Cotter and Joy, 2011).

Table 2. *Bachelor degree completion rates for true cohorts in some European countries (Vossensteyn et al., 2015; Higher Education Statistics Agency (UK), 2018).*

Country	***Completion rate / %***
Denmark	79
Germany	75.9
Belgium	64.5
France	39.4
Iceland	69.1
The Netherlands	70.9
Norway	71.5
Sweden	68
Switzerland	66
United Kingdom	80

1.2.1. Models of persistence

Before the first persistence theory proposed by Spady in 1970 (Spady, 1970), dropping out of studies was considered to be caused by the shortcomings of the students (Habley, Bloom and Robbins, 2012). Spady's theory (see e.g. Bean, 1982) more or less related dropping out to suicide: shared group values and support from friends are expected to reduce suicide rates and Spady suggested the same to be true for dropping out. After Spady, several models of persistence have been suggested. The most influential of these are considered to be those of Tinto (1975) and Bean (1980), both of which have been revised later on (e.g. Bean and Bogdan Eaton, 2002; Tinto, 2010). Other models include e.g. those of Pascarella and Terenzini (1980): "student-faculty informal contact model", Brower (1992): "life task model" and Altonji (1993): "sequential choice model" as well as that of Cabrera et al. (1992) that combines the models of Tinto and Bean. More detailed information on the models can be found in e.g. the reviews of Bean (1982) and Kuh et al. (2006).

The model of Tinto (2010) is the most widely used one for persistence, and that is why it is taken here as an example. As expressed in a report by Bailey and Alfonso (2005): “Tinto’s model is designed to help colleges understand why students leave, so the institutions can design activities to better serve students’ needs and thereby increase retention and graduation rates.” The model (Figure 2) was influenced by that of Spady and it takes a sociological perspective. It assumes that at university a student faces two systems, an academic and a social one, that he must integrate into (Habley, Bloom and Robbins, 2012). When entering the university, the student has his own pre-entry attributes due to his family, individual attributes and previous school experiences. The family background includes social status, values and expectations, whereas the individual attributes include race, sex and academic ability. Previous school experiences cover grade point averages as well as other academic and social merits. These together with external commitments, such as job or family commitments (Aljohani, 2016), influence the intentions, goals and commitments that a student has in the beginning of his studies. The integration to the academic system contains the academic performance, which is evaluated by the student extrinsically from the grade performance and intrinsically from intellectual development (McCubbin, 2003). The academic performance combined with the student’s interactions with the staff of the university yields the notion of how well academic integration has succeeded. At the same time, the student participates in the social system through extracurricular activities and interactions with student peers. The success in those determines the degree of social integration. These two aspects of integration felt by the student will or will not affect the intentions, goals and commitments, which are again affected by the current external commitments. Finally, the student makes his decision on whether the refined set of goals and commitments still fits with the idea of studying at the university. If the fit is good enough, the student will persist. Otherwise, he will drop-out completely from all education system or transfer to another that suits his goals and commitments better.

The model of Tinto has faced criticism mostly because it works only for a “traditional student” (Metz, 2004). A “traditional student” student would be young and come to university straight after high school and he would live on-campus or very nearby (Rovai, 2003). For example, older students will have their own strong social network outside the university and thus they do not need to build one at the university (McCubbin, 2003). Similarly, students who are involved in distance education or live otherwise far from the campus, will not be able or need to integrate in the university’s social network (Rovai, 2003).

Each persistence model includes many variables that may have different impacts and different correlations between them. It is thus clear that the main contributors to persistence show great variation in the literature. Examples of these are presented in Table 3 below. Already that small set of examples indicates that one perspective of persistence, be it sociological, psychological, organizational, economic or cultural, is not sufficient. Instead, an integrated perspective is needed (Habley, Bloom and Robbins, 2012). But, regardless of the viewpoint of the theories and empirical studies, the common factors are that there is always an interplay between 1) what the student was before starting the studies and 2) how the studies influence the student. This interplay determines if the student persists or not.

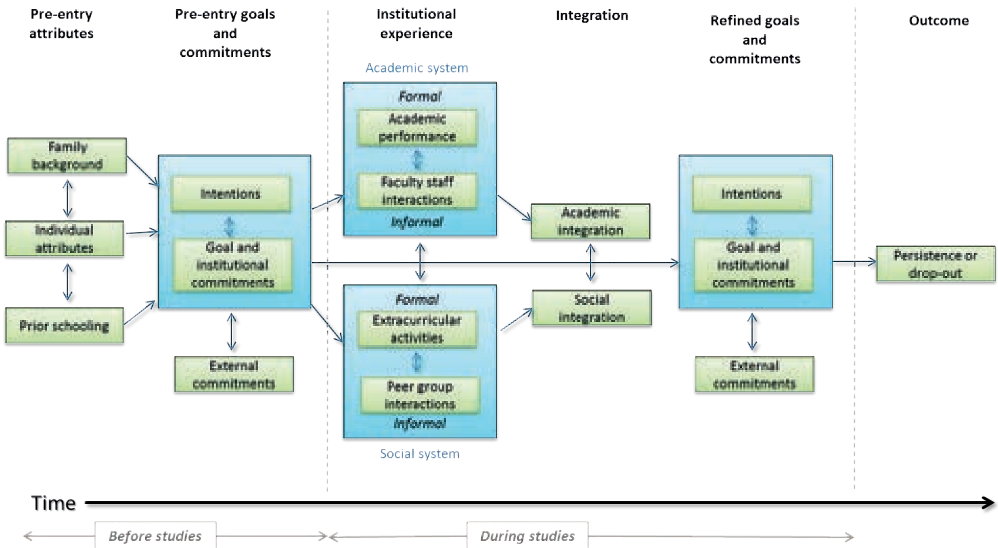

Figure 2. *The persistence model of Tinto (redrawn and adapted from McCubbin, 2003; Aljohani, 2016) with the before and during studies phases indicated.*

Table 3. *Some factors reported as main contributors to persistence in university studies.*

Main contributor	***References***
Financing	(Cabrera *et al.*, 1992; Bennett, 2003; Herzog, 2005; Lassibille and Gómez, 2008)
First year grades and academic performance	(Montmarquette, Mahseredjian and Houle, 2001; Wintre and Bowers, 2007; Araque, Roldán and Salguero, 2009; Ost, 2010)
Major subject	(Leppel, 2001; St. John *et al.*, 2004)
Level of motivation	(French, Immekus and Oakes, 2005)
Level of commitment	(Pascarella and Terenzini, 1983; Wintre and Bowers, 2007; Willcoxson, Cotter and Joy, 2011)
Interaction	(Pascarella and Terenzini, 1983; Lehmann, 2007; Wintre and Bowers, 2007)
Interest-major fit	(Allen and Robbins, 2008)
Preparation to university studies	(Allen and Robbins, 2008; Lassibille and Gómez, 2008)
Self-efficacy for educational requirements	(Lent, Brown and Larkin, 1984)
Major subject's first year curricula linkage	(Lifton, Cohen and Schlesinger, 2007)
Student peers	(Ost, 2010)
Parental support	(Wintre and Bowers, 2007)
Age	(Lassibille and Gómez, 2008; Araque, Roldán and Salguero, 2009)
Family characteristics	(Lehmann, 2007; Lassibille and Gómez, 2008; Araque, Roldán and Salguero, 2009)
Quality of teaching	(Bennett, 2003)
Flexibility of studies	(Di Pietro and Cutillo, 2008)

1.2.2. Desire to change the major subject

Based on the fact that pre-entry goals and commitments play an important role in persistence, one can expect that if a student has the desire to change his major subject, it is highly probable that he will not persist with that major. According to the classic categorization of Hackman and Dysinger (1970) there are four main types of students with differing competence and commitment levels. These types are 1) persisters, who show a high level of academic competence and commitment, 2) voluntary withdrawals, who are low in both commitment and competence, 3) academic dismissals, who have a high level of commitment, but low level of competence, and 4) transfers, who are students with high competence and low commitment. This classification suggests that a student needs both high competence and high commitment in order to continue studies in a study program at the university level. Thus, the lack of commitment towards the major subject will predict voluntary withdrawal or transfer. A more recent study by Mäkinen *et al.* (2004) of students from different faculties of one Finnish university supported this classification: students with a non-committing orientation were observed to have quit studies or changed their major more often than those with more commitment. In the study of Mäkinen *et al.* (2004), the students with low commitment were mostly those from the faculty of Mathematics and Natural Sciences. Furthermore, these non-committed students did not indicate increased anxiety or submissiveness both of which are common for non-committed students at high risk to quit their studies. This result demonstrates well the fact that most of the subjects taught in the faculty of Mathematics and Natural Sciences are, indeed, good one- or two-year training courses for students with their primary goal in in medicine or polytechnics. Because the students are having such a clear goal in another major, the non-commitment towards the "training" major will not amount to anxiety or submissiveness (Mäkinen, Olkinuora and Lonka, 2004).

As suggested by the findings of e.g. Hackman and Dysinger (1970) and Mäkinen *et al.* (2004), motivation is a key factor in the students' choice of major subject. If the motivation is intrinsic, the student will do things because they feel it is rewarding as such. On the other hand, if the motivation is extrinsic, the student will focus on the outcome, *e.g.* the profession to be achieved (Mikkonen *et al.*, 2009). It seems clear that students with extrinsic motivation are usually most effective in earning grade points (Mäkinen, Olkinuora and Lonka, 2004), but, on the other hand, both extrinsic and intrinsic motivation are needed to keep up the motivation over time (Mikkonen *et al.*, 2009). For example, Woosley and Jackson (2002) reported that most students changed their major because of the more attractive features of the new major. Such features can be e.g. available job openings, career possibilities and more interesting courses. The students who had changed their major were usually not dissatisfied with their old one, but they had more both extrinsic and intrinsic motivation towards the new major. The driving force for the motivation may be that the students have a clearer future occupational identity either in their original (Van Bragt *et al.*, 2011) or changed major subject (Titley, Titley and Wolff, 1976).

In terms of the interplay between learning approaches and persistence there seems to be only very few studies. This is thus a more or less unexplored field of study. Most of the studies have named learning approaches as an influence for retention to studies, but have given no actual research results on that topic (e.g. Cuseo, 2007; Majeski and Stover, 2007; Crosling, Heagney and Thomas, 2009; Jones DeLotell, Millam and Reinhardt, 2010). In one publication, 550 Finnish law students were studied for the interplay between learning approaches, study success and progress as well as degree completion. The results indicated that a deep approach would yield best grades and highest number of credit points within a time unit (Haarala-Muhonen *et al.*, 2017). The high number of credit points would also predict faster graduation. However, these were only true if the studying with deep approach was organized. Since law is one of the disciplines with highest persistence (see Table 1), it cannot be compared very well with the situation of chemistry. Another publication reports a study of learning patterns for 4000 Dutch university students of different disciplines (Van Bragt *et al.*, 2011). In that case, the overall non-persistence rate between the first and second study years was around 15 %. The results indicated that the students who persisted showed higher scores in the learning pattern features connected to deep approaches than did the non-persisting ones. The learning pattern model is not discussed in this thesis, but the model builds on the learning approaches one and extends it further with the aim of providing a more comprehensive view of learning (Vanthournout *et al.*, 2014).

It must be kept in mind that if a student has enrolled to a study subject that is not his most preferred one and that it is very often so that such students may not have any intention to participate in the studies (Ozga and Sukhnandan, 1998), it is still possible that this student will persist with that major (Liljander and Määttä, 1994). There is thus a possibility for the educators to have an influence towards persistence.

1.2.3. Institutional practices for increasing persistence

While it is not possible for university educators to influence what the students' characteristics were before they enrolled into university, there are some institutional practices that have been proven effective in improving persistence. For example, in 2005, Kuh et al. (2005) reported a study of twenty colleges that had unexpectedly high graduation rates in the United States. In these colleges the effective practices for improving persistence were identified as the following: provide academic challenge, use active and collaborative learning techniques, provide high levels of faculty-student interaction, provide a wide variety of educational experiences, provide high-quality student relationships with students, faculty and administrative personnel. In the same study, they identified the following conditions that were common to all these twenty colleges: 1) "living" mission and "lived" educational philosophy, 2) unshakeable focus on student learning, 3) environments adapted for educational enrichment, 4) clearly marked pathways to student success, 5) improvement-oriented ethos, and 6) shared responsibility for educational quality.

Habley et al. (2012) summed up persistence literature from the 1970s up to 2012 and concluded that the four main institutional practices for improved persistence are the following: 1) Facilitation of a smooth transition into college, 2) giving advice and counselling to help identification and committing to studying, 3) using entry level tests to place students to appropriate level courses and to provide support for students at risk, and 4) focusing on student learning as an active, collaborative and challenging process. The review of Kuh et al. from 2006 (Kuh *et al.*, 2006) reports similar findings adding also that it is important to have early warning systems to identify students at risk as well as to engage students in learning communities.

The practices introduced above are all of very general nature and thus not specific to any discipline. In 2013, Graham et al. (Graham *et al.*, 2013) introduced a "persistence framework" for students in the fields of science, technology, engineering and mathematics (STEM). This framework, based on studies in colleges in the United States, contains three interventions that are recognized as factors to increase persistence, i.e. 1) early research experiences, 2) active learning in introductory courses, and 3) membership in STEM learning communities (Figure 3). The framework recommends that all beginning students should be involved in real research as soon as possible so that they can design experiments, collect data and analyse it, and possibly make significant discoveries. Introductory courses should be such that the students are engaged in active learning in order to give opportunities to reflect on or apply their own knowledge. Such participation in scientific thinking with peers helps the students to identify themselves as scientists. The learning communities are such structures that provide meeting places or events where students can work together and learn from each other. Their first importance comes from the fact that understanding how knowledge is produced in one's own discipline helps the students to understand the importance of learning of course contents (Murtonen, 2015). Their second important function is that they help the students to grow up to be a member of the scientific community (Hakkarainen *et al.*, 2004).

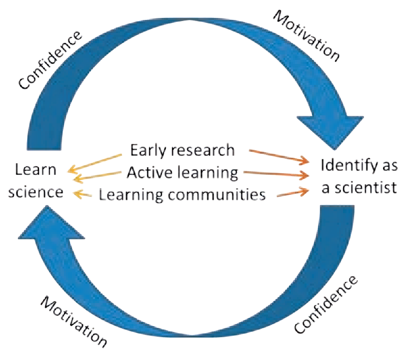

Figure 3. *The persistence framework (redrawn from Graham et al., 2013).*

1.2.4. Identifying chemistry students at risk

The ways of identifying students at risk for not completing general chemistry courses or studies at the university level have been the topic of studies at least from the 1920s (Scofield, 1927). Since then, the studies have concentrated mostly on statistical models for predicting grades in college chemistry. These models are based on data such as high school grades, standardized (placement) tests and first chemistry exams in college

(Lewis and Lewis, 2007; Mills, Sweeney and Bonner, 2009; Hailikari and Nevgi, 2010; Chan and Bauer, 2014).

The high school grades accounted for are either those of chemistry, mathematics or the grade point average. There seems to be a trend that lower grades in high school predict lower grades in college, whereas higher high school grades do not necessarily predict success in college chemistry (Nordstrom, 1990; Tai, Sadler and Loehr, 2005). The placement tests include e.g. the ACS Toledo Chemistry Placement Exam, CCDT and SAT-M, which measure prior chemistry and/or mathematics knowledge (Table 4). They can be very successful in predicting chemistry grades: for example Russell (1994) reported a linear relationship between the CCDT score and chemistry grade average and Spencer (1996) observed a similar linear trend for SAT-M. However, the problem with these tests is that even if they may predict grades rather well, they do not predict learning (Lewis and Lewis, 2007) or persistence. Wagner et al. (2002) point out that although the ACS Toledo Chemistry Placement Exam and SAT-M are very good in predicting grades, they cannot predict failing very well. Thus, they report a test (SPSA, Table 4) that combines prior chemistry and mathematics knowledge with demographic information (age, number of prior chemistry courses, and highest level of prior mathematics course), which can predict also failure to complete a chemistry course. On the other hand, Potgieter et al. (2010) report that the demographic information does not give any added predictive power, but if prior knowledge is complemented with the extent of overconfidence (i.e. ratio between expected and actual performance), very good prediction accuracy is obtained. However, because none of the tests discussed above give any information about learning, they cannot suggest any teaching strategies to reduce the risks they predict to exist (Pyburn *et al.*, 2013). On the other hand, there are also such standardized tests used that measure other factors than prior knowledge. Those include e.g. ACT, ACE and TOLT (Table 4). These test also use grades as the indicator for being at risk, and even these test cannot suggest any teaching strategies.

Table 4. Some tests used for identifying chemistry students at risk.

Standardized test	Measures	Reference
ACS Toledo Chemistry Placement Exam	Mathematical ability, general and specific chemistry knowledge	(Hovey and Krohn, 1963)
California Chemistry Diagnostic Test (CCDT)	Mathematical skills, chemistry knowledge laboratory skills	(Russell, 1994)
Mathematical Scholastic Aptitude Test (SAT-M)	Mathematical skills	(Spencer, 1996)
American College Testing Program (ACT)	Self-rating of overall academic ability, drive to achieve and mathematical ability; Intellectual self-confidence; Expectation to graduate with honors or to graduate with at least B average; Years of high school mathematics	(House, 1995)
American Council of Education Psychological Examination (ACE)	Psychological indicators	(Boe, 1964)
Test of Logical Thinking, TOLT	Formal reasoning ability	(Tobin and Capie, 1981)
Student Pre-Semester Assessment (SPSA)	Mathematics, chemistry, demographics	(Wagner, Sasser and DiBiase, 2002)

1.3. Learning approaches

Introduced by Marton and Säljö in 1976, the students' approaches to learning (SAL) are defined classically as the deep and surface approaches (Marton and Säljö, 1976). An approach to learning contains both a motivational and a strategic component (Vanthournout *et al.*, 2014). Thus, it can be considered a combination of a specific motive or intention and the connected learning strategies or learning and study processes.

Students applying the surface approach concentrate on the text they need to study and they try to learn by heart as much as possible. The goal is to get by with the requirements of the study course. The surface approach involves *e.g.* not seeing value in courses and tasks, studying with no consideration of purpose or strategies, doing procedures routinely, handling the course material as unrelated pieces of knowledge, feeling difficulty in understanding new material, feeling excessive pressure and worry about work (Lovatt, Finlayson and James, 2007; Almeida *et al.*, 2011). In contrast, the deep approach involves the aim of taking hold of the meaning of the text (Case and Gunstone, 2003). Students employing this approach relate ideas to prior knowledge as well as seek patterns and underlying principles, since they are actively interested in the content to be studied. Furthermore, they use evidence and relate it to conclusions as well as look at logic and arguments thoughtfully (Almeida *et al.*, 2011). The deep approach thus includes a high degree of metacognition as well as the ability to manage learning by developing self-regulation strategies. However, even if the deep approach is thought to be connected to higher conceptions of learning and the surface approach to lower conceptions of learning, higher conceptions do not necessarily mean that a person would use a deep approach. This is thus a two-way interrelation (Evans, 2014).

In 1978, Biggs identified the need of adding a third component to the deep-surface classification, i.e. the strategic approach to learning (Biggs, 1978). This approach includes the aim of achieving as high grades as possible. If this approach is used, the student will set consistent effort into studying, manage both effort and time efficiently as well as be able to optimize the conditions and find the best materials for studying. A student applying the strategic approach is also well aware of assessment criteria and requirements as well as able to direct work towards the preferences they perceive during lectures (Almeida *et al.*, 2011). Later on, this strategic approach has broadened into an organized approach covering effective learning and studying as a whole. It includes an awareness of the learning process, but without trying to take shortcuts to high marks (Entwistle, 2018). There has been debate over how many dimensions are needed to describe learning approaches (Entwistle and McCune, 2004). Some state that the organized/strategic approach is not an approach as such but more a subscale that can be a part of both the deep and surface approaches (Zeegers, 2002). On the other hand, when Entwistle and McCune (2004) reviewed six prominent inventories for probing study strategies, they concluded that three dimensions (deep, surface and organized) are needed.

There are also other definitions of learning approaches than the deep-surface dichotomy. Those are actually very similar than the deep-surface one, but they use different names. For example, Booth reported in 1992 the following four approaches: the expedient opportunistic, constructual opportunistic, operational interpretative and structural interpretative (Booth, 1992). The first two are similar to the surface approach, whereas the latter two are similar to the deep approach. Furthermore, also intermediates between the deep and surface have been classified. These contain the procedural deep and algorithmic (procedural surface) approaches recognized in engineering education (Case and Gunstone, 2003). The algorithmic one involves the memorization of mathematical formulas and substituting appropriate values into them as needed in examinations. In the procedural deep approach, the student creates connections between formulas to reach understanding at some later time (Case and Marshall, 2004). Yet another viewpoint is that the deep and surface approaches are extremes in between of which there is a continuous distribution of different shades of learning approaches (Case and Gunstone, 2003).

The possible connection between learning approaches and learning outcomes is not very clear. Sometimes there has been no correlation between these two, but sometimes there has (Vermunt, 2005). Often, students using the deep approach are reported to score higher grades as well as to retain, integrate and transfer information at higher rates than those using the surface approach (Laird, Shoup and Kuh, 2003). This has been reported in many fields of study, including chemistry (Almeida *et al.*, 2011). However, the "paradox of the Chinese learner" indicates that Asian students memorize extensively, but nonetheless show very high quality learning outcomes (Kember, 1996; Cooper, 2004). Because of this, two forms of memorization have been classified. One type of memorization involves comprehension, whereas the other does not. This classification thus adjusts the paradox into the deep-surface domain. On the whole, the deep-surface classification has given a good explanation for the different learning outcomes shown by students at different levels of study (Case and Gunstone, 2003).

1.3.1. Factors that affect learning approaches

The key question of the past years in the theories of learning approaches has been their stability, or instability, as affected by personality, time and context. The present theories of learning and expertise development view personality as a very flexible feature that changes over time and due to the environment (Chamorro-Premuzic and Furnham, 2009). This indicates that the learning of one student during the entire period of their university studies cannot be described with one stable approach. Therefore, any one student may employ a deep approach at some point and a surface one at some other point in their studies. The approach used would depend on the learning task as well as the conditions prevailing when the task is carried out (Laird, Shoup and Kuh, 2003). On the other hand, if a student has a disposition to understand, it is probably both more stable than the deep approach and it will also support a student in maintaining a deep approach (Entwistle and McCune, 2013; Postareff, Lindblom-Ylänne and Parpala, 2014). Also, it has been reported that if university students agreed on needing research skills in their future work, they were more deeply oriented in research courses than those students who felt they had no such need (Murtonen *et al.*, 2008), i.e. the students' conception of the need of a skill was connected to their learning approaches.

The learning approaches of students may change during their education and the changes may be unpredictable (Lindblom-Ylänne, Parpala and Postareff, 2014). Therefore, there are many different kinds of results, when the evolution of learning approaches with study years in considered (Asikainen and Gijbels, 2017). For example, Vermetten (1999) studied students from different departments in Dutch universities and reported increased use of the deep approach from the first to the third semester. However, time had no effect on the surface approaches, which suggests that the surface and deep approaches are independent of each other. Zeegers (2001) carried out a longitudinal study involving beginning Australian science majors taking part in a chemistry course. In the beginning, he noticed a little decrease of the deep and a little increase of the surface approach. However, as time progressed both returned to their original values. In a similar study of Finnish medicine and psychology majors, no changes in the learning approaches were observed between the first and fifth study year (Lonka and Lindblom-Ylänne, 1996). It must be noted that the age of the students is an important factor, as well: Older students tend to adopt a deep approach more readily and a surface approach less readily than younger students (Sadler-Smith, 1996).

Context may have an even more significant effect than time on the learning approaches. For example, the first years in university chemistry include a high number of things that need to be learned. One has to memorize and it is probably not possible to connect the information to build a bigger picture out of it. There are many things to learn and the syllabus tends to be packed, which causes high workload and very little freedom in learning. This drives towards surface approaches (Ramsden and Entwistle, 1981; Entwistle and Tait, 1995; Minasian-Batmanian, Lingard and Prosser, 2006). After the beginning years, the course contents will become more concentrated to specific topics only and thus they leave more room for deep learning. Therefore, it has been reported that students of chemistry and other physical sciences use the surface approaches in the beginning of their studies far more often than do the students of humanities (Case and Gunstone, 2003). However, Li et al. (2013) have reported also contrary results from Taiwan stating that in addition to the deep strategy approach many students employ the surface motive one in the latter stages of their studies. This is because of the high demand of chemistry masters in Taiwan, which encourages the use of the surface motive approach in order to graduate faster and start earning money. There is also evidence that students of chemistry, physics and engineering use the deep approach during their entire studies much less than the students of e.g. humanities and arts do (Laird, Shoup and Kuh, 2003). This is in accordance with the classification of hard and soft sciences and the usual finding that the students of soft sciences (like arts and humanities) use more deep approaches than the students of hard sciences (like physics, chemistry and engineering) (Parpala *et al.*, 2010). However, Smith and Miller (2005) point out that while students of hard sciences tend to use more surface approaches on average than do the students of "soft" sciences, there is also variation depending on the specialization areas within the discipline. In line with this, Laird and co-workers (2008) used the classification of Biglan (1973) that accounts for the additional (in addition to hard/soft) categories life/non-life and pure/applied to study the effects of these sub-categories.

They observed that the hard/soft classification had the strongest effect on the learning approaches, but life/non-life and pure/applied also had significant effects. That is, life and pure predicted a higher use of deep approaches than did non-life and applied. If one assumes the fact that the boundaries of chemistry and some other disciplines are difficult to define, a chemist working in pure life sciences, such as a person doing basic research of biomolecules (i.e. chemistry expanded towards biochemistry or biology), would be more probable to use a deep approach than a chemist working in applied non-life cases, such as a person studying inorganic photochromic materials for use as personal dosimeters (i.e. chemistry expanded towards chemical or materials engineering).

In addition to the subject of study, the learning environment is also a very important contextual parameter that affects learning approaches: students have been reported to show different learning approaches in different contexts at the same period of time (Eley, 1992; Vermunt and Vermetten, 2004). One example of this is that the use of the deep approach may decrease during study years, because the students are adapting better and better to the perceived requirements of courses (Jackling, 2005). Another example comes from Kyndt et al. (2014) who reported that workload affected in such a way that quantitative aspects (amount of things to do) increased the surface approach whereas increase in qualitative workload (task complexity) increased the deep approach. The same study addressed also the ties between information stored in the long-term memory (i.e. familiarity) and learning approaches and found that familiarity could increase either the deep or the surface approach. If the task was not challenging enough, familiarity increased the lack of challenge and thus increased the surface approach. On the other hand, if the task was challenging, familiarity increased confidence in using the deep approach.

Such adaptation discussed above is something that can be used to enhance learning, i.e. the teaching-learning environments can be adjusted to stimulate the students' willingness to understand deeply and the desire to learn (Baeten *et al.*, 2010; Dolmans, Wolfhagen and Ginns, 2010; McCune and Entwistle, 2011). Sometimes this is successful (Trigwell, Prosser and Waterhouse, 1999), but sometimes students who employ a deep approach in traditional learning environments may find it difficult to adapt to an environment designed to stimulate deep learning, and students usually employing the surface approach may find it even more difficult (Almeida *et al.*, 2011). Similarly, it has been reported that changing teaching to promote deep learning may have unintended consequences, i.e. while some students do increase their use of the deep approach, others start using the surface approach increasingly (Balasooriya, Toohey and Hughes, 2009). There is also evidence that changing the approaches is very difficult (Gijbels *et al.*, 2009; Baeten, Struyven and Dochy, 2014). Nevertheless, keeping in mind that not all students experience the same context similarly (Kyndt, Dochy and Cascallar, 2014), supporting self-regulation, requiring time and effort from the students, and controlling the level of challenges are important for promoting deep learning (Lindblom-Ylänne, Parpala and Postareff, 2014).

Price and Richardson (Price, 2014) have proposed a model to describe the factors that affect learning outcomes. This 4P model (Presage-Perceptions-Process-Product) indicates students' approaches to learning as the first key factor influencing learning outcomes (Figure 4). This model also describes the complex network of factors that affect learning approaches: The way how students conceive learning will have a strong effect on their approaches to learning. That is, if a student conceives learning as a) increase in knowledge, b) memorization or c) the acquisition of facts and procedures that can be used in practice, the approach used will be the surface one. On the other hand, if the student conceives learning as d) the abstraction of meaning or e) the interpretative process aiming to the understanding of reality, the approach will the deep one. Furthermore, the students' perceptions of context, i.e. of the requirements of the task (including how the assessment is graded) as well as of the nature and style of teaching, also influence the approach adopted. The second key factor in the 4P model is the teachers' approaches to teaching. These may be teacher-focused, student-centered or have teacher-student interaction. The teacher-focused approach involves mostly the transmission of information from the teacher to the student, whereas the student-centered approach will help the students to develop and change their conceptions.

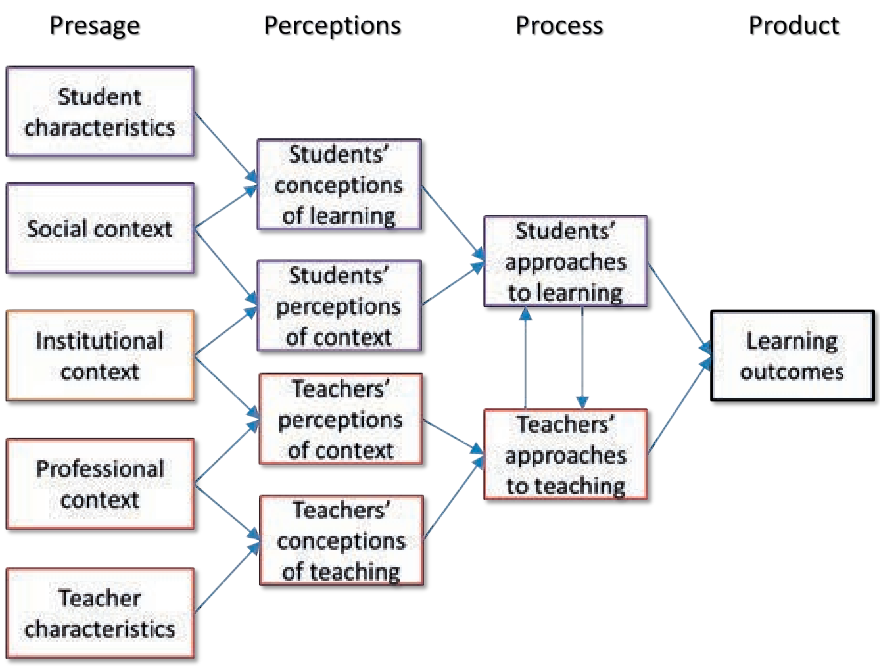

Figure 4. *The 4P model (redrawn from Price, 2014).*

1.3.2. Instruments for probing learning approaches

Learning approaches are conventionally probed by using self-report questionnaires and some of them are listed in Table 5. The definition of the deep approach, and thus also the surface approach, may be significantly different in different contexts, and thus also the instrument used to probe the approach should be appropriate for the definition (Evans, 2014). Generally, the questionnaires used have been criticized for not probing the actual learning processes but only the general qualities (Heikkilä and Lonka, 2006) and for not being sensitive to the context (Boekaerts, 1996). It has also been suggested that much attention should be paid on the fact that the method used to study the approaches may have an effect on the results. Thus a rich variety of methods should be used to minimize such effects (Lindblom-Ylänne, Parpala and Postareff, 2014).

Table 5. *Some approaches to learning instruments* (Kember, Biggs and Leung, 2004; Lee, Johanson and Tsai, 2008; Li, Liang and Tsai, 2013; Parpala *et al.*, 2013; Evans, 2014; Herrmann, Bager-Elsborg and Parpala, 2017).

Name	***Authors***
Approaches to Studying Inventory (ASI)	Entwistle and Ramsden (1983)
Lancaster Approaches to Studying Questionnaire (LASQ)	Ramsden (1983)
Learning Process Questionnaire (LPQ)	Biggs (1987)
Study Progress Questionnaire (SPQ)	Biggs (1987)
Inventory of Learning Strategies (LIS)	Vermunt and van Rijsvik (1988)
Reflections of Learning Invetory (RoLi)	Meyer, Parsons and Dunne (1990)
The Revised Inventory of Learning Processes	Schmeck, Geisler-Brenstein and Cercy (1991)
The Motivated Strategies for Learning Questionnaire (MSLQ)	Pintrich, Smith, Carcia and McKeachie (1993)
Inventory of Learning Styles in Higher Education (ILSHE)	Vermunt (1994)
Revised Approaches to Studying Inventory (RASI)	Tait and Entwistle (1996)
Approaches to Study Skills Inventory for Students (ASSIST)	Tait, Entwistle and McCune (1998)
The Inventory of Learning Styles (ILS)	Vermunt (1998)
Revised Two-Factor Study Process Questionnaire (R-SPQ-2F)	Biggs, Kember and Leung (2001)
Inventory of General Study Orientations (IGSO)	Mäkinen, Olkinuora and Lonka (2002)
Experiences of Teaching and Learning Questionnaire (ETLQ)	Entwistle, McCune and Hounsell (2003)
Revised two-factor version of the Learning Process Questionnaire (R-LPQ-2F)	Kember, Biggs and Leung (2004)
ILS-SV	Donche and van Petegem (2008)
Approaches to Learning Science (ALS)	Lee, Johanson and Tsai (2008)
Approaches to Learning Chemistry (ALC)	Li, Liang and Tsai (2013)
Learn	Herrmann, Bager-Elsborg and Parpala (2017)

Many different general inventories and/or interviews and/or essays have been used for the assessment of learning approaches of chemistry students, Concerning the inventories, for example Almeida et al. (2011) used the ASSIST inventory (Entwistle, McCune and Tait, 1997), which is the successor of ASI and RASI (see Table 5). This instrument probes deep, strategic and surface approaches to studying with each approach having subscales. For the deep approach, these are seeking meaning, relating ideas, use of evidence, interest in ideas and monitoring effectiveness. The strategic approach contains organized studying, time management, achieving and alertness to assessment demands as subscales. For the surface approach, the subscales are lack of purpose, unrelated memorizing fear of failure and syllabus boundness. Laird and co-workers (Laird, Shoup and Kuh, 2003; Laird *et al.*, 2008) used the College Student Report of NSSE (National Survey of Student Engagement, 2004) which contains sections about self-reported grades as well as gains in personal and intellectual development. Furthermore, sections about satisfaction with college as well as 15 items for measuring deep learning approach features are included. The 15 items make up three subscales assessing higher-order learning, integrative learning and reflective learning. Dart et al. (1999) report the use of the LPQ questionnaire (Biggs, 1987a). This instrument can categorize the learning approaches as follows: deep, deep-achieving, achieving, surface-achieving, surface and low-achieving. Trigwell and co-workers (1999) as well as Eley (1992) report the use of the SPQ instrument which contains the deep and surface scales with intention and strategy as sub-scales in both (Biggs, 1987b). Tsai and co-workers have used the ALS questionnaire (Lee, Johanson and Tsai, 2008; Liang, Lee and Tsai, 2010), which was modified from the R-LPQ-2F (Kember, Biggs and Leung, 2004) to address (hard) science learning in particular.

It seems that only one questionnaire has been reported for studying especially the learning approaches of chemistry students: the Approaches to Learning Chemistry, ALC (Li, Liang and Tsai, 2013). It was modified from ALS (Lee, Johanson and Tsai, 2008). Similarly to R-LPQ-2F, both ALS and ALC also have the scales of deep motive, deep strategy, surface motive and surface strategy. Li et al. (2013) reported that their ALC data based on the replies of 369 college students from Taiwan did follow this expected four-factor structure.

While it seems clear that e.g. the aforementioned studies have been successful in gaining information about the learning approaches of chemistry students, the inventories used (even ALC) fail to asses one important aspect, namely laboratory work. Laboratory exercises make a highly important part of chemistry education and a chemistry laboratory clearly constitutes a different learning context than e.g. lectures or studying at home. Considering the important contribution of context to learning approaches (see Chapter 1.3.1.) there is clearly a need to study how learning approaches are employed in the laboratory as well as how those approaches link with the approaches employed outside the laboratory. This calls for the need of developing a new questionnaire for assessing the learning approaches of chemistry students. It must be noted, however, that there is contradictory evidence concerning the helpfulness of laboratory work in promoting the learning of chemistry (see e.g. Nakhleh, Polles and Malina, 2003; Hofstein and Lunetta, 2004; Elliott, Stewart and Lagowski, 2008), but nevertheless a chemist needs the practical skills that can be acquired only by practicing in the laboratory. This thus leaves the possibility of learning chemistry theories and scientific thinking in parallel with the practice if the exercises are properly constructed (Högström, Ottander and Benckert, 2010; Bretz *et al.*, 2013).

1.3.3. Validation of learning approach inventories

Above, it was discussed that there are many factors that can affect the learning approaches adopted by students. However, also the instrument itself that is used for the data collection and assessment can affect the results obtained (Lindblom-Ylänne, Parpala and Postareff, 2014). It is known that responses of one person to similar questions may have poor correspondence with each other. Moreover, replies to exactly the same question at different points in time may vary. It has been shown that such variations are higher for questions concerning judgements than for those concerning descriptions (Wikman, 2006). In some cases temporal variation may be a result of actual change due to contextual or other influences, but in other cases this may indicate the poor repeatability of the measurement, i.e. a poor reliability (Richardson, 2009). Testing and re-testing is thus one means of assessing reliability. Another way for evaluating reliability is to examine the internal consistency with Cronbach alpha (Cronbach, 1951; Bland and Altman, 1997) or other values such as general reliability (Tarkkonen and Vehkalahti, 2005). For a questionnaire to be used as a research instrument, one must know that the questionnaire being used measures what it is supposed to measure and that the results obtained can be interpreted objectively, i.e. that it is valid for that particular case (Kim, 2009). The validity can be manifested in different forms: face validity (wording and structure of items), construct validity (relationships between scores of a sample of students in different parts of the instrument), criterion validity (correlation between the scores of the instrument in comparison with an independent criterion), and discriminative validity (ability to discriminate scores that should differ) (Richardson, 2009). Below, I use one established general instrument as an example for showing the results of its validation in different contexts. All the evaluations presented are based on confirmatory factor analyses.

The Revised Two-Factor Study Process Questionnaire, R-SPQ-2F, (Biggs, Kember and Leung, 2001) is a rather recent general instrument for probing learning approaches, and it has been validated in quite a few different settings. It contains 20 items and the sub-scales of deep motive, deep strategy, surface motive and surface strategy. The initial validation in 2001 was based on two sets ($N = 229$ and 495) of students of health sciences in one university in Hong Kong. Later on, Justicia et al. (2008) studied two independent groups ($N = 314$ and 522) of Spanish undergraduate students of psychology and education. They reported that the latent structure was best represented by two factors, deep and surface, instead of four. Sulaiman et al. (2013) studied 426 Malaysian university students and reported also these two scales, but a good fit required the omission of six of the items. Munshi and co-workers (2012) came to the same conclusion for the Arabic version as did Fryer et al. (2012) for the Japanese and Mokhtar et al. (2010) for the Malay ones. Immekus and Imbrie (2010) studied two separate cohorts (N = 1490 and 1533) of university students from the United States and reported a four-factor structure, but with different item distribution than in the original validation (Biggs, Kember and Leung, 2001). Stes and co-workers (2013) validated the Dutch version of the instrument with data from 1974 university students from different disciplines. They also found four sub-scales that differed from the original ones and renamed them as studying is interesting, spending extra time, minimal effort and learning by heart. As suggested by Stes and co-workers (2013), the questionnaire is sensitive to the context that it is being used in and thus one should avoid using the sub-scale structure suggested by the original authors by default. Although this is an example of just one questionnaire, it seems that a similar behavior can be expected for other questionnaires, as well, which then calls for context-specific validation.

2. AIMS

The main aim of this thesis was to study if persistence in chemistry major could be predicted by the learning approach features adopted by the students when studying chemistry. Study I focused in analyzing the Finnish chemistry students' learning approaches and their relationship to intentions to persist by developing a tailor-made ChemApproach questionnaire to meet the specific needs of chemistry learning. Study II involved the validation of the ChemApproach instrument to enable its to use it for a more extensive data collection in a specific population, namely among Finnish chemistry students. Study III presented a model for predicting persistence and drop-out of chemistry students in the Finnish context. The specific research questions of the studies were as follows:

1) What kind of learning approaches do Finnish chemistry students have and are they connected to intended persistence in studies? In addition, do practical studying features (i.e. laboratory practicals) emerge as an independent learning approach (Study I)?
2) Does the learning approach questionnaire ChemApproach developed in Study I work for a large sample (Study II)?
3) Is it possible to predict persistence and drop-out of chemistry students by using the ChemApproach questionnaire. (Study III)?

The design of the work presented in Figure 5 involves considering learning approaches and the desire to change major as two main contributors to persistence or drop-out. These are probed by using the developed questionnaire. Chemistry grades are considered as a third contributor to persistence or drop-out and those are obtained from study records. Statistical methods are used to construct a model for predicting persistence or drop-out from the questionnaire data, grades and information of actual persistence or drop-out.

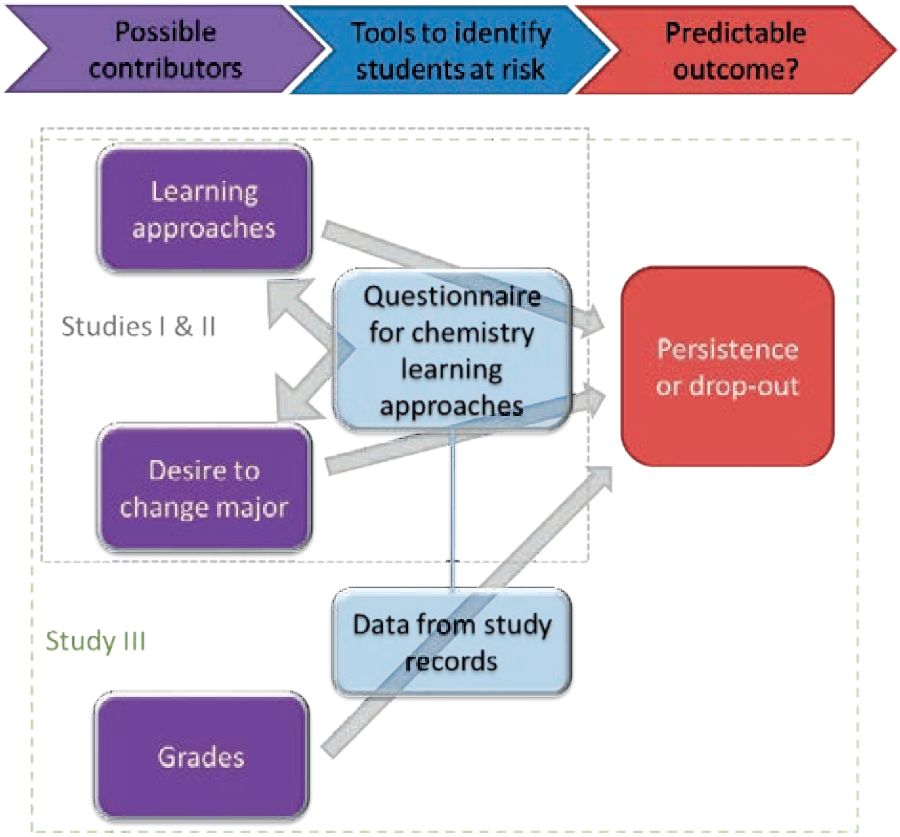

Figure 5. *The design of this thesis work.*

3. MATERIAL AND METHODS

3.1. Participants

The participants in the studies were students participating in chemistry education in Finnish universities. They had chemistry either as a major or minor subject. Participation was voluntary and informed consent was obtained. The data were collected between 2012 and 2016. The participants in Study I (Lastusaari and Murtonen, 2013) consisted of 118 first to fifth year chemistry majors and minors at one Finnish university. The participants in Study II (Lastusaari, Laakkonen and Murtonen, 2016) consisted of 561 chemistry majors and minors from all study years at four Finnish universities, whereas Study III (Lastusaari, Laakkonen and Murtonen, 2018) included 733 bachelor level chemistry majors and minors from four Finnish universities.

3.2. Materials, data collection procedures and analyses

Before the beginning of this work, there had been different surveys at the Department of Chemistry at University of Turku for finding out which reasons, other than the obvious moving to the medical studies, would lead to the dropping-out of students. There had been hints of the possible importance of learning approaches in making this decision. Because of the probable context-sensitivity of general questionnaires (as exemplified in chapter 1.3.3. for the R-SPQ-2F) and especially because of the lack of the essential part accounting for laboratory work (see chapter 1.3.2.), it was decided that a self-made questionnaire should be constructed for this work.

The new questionnaire, ChemApproach, was based on the tradition of SAL instruments. The main influence was ILS (Vermunt, 1994) but also ETLQ (Entwistle, McCune and Hounsel, 2002) was used as a source. For example:

> ILS: *"I try to combine the subjects that are dealt with separately in a course into one whole."*
>
> ChemApproach: *"I try to fit parts of a course into a whole picture."*
>
> ETLQ: *"Much of what I've learned seems no more than lots of unrelated bits and pieces in my mind."*
>
> ChemApproach: *"Many things that I learn remain isolated and do not link as a part of a bigger picture."*

Most ChemApproach items are just generally linked to the SAL theory and have no specific source. In addition to those items following the SAL tradition, also such that consider laboratory work were included. For example: "I have often understood a chemical phenomenon only after doing practical work on it.”. The questionnaire contains the following parts: A) Background information, B) Preparation for a chemistry examination, C) Chemistry lecture, D) Studying chemistry, and E) Chemistry practicals. The replies are collected based on a five-point Likert scale. In addition to these Likert scale items, the questionnaire also contains background questions about e.g. willingness to change major subject (yes/no), gender and study year. Please see Appendix for the complete questionnaire.

The empirical studies in this dissertation are based on three different data sets. Table 6 summarizes the methods used in each study. All studies used the self-made self-test survey with cross-sectional student samples. The data was collected during lectures and laboratory practicals. Information about persistence and grades were obtained from the statistics of the university whose students were considered. The data from these studies were analysed using basic statistical methods, principal component analyses (PCA), Cronbach α, one-way ANOVA (i.e. analysis of variance), k-means clustering, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). In Study III, also non-parametric ANOVA test were carried out for the smallest data subsets.

Table 6. *Summary of methods.*

Study	Participants	Materials and data collection methods	Analyses
I	First to fifth year chemistry majors and minors from one Finnish university; N = 118	Self-made questionnaire	PCA, Cronbach α, one-way ANOVA, k-means clustering
II	Chemistry majors and minors of all study years from four Finnish universities; N = 561	Self-made questionnaire (ChemApproach)	PCA, EFA, CFA,
III	Bachelor level chemistry majors and minors from four Finnish universities; N = 733	Self-made questionnaire (ChemApproach)	CFA, one-way ANOVA, Kruskall-Wallis H-test

4. RESULTS: OVERVIEW OF EMPIRICAL STUDIES

The following chapters discuss very briefly Studies I-III. More detailed discussion on them is found in the attached publications.

4.1. Study I

Lastusaari, M. and Murtonen, M. (2013) ‘University chemistry students’ learning approaches and willingness to change major’, *Chemistry Education Research and Practice*, 14(4), pp. 496–506.

The knowledge of the principles of chemistry is required in most natural sciences (Tai, Sadler and Loehr, 2005). To acquire such knowledge, the student needs to take control of all the three forms of chemistry, i.e. macro, submicro and representational (Johnstone, 2000b). The big challenge in learning chemistry is to make the transition of one’s understanding from the macro level to especially the submicro but also the representational one. Therefore, the learning approaches of the student have a crucial effect on this transition.

The main goal of Study I was to investigate the learning approaches of students of natural sciences taking part in chemistry courses. A second goal was to develop a questionnaire to suit just this purpose. Thus, a specialized questionnaire with 22 Likert-type items was developed as an instrument for this study. Cross-sectional data (N = 118) was collected from students of different study years in one Finnish university. 42 % of the participating students expressed a will to change their major subject. Therefore, this group was also analyzed for possible special learning approach characteristics. Principal component analysis with Varimax rotation was carried out for the data to yield groups of learning approach features. Communalities were calculated to confirm that the sample size was large enough. Cronbach α values were calculated to assess the reliability for the scales assigned to each approach. Mean learning approach score variables were calculated and one-way ANOVA was employed to study if there were learning approach differences between the different study year groups or gender. Finally, a k-means cluster analysis was carried out to see if students could be grouped based on their learning approach features

Six distinct features of learning approaches were identified from the data (Table 7). The corresponding scales were named based on the nature of the items contained within them. Three of them reminded the classical surface approaches (Marton and Säljö, 1976; Entwistle, 2018) and three were classified as deep approaches. The three surface approaches were named as submissive surface, memorizing surface and technical surface. The deep approach scales were named as active deep, processing deep and practical deep approaches. The original questions loaded on these factors are shown in Table 7. The submissive surface (SubSurf) approach characterizes a person, who is just studying chemistry and has very little interest in learning on any level. He is not willing to make too much effort in making the learning outcomes better. The memorizing surface (MemSurf) characterizes a learner who puts a lot of effort in passing the assessment tests. He uses mostly memorizing to store information and does not pay much attention to connecting the memorized bits to larger units of knowledge. The technical surface (TechSurf) student would go a little bit further by actively using different techniques for surface learning instead of just pure memorization. In the deep approach scales, the active deep (ActDeep) scale describes a learner who actively seeks for additional material to complement his view of the studied subject and wants to have an understanding of the material to be learned already before the lecture. Utilization of the processing deep (ProcDeep) approach involves the active collecting and cognitive processing of information for the construction of a total conception of the matter to be studied. Finally, the practical deep (PractDeep) characterizes a student who uses chemistry practicals as the means to achieve deeper understanding of the studied matter.

The introductory level students who intended to change their major subject showed the highest scores for the technical surface approach ($p = 0.01$). Those willing to change their major scored also higher in the memorizing surface ($p = 0.03$) as well as lower on the practical deep ($p = 0.002$) than those who were content with staying as chemistry majors. The practical deep score was observed to increase with increasing study years ($p = 0.004$) as an indication of increasing understanding of the ties between chemical practice and theory. The students could be grouped to four categories based on their learning approach features. These were submissive, diligent, enthusiastic and technical. A strong majority of the students intending to change their major belonged to the technical group, but many of them were in the group of enthusiastic students. Other introductory and basic level students showed no preference for any group, whereas advanced level students who did not intend to change their major were in the group of enthusiastic students.

The results showed that the new questionnaire developed for this study functioned well and the used questionnaire items were able to bring out specific features of chemistry students' learning, especially concerning the learning in practical laboratory sessions. The discovery of a practical deep approach appears to be very important for chemistry education. Finally, because a considerable amount of the first year students intending to change their major were enthusiastic towards learning chemistry deeply, it seems like there is a chance for the teachers to persuade them to persist with chemistry.

Table 7. *The final rotated component matrix. The highest loads (marked with bold text) for each factor were used in the assessment of the six approaches to learning.*

Item	SubSurf	MemSurf	TechSurf	ActDeep	ProcDeep	PractDeep
Many things that I learn remain isolated and do not link as a part of a bigger picture.	**0.68**				-0.349	
When reading the course book, I often do not understand how a new topic relates with any old one.	**0.81**					
I have to memorize things without having the opportunity to understand them.	**0.74**					
During a lecture, I often do not understand what a new thing is connected with.	**0.81**					
I learn everything exactly as it has been presented in the course book.		**0.61**				
I remember many isolated things from the lectures.		**0.60**				0.36
I learn a new thing easily, if it is presented as text.		**0.48**				
It is important that the things presented in the course book are dealt with during the lectures.		**0.65**				
I find it easy to learn things by memorizing them.		**0.52**				
I make my own notes when studying for an examination.			**0.75**			
I make mnemonics to learn things better.		0.30	**0.73**			
I underline while reading for chemistry examination.			**0.78**			
I make myself acquainted with the subject of the next lecture beforehand.				**0.80**		
I usually search and read additional material concerning the course.				**0.72**		
I try to connect things from a course as parts of a bigger picture.					**0.70**	
I often chew over the thoughts awoken by scientific texts as well as connections between them.					**0.78**	
I look for justifications and evidence to make my own conclusions about things to be learned.					**0.79**	
I like to do practicals.						**0.74**
I have often understood a chemical phenomenon only after doing practical work on it.						**0.69**
When doing a practical, I usually try to understand what its different parts are based on.					0.35	**0.75**
One can learn a chemical phenomenon only by doing practical work on it.						**0.57**
My most important goal for a practical is to have it done in a way accepted by the teacher.		0.34				**-0.55**

Note: loadings less than 0.30 are omitted

4.2. Study II

Lastusaari, M., Laakkonen, E. and Murtonen, M. (2016) 'ChemApproach: validation of a questionnaire to assess the learning approaches of chemistry students', *Chemistry Education Research and Practice*, 17, pp. 723–730.

The knowledge of the learning approaches of students may serve as an important indicator of how the students perceive the learning environment. One way to obtain such information is to use questionnaires designed to probe learning approaches.

The primary aim of Study II was to investigate whether the questionnaire developed in Study I could be used for a bigger dataset , i.e. could the instrument be proven to be valid. The questionnaire of Study I was modified based on the experience acquired from the first version. This meant that items that would not load well to any of the scales were removed and others were added to increase the number of items in each scale. Moreover, an enquiry for the name of the respondee was added to the questionnaire to allow later longitudinal studies as well as connecting the obtained data with e.g. information on persistence or results obtained with other methods. Data was collected from four Finnish universities (N = 561). Principal component analysis with Varimax rotation was first carried out for the data to find a structured factor solution. Next, the value of the Bayesian information criterion was calculated for different numbers of factors in order to find the number of factors that would yield the best balance between the complexity of the model and the fit. This number of factors was then used to carry out an exploratory factor analysis with Geomin rotation to obtain the statistical significances and correlations that would not be obtainable using principal component analysis. The model resulting from the exploratory factor analysis was finally used as the hypothesized factor model for confirmatory factor analysis. The fit was evaluated based on the values of χ^2, the comparative fit index, Tucker–Lewis index, root mean square error of approximation and standardized root mean square residual. The questionnaire was given the name ChemApproach.

The results obtained in Study II indicated that the instrument was valid and that it can be used to explore the learning approaches of chemistry students. As a consequence of having a larger dataset than in Study I, the memorizing surface approach found in Study I merged with technical surface and the processing deep approach merged with active deep. Thus, the final scales obtained after the validation were: submissive surface, technical surface, active deep, and practical deep. The results obtainable with ChemApproach may be used to optimize the teaching conditions to best suit the specific group of students the instrument was used for, e.g. helping a certain student group to develop their learning skills.

4.3. Study III

Lastusaari, M., Laakkonen, E. and Murtonen, M. (2018) 'Persistence in Studies in Relation to Learning Approaches and First Year Grades: A Study of University Chemistry Students in Finland', *Scandinavian Journal of Educational Research*, under review.

Teaching given at universities for students who drop out or change their major subject may be considered as a waste of opportunities and also money. Therefore, it is of great importance to establish means of identifying students at risk of dropping out as well as to investigate what factors influence the students' persistence. If such information is available, it is possible to start considering how universities could affect the persistence and by what means that could be done.

Study III aimed in proposing a model for the prediction of persistence and drop-out. The goal would be reached by investigating the connections between intentions to change major subject, actual persistence, first year chemistry grades and learning approaches. The ChemApproach questionnaire was used to collect learning approach data from 733 bachelor level students in four Finnish universities. For a subset from one university ($N = 177$), complementing information about persistence and first year chemistry grades were obtained from the statistics of that university. First, the ChemApproach data of the whole dataset ($N = 733$) was subjected to confirmatory factor analysis to confirm the factor structure obtained in Study II. The fit was evaluated from the values of χ^2, the comparative fit index, Tucker–Lewis index, root mean square error of approximation and standardized root mean square residual. Mean learning approach score variables were calculated and one-way ANOVA was employed to study if there were learning approach differences between students how intended or did not intend to change their major. Next, the factor structure of the subset ($N = 177$) was confirmed with confirmatory factor analysis based on the goodness-of-fit values described above. The subset data was grouped according to intentions and actual persistence. Grade point averages were calculated for first year chemistry courses and (practical deep score):grades ratios were calculated. One-way ANOVA was employed to study for differences between the groups, grades, (practical deep score):grades ratios and learning approach features. Because of the small number of students in one of the groups, also nonparametric Kruskal-Wallis H tests were carried out.

The results of Study III confirm four distinct approaches to learning, i.e. submissive and technical surface as well as active and practical deep. The data suggests that persistence is most importantly affected by the during-studies influence. If a student has a high submissive surface score, he is at high risk for dropping out ($p = 0.001$). In contrast, with a low submissive surface score the (practical deep score):grades ratio is the best predictor of persistence ($p < 0.001$). With the practical deep dominating over grades, a student is most likely to persist. These findings are summarized below in Figure 6.

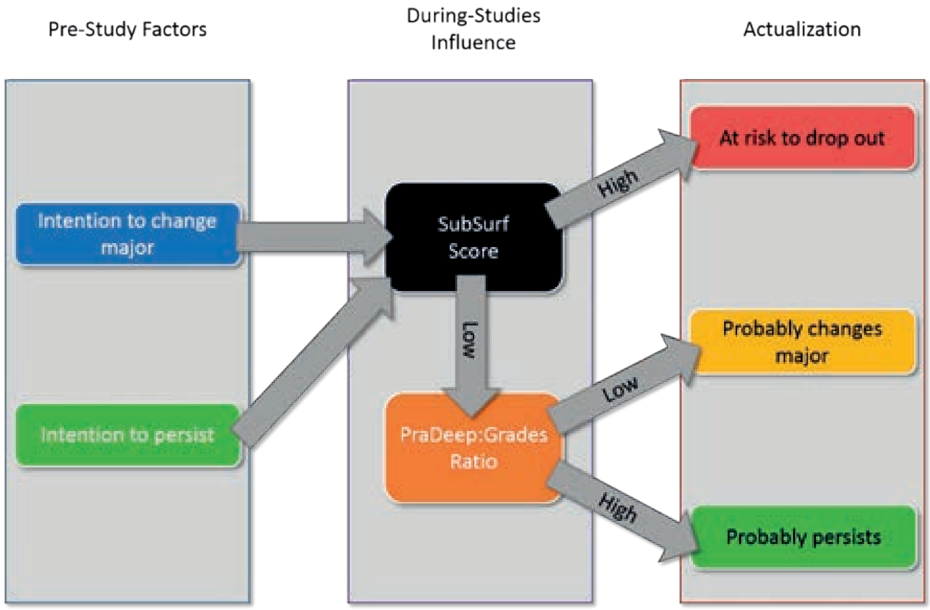

Figure 6. *The findings of Study III set to the general three-stage framework common to models of persistence.*

The results confirm that the ChemApproach questionnaire can be used to identify chemistry students at risk of not persisting. Thus, the questionnaire may serve as a useful tool for evaluating the necessity of changes in teaching to minimize the risks possibly leading to dropping out or change of major.

5. DISCUSSION

5.1. Learning approaches reflect motivation and commitment towards chemistry

The main goal of this work was to utilize the learning approaches of students having chemistry as their major or minor subject at university for predicting persistence and/or drop-out. Studies I, II and III revealed four distinct learning approaches associated with chemistry students: submissive surface, technical surface, active deep and practical deep. The first three can be thought to be present in the learning of all fields of study (i.e. disciplines), but the practical deep is strongly associated to fields where laboratory work is essential. That approach indicates a person who uses laboratory work as a means to learn chemistry deeply.

The results of both Study I and Study III indicate that those students that have the desire to change their major subject score higher in the surface scales and lower in the deep scales than do those students that do not want to change their major. Overall, according to Study III, the technical surface scale is the surface scale that shows the highest scores for the students. On the other hand, the practical deep scale is the deep learning approach that is most used by the students in the present study.

If one considers that a learning approach is a combination of motivational and strategic aspects (Vanthournout *et al.*, 2014), one could say that those who wish to change their major study chemistry predominantly in a "quantitative" way whereas those who want to stay in their major focus on "quality". If a student has the motivation outside of chemistry, he will have a strategic aim to pass as many chemistry courses as possible with as little time as possible wasted on thinking about the theoretical background of chemistry. This means that the student will have a lack of commitment towards chemistry (Mäkinen, Olkinuora and Lonka, 2004) but a strong extrinsic motivation to complete chemistry courses (Mikkonen *et al.*, 2009). Thus, he will use a surface approach to learning. In this work, it was the technical surface, because it involves active surface learning with the student having belief in himself concerning completing courses efficiently. A pure technical surface student will memorize things by using actively different memorizing techniques. This approach is strongly connected with the organized studying approach, which has also previously been reported to be a feature resulting in good grades and efficient earning of grade points for e.g. law students (Haarala-Muhonen *et al.*, 2017), bioscience students (Rytkönen *et al.*, 2012) and chemistry students (Li, Liang and Tsai, 2013). On the other hand, if a student wants to become a chemist, he will spend more time on understanding the backgrounds of the things to be learned, i.e. use a deep approach. In the present work, this was manifested by the use of the practical deep approach. It involves the student emphasizing especially chemistry laboratory work as the means to learn and understand the theoretical basis of chemistry. This ties well with the previous observation that if a student feels that he needs certain skills in his future work, he will use more deeply oriented approaches than if no such need is felt (Murtonen *et al.*, 2008).

It must be kept in mind that the intention to change major subject does not itself mean that a student would not persist with chemistry. However, it serves as a strong indicator that a student is not motivated or committed to studying chemistry deeply, at least not at that moment. The level of motivation may increase later, e.g. if the student cannot acquire a study position in his preferred major. Such lack of motivation or commitment may act as a factor that makes learning chemistry more difficult at a later point, if the student would persist with chemistry against his initial desires. This is because the predominance of a surface learning approach can indicate that the student's understanding of chemistry has not reached the submicro corner of the chemistry triangle.

5.2. Learning approaches may predict students at risk

Because of the importance of having early warning systems for the prediction of students at risk (Kuh *et al.*, 2006), the main aim of this study was to evaluate whether learning approach features could be linked to actual persistence at chemistry studies. Previous literature on this subject appears to be non-existent. However, Study III showed that such a link actually does exist.

In Study III, the students who dropped out completely showed high scores in the submissive surface scale. A pure submissive surface approach would imply studying chemistry in a passive way by just memorizing things. The student would have no interest in learning or will to put effort in learning. It may be that he does not even believe in his abilities in learning chemistry. Therefore, it seems that these students with a high degree of the submissive surface approach do not really know what to do with their studies. This means that they lack the strategic or organized component. They are thus very different from those who wish to change their major and employ the technical surface approach, since such strongly strategically oriented students do not show any submissiveness (Mäkinen, Olkinuora and Lonka, 2004). The fact that the students who dropped out showed submissive features in their during-studies phase can be interpreted in terms of the persistence model of Tinto (Tinto, 1975, 2010) that they have not experienced good enough integration to the academic and/or social systems at the university.

A low score in the practical deep approach was another indicator observed in Study III for students at risk of not persisting with chemistry. Such low score was not associated with students who dropped out but only to students who were successful in changing their major. These students did not show the high submissive surface score, either, which indicates that they probably had no problems in becoming members of the academic and social systems of the university. However, because their commitment was strongly outside of chemistry, they kept their commitment and left chemistry studies despite the good integration. This means that they were able to obtain a better interest-major fit (Allen and Robbins, 2008) by changing their major.

5.3. Are there ways to support persistence in chemistry studies?

The ultimate goal of the present thesis work was to have suggestions for increasing persistence. Based on the results discussed above in chapter 5.2. it is clear that one should focus on decreasing the submissive surface and increasing the practical deep scores to support persistence.

It seems rather straightforward that the decrease of submissiveness will require measures that help the students' integration to the university systems. That would require the buildup of a system that will make the transition from high school to university easier, give counselling and advice to help identification and commitment as well as to improve study skills (Habley, Bloom and Robbins, 2012), and involve students in learning communities (Kuh *et al.*, 2006; Graham *et al.*, 2013). As an example of such a setup is that initialized at the chemistry department of University of Turku in 2013. It involves the early engagement of students to learning groups, early introduction of the research done at the department, early involvement in laboratory work, and using a boosted tutor teacher system. Because of the high importance of the first study year when persistence is considered (Willcoxson, Cotter and Joy, 2011) this setup starts from the very first study week of the students at university. Such system has decreased the amount of drop-outs from 6 % between 2010 and 2012 to 3 % between 2013 and 2015. In the same time intervals, the average annual number of students changing their major has decreased from 46 % to 31 %, because of these measures (Lastusaari, Murtonen and Laakkonen, unpublished).

Increasing the practical deep approach will be more difficult, because it will involve adjusting teaching in a wide spectrum at departmental level. It seems, however, that even more pin-pointed general actions such as those described above for University of Turku may have a marked effect. In line with the"persistence framework" of science students (Graham *et al.*, 2013), chemistry students should be involved in real chemistry research as soon as possible and introductory chemistry courses should engage in active learning. Similarly, the results of the present thesis study imply that the amount of laboratory work should be increased in order to increase persistence as well as enhance learning. Of course, a mere increase in the amount of laboratory work would not be sufficient unless the exercises can be made something more activating than such that can be completed by simply following instructions. These measures will help the students to identify themselves as chemists as soon as possible. The difficulty with these is that they require additional work power or drastic reorganization of resources. For example, in Finland the introductory chemistry courses are mass courses, i.e. so many students participate in them that it is practically impossible to put introductory courses into practice by any other means than lecturing, except if more work power can be recruited. It seems thus clear that faculty, university or even government level changes or decisions are needed in order to have the possibility to improve the practical deep approach scores as much as possible.

Finally, one important countermeasure against attrition is to have a working system for the early identification of students at risk (Kuh *et al.*, 2006). This should be a tool that is easy to use and that gives results that can be easily interpreted. Based on the results obtained in the present work, the ChemApproach questionnaire developed during this thesis work promises to be such a tool.

5.4. Reflections on the quality of the studies and research ethics

In this thesis work, quantitative methods were used to investigate the learning approaches and their interplay with persistence in studies as well as first year grades. If one thinks that the new questionnaire could reach general use among university chemistry teachers, it should be easy to use. The only way to obtain that was to construct it so that the data input in the questionnaire would require no extra interpretation. Thus, a qualitative or a mixed method approach was not considered, even if that could render the results biased in some way (Lindblom-Ylänne, Parpala and Postareff, 2014). There are a few factors that need to be considered, when thinking about the generalizability of the results.

The first factor is the specialty of the Finnish university system. In Finland, the background of the students entering bachelor education at universities is very homogeneous. All students have gone through the compulsory public nine-year primary school, which has the same contents for all students. After that, almost all students enrolling into universities have studied in public high schools. A small per cent may come from public vocational schools. By default, one can assume that all students have had the same quality of schooling regardless of, for example, their parents' societal status. At the bachelor level also the ethnicity of the students is very homogeneously Finnish, and those with foreign background would already have integrated to the Finnish schooling system before university. Another special feature of the Finnish system is the use of the natural sciences as a springboard towards medicine. Such a homogeneous set of students and the presence of such a high number of students willing to change their major subject may have affected the results in the present thesis work in such way that it was possible to concentrate on the most important factors, i.e. the learning approaches and persistence. This is because no disturbing additional factors would be present and because such a large amount of major changers could be investigated. Therefore, even if the problem of student attrition is worldwide, the Finnish system actually offers a very good platform for isolating and thus identifying the learning approach features that are connected with persistence.

The second factor is the size and representativeness of the sample. In Study I, the number of participants was 118 and Cronbach α values were calculated for all scales identified with principal component analysis. The values varied from varied from 0.54 to 0.81, and thus some of them fell out of the commonly accepted range of 0.70 to 0.95 (Bland and Altman, 1997). Nevertheless, the values below that range are still not any lower than those presented previously in similar types of data handling (Lonka and Lindblom-Ylänne, 1996). The lower α values may be considered as an indication that the items are not as uniformly describing an approach as would be the case with higher α values. In fact, in Study II, which consisted of a dataset from 561 students, it became evident that two of the approach features found in Study I would need to be merged with two others. Thus, the dataset in Study I had, indeed, been too small to get a comprehensive view of the scale structure. On the other hand, the whole dataset (N = 561) in Study II enabled the building of a model of four learning approach types, and the validity of this structure could be verified with confirmatory factor analysis. Subsequently, the data was divided to subsets which passed tests for configural and metric invariance. Tests for scalar invariance were successful for all but three items out of the total 21 ones. These were linked with differences in the features between the genders, but since all other items in the same scale reached invariance, the model could be verified to work even in smaller subsets. Finally, in Study III, the whole dataset from 733 students was confirmed to suit the four factor model established in Study III by confirmatory factor analysis showing good fit and reliability. The 177 student subset from one university was also proven to fit the same four-factor model based on confirmatory factor analysis. After the division of this group to five more subgroups based on persistence, these subgroups were so small that it was necessary to carry out a nonparametric independent samples Kruskal-Wallis H test, but it was observed to comply with the results of one-way ANOVA. Therefore, all the results of this thesis work were proven statistically reliable and valid.

One thing that would provide the results of this thesis work even more solidity would be comparisons with established SAL instruments. From the point of view of good scientific research practice, the use of multiple methods for the same purpose would even be essential. However, all the results discussed above as well as in the publications of Studies I – III have proven that the ChemApproach instrument is a powerful and obviously a valid tool for probing learning approaches of chemistry students.

All research reported in this thesis were carried out according to the ethical guidelines for responsible conduct of research issued by the Finnish Advisory Board on Research Integrity (2012). Furthermore, data collection, handling and analysis was done following the Finnish ethical principles of research issued by the National Advisory Board on Research Ethics (2009). This means that the following points were carefully followed: 1) The autonomy of research subjects. All participating students were volunteers and all gave their written consent for participation. The participants were told what the study is about, what participating in the study would mean in concrete terms, how long it would take to participate and who is the contact person for the study. 2) Avoiding harm. All students were informed that consenting or not consenting would not affect their status or grades. Moreover, the research was carried out in such way that no mental, financial and social harm could result for the students. 3) Privacy and data protection. Each database for empirical studies was processed in such a way that the participants could not be identified at any stages of data handling or from published results. Primary data with identification is stored only by the three people listed as authors in Studies I-III. Permission to obtain the identification data will not be given to others.

5.5. Conclusions and directions for future research

This thesis work enabled the development of a new instrument for studying learning approaches. This instrument, ChemApproach, is specially designed for chemistry students. As one part, it includes a practical deep approach scale that addresses learning approaches connected to chemistry laboratory work. This kind of a unique scale, that is not available in any established SAL instrument, was proven very powerful in the identification of students prone to change their major subject. Similarly, the submissive surface scale of ChemApproach was confirmed to be a good meter for recognizing students at risk of dropping out of studies.

These two scales are clearly linked to the integration to the social and academic systems at the university (the submissive surface scale) as well as the functionality of laboratory courses (the practical deep scale). Therefore, the results obtainable by using the ChemApproach questionnaire can be used for evaluating the effectiveness of departmental practices and teaching as well as for suggesting changes in these.

Although the questionnaire was designed for chemistry, there should not be any problem in adjusting the items' wordings to match any other disciplines that use practicals as a form of teaching. This is also one of the future directions for research: to test the questionnaire in other disciplines. Another future research will be to utilize the ChemApproach instrument in other countries to see how the instrument will maintain its usability in such cases where the student population is more heterogeneous than in Finland. It is also essential to test the ChemApproach intrument's functionality against those of established SAL questionnaires, and this will be done in the future, as well. In the context of learning chemistry, it would be very interesting to combine the data obtained with ChemApproach with data on conceptual change and epistemological beliefs. In terms of persistence, the combination of ChemApproach data with information on motivation and regulation as well as academic and social integration could yield fruitful results. In addition, it will be very interesting to study how the recent changes made by the Finnish government resulting in the more difficult admission to other study positions after accepting one study position will affect persistence in the future. These may also be where this research will continue.

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APPENDIX

The ChemApproach questionnaire (English translation).

ChemApproach

HOW DO I STUDY AND LEARN CHEMISTRY

Mika Lastusaari and Mari Murtonen
University of Turku, Finland

University of Turku

A) Background information

Student number or name:
Gender: Female ☐ Male ☐
Major subject:
Study year (first, second, etc.):
Do you intend to change your major subject? Yes ☐ No ☐
To which major?
Have you given your reply to this same questionnaire before? Yes ☐ No ☐

The results will be handled and reported anonymously. Identification information will be replaced with codes, and thus individual persons cannot be identified later. The identification information is used only for combining results from different years.

Permission

I hereby give my permission to use my replies in this study.

Date ______________________________

Signature ______________________________

Print name ______________________________

B) Preparation for a chemistry examination

	Disagree totally		In between		Agree totally
I underline while reading for chemistry examination.	☐	☐	☐	☐	☐
I study the answers to previous chemistry exams, if they are available.	☐	☐	☐	☐	☐
I divide the course material to parts, which I learn for the chemistry examination.	☐	☐	☐	☐	☐
When reading for a chemistry examination, I try to make summaries of different unities with my own words	☐	☐	☐	☐	☐
It is usually easier to study for an exam by using course handouts than a textbook.	☐	☐	☐	☐	☐
Many things that I learn remain isolated and do not link as a part of a bigger picture.	☐	☐	☐	☐	☐
Usually, one really must understand things in order to pass a chemistry exam.	☐	☐	☐	☐	☐
When reading the course material, I often do not understand how a new topic relates with any old one.	☐	☐	☐	☐	☐
I make my own notes when studying for an examination.	☐	☐	☐	☐	☐
I learn everything exactly as it has been presented in the course handouts/textbook.	☐	☐	☐	☐	☐
I have to memorize things without having the opportunity to understand them.	☐	☐	☐	☐	☐
Course web pages are usually important for learning the things taught during the course.	☐	☐	☐	☐	☐
When I am preparing for a chemistry exam, it does not matter if I don't understand what a matter to be learned is connected with.	☐	☐	☐	☐	☐

Please turn over

APPENDIX continued

C) Chemistry lecture

	Disagree totally		In between		Agree totally
I make myself acquainted with the content of a coming lecture beforehand.	☐	☐	☐	☐	☐
After a chemistry lecture, I often chew over the things taught.	☐	☐	☐	☐	☐
Based on chemistry lectures, I find it easy to imagine working on this field after graduation.	☐	☐	☐	☐	☐
I remember many separate things from chemistry lectures.	☐	☐	☐	☐	☐
I learn a new thing easily, if it is presented in a written form.	☐	☐	☐	☐	☐
It is essential that all the things presented in course handouts/web pages/textbook are dealt with during lectures.	☐	☐	☐	☐	☐
During a chemistry lecture, I often do not understand what a new thing is connected with.	☐	☐	☐	☐	☐

D) Studying chemistry

	Disagree totally		In between		Agree totally
I find it easy to learn things by memorizing them.	☐	☐	☐	☐	☐
I usually search and read additional material concerning the course.	☐	☐	☐	☐	☐
I try to fit parts of a course into a whole picture.	☐	☐	☐	☐	☐
I often chew over the thoughts awoken by scientific texts as well as connections between them.	☐	☐	☐	☐	☐
I look for justifications and evidence to make my own conclusions about things to be learned.	☐	☐	☐	☐	☐
I make mnemonics to learn things better.	☐	☐	☐	☐	☐
If I don't understand the connection between a new thing and what I have learned before, I try to clarify the connection.	☐	☐	☐	☐	☐
After a chemistry lecture, I usually return to the taught subject by reading a book, notes or handouts.	☐	☐	☐	☐	☐
I try to think about possible connections between chemical phenomena and everyday life.	☐	☐	☐	☐	☐
Calculation exercises usually help learning a new thing in chemistry.	☐	☐	☐	☐	☐

E) Chemistry practicals

	Disagree totally		In between		Agree totally
I like to do practicals.	☐	☐	☐	☐	☐
I have often understood a chemical phenomenon only after doing practical work on it.	☐	☐	☐	☐	☐
When doing a practical, I usually try to understand what its different parts are based on.	☐	☐	☐	☐	☐
One can learn a chemical phenomenon only by doing practical work on it.	☐	☐	☐	☐	☐
During chemistry practicals, my main goal is to complete the work acceptably.	☐	☐	☐	☐	☐

Thank you for your answers!

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