

Päivi Porras

UTILISING STUDENT PROFILES IN MATHEMATICS COURSE ARRANGEMENTS

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Abstract

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This thesis develops a method for identifying students struggling in their mathematical studies at an early stage. It helps in directing support to students needing and benefiting from it the most. Thus, frustration felt by weaker students may decrease and therefore, hopefully, also drop outs of potential engineering students.

The research concentrates on a combination of personality and intelligence aspects. Personality aspects gave information on conation and motivation for learning. This part was studied from the perspective of motivation and self-regulation. Intelligence aspects gave information on declarative and procedural knowledge: what had been taught and what was actually mastered.

Students answered surveys on motivation and self-regulation in 2010 and 2011. Based on their answers, background information, results in the proficiency test, and grades in the first mathematics course, profiles describing the students were formed. In the following years, the profiles were updated with new information obtained each year. The profiles used to identify struggling students combine personality (motivation, self-regulation, and self-efficacy) and intelligence (declarative and procedural knowledge) aspects at the beginning of their studies.

Identifying students in need of extra support is a good start, but methods for providing support must be found. This thesis also studies how this support could be taken into account in course arrangements. The methods used include, for example, languaging and scaffolding, and continuous feedback. The analysis revealed that allocating resources based on the predicted progress does not increase costs or lower the results of better students. Instead, it will help weaker students obtain passing grades.

Keywords: engineering mathematics, motivation, self-regulation, learning, teaching

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In 2010, I was participating in a seminar on mathematics education. On the way back home, I started to mull over the idea of this thesis. I wish to give special thanks to Alpo Jääskeläinen and Matti Heiliö for not shooting down my almost senseless ideas. This journey has definitely changed my perception of psychology and learning, and hopefully, it will also have an influence on the learning results of my students.

I wish to express my sincerest gratitude to my colleagues Perttu Laivamaa and Petteri Karkkulainen. This research would have been impossible without your help, as you have given the data, criticised my findings, and given support at the right time. Special thanks to Petteri for helpful hints in my continuous fight with Word. I am also grateful to all my superiors for their support during the research.

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To my wonderful husband Jari, I wish to express my gratitude for your comments and support during the research. Without your suggestions, this would have taken much more time. I love you.

To my lovely children Henna, Hans and Neea, I would like show with this thesis that anything is possible. Believe in your abilities.

Lopuksi haluan esittää erityiskiitokset äidilleni Leilalle. Ilman sinun ja edesmenneen isäni Taiston myötävaikutusta ja tukea olisin tuskin koskaan lähtenyt akateemiselle uralle.

Päivi Porras
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Contents

List of publications	9
1 Introduction	11
1.1 Introducing the chapters	14
2 Theoretical framework	15
2.1 Personality in learning	18
2.1.1 Motivation.....	18
2.1.2 Self-Regulation	22
2.2 Intelligence.....	25
2.3 Learning instruments.....	26
2.3.1 Understanding	27
2.3.2 Easy ways for teachers to promote learning	28
3 Research goal and methodology.....	31
3.1 The research problem.....	31
3.2 Research process	32
3.3 Measuring the learning aspects	34
3.3.1 Motivation survey	34
3.3.2 Self-regulation survey	36
3.3.3 Mathematical knowledge	39
4 Summary of publications.....	41
4.1 Publication I: Motivation towards Mathematical Studies in Engineering41	
4.1.1 Research objectives and methods	41
4.1.2 Results.....	41
4.1.3 Relation to the whole	42
4.2 Publication II: Enthusiasm towards Mathematical Studies in Engineering42	
4.2.1 Research objectives and methods	42
4.2.2 Results.....	42
4.2.3 Relation to the whole	43

4.3 Publication III: Profiles of Engineering Students in Mathematics	43
4.3.1 Research objectives and methods	43
4.3.2 Results.....	43
4.3.3 Relation to the whole	43
4.4 Publication IV: Students' conceptions of their learning may help in predicting their progress	44
4.4.1 Research objectives and methods	44
4.4.2 Results.....	44
4.4.3 Relation to the whole	44
5 Results and discussion.....	45
5.1 Further analyses of prediction.....	46
5.2 Further actions on course arrangements.....	51
6 Conclusions	57
6.1 Summary and contributions	57
6.2 Limitations of this study	59
6.3 Future research.....	59
7 Bibliography	61
Appendix A. Motivation survey in Finnish.....	71
Appendix B. Self-regulation survey in Finnish	77
Appendix C. Forming profiles	81
Appendix D. Final profiles in Finnish	83
Appendix E. Publications	85

List of publications

This thesis is based on the following papers. The rights have been granted by publishers to include the papers in this dissertation.

- I. Porras, P. (2011). Motivation towards Mathematical Studies in Engineering, In: Stillman G. *Proceedings of ICTMA15*, <http://www.ictma15.edu.au/>.
- II. Porras, P. (2012). Enthusiasm towards Mathematical Studies in Engineering. In: Tai-Yih Tso *Proceedings of the 36th Conference of the International Group for the Psychology of Mathematics Education*, 3, pp. 313-320.
- III. Porras, P. (2012). Profiles of Engineering Students in Mathematics. In: Björkvist M.-J. et al. *International Conference of Engineering Education 2012*, 1, pp. 50-56.
- IV. Porras, P., Turunen, J. (2014). Students' conceptions of their learning may help in predicting their progress. *Educational Alternatives*, 12, pp. 49-57.

Author's contribution

The only joint article is paper IV. I analysed the data and I am also the principal author of the article.

1 Introduction

Engineering is traditionally understood as incorporating skills to manage technical challenges. Engineering challenges are becoming more and more complex and they also require knowledge from many other fields, e.g. social, environmental, and economic. Grasso et al. (2010) talk about holistic engineering instead of isolated engineering. According to them, holistic engineers can manage, lead and understand complex systems involving also non-engineering fields like law, public policy and arts. Thus, in order to succeed in the field of engineering, engineers must be able to adapt new knowledge continuously.

It is impossible to work as a professional in the field of engineering technology without mathematical knowledge, although programs and computers do most of the calculations. In fact, as Kilpatrick et al. (2001) point out, technology is built on mathematical knowledge: good jobs require high level mathematical expertise. However, more and more students have difficulties in passing mathematics courses in Finnish universities of applied sciences. Several articles deal with the similar phenomenon all around the world (Carr, Bowe, & Fhloinn, 2010; Schwenk & Kalus, 2010; UniversityAffairs, 2010; Warwick, 2006; Hearne, 2002; Engineeringtalk, 2001). Schwenk and Kalus (2012) have long-term data on students' elementary mathematical skills. Their results are evaluated with respect to their previous school, their gender, voluntary participation in a bridging course, and migration. Fortunately to them, the decrease in the average score in the proficiency test seem to stop or at least slow down in their university. However, all of these articles express a concern about mathematical skills in engineering.

Development of mathematics teaching has traditionally meant development of the mathematics curriculum. In past decades, teaching methods have shifted away from the traditional and rather behaviouristic approaches. Like E. G. Begle has formulated, the problem is no longer so much teaching better mathematics as it is teaching mathematics better (Kilpatrick, Swafford, & Findell, 2001). Students are seen today in a social-constructive context, where the social environment (teachers, family, friends, etc.) and pre-knowledge have an influence on learning. In a constructive conception of learning, a person is thought of as an active builder, constructing knowledge based on his or her own comprehension and experience.

These cognitive structures play an important role in learning. They are not included in the theory of this thesis, but may explain the teaching methods used. Bellmer (2010) showed an example of division. The division $\frac{6}{2}$ may have been explained as 6 euros is divided evenly to two persons. Consequently, the division $\frac{6}{0}$ may get be explained either as

1) 6 euros is distributed among zero persons, so there is still 6 euros $\Rightarrow \frac{6}{0} = 6$,

or

2) 6 euros is distributed among zero persons, so nobody gets anything $\Rightarrow \frac{6}{0} = 0$.

Many of these types of cognitive structures are modified already at the primary school level, and for that reason have a significant influence on learning.

Students with less experience in mathematical expressions may have difficulties in understanding the meaning of the expression and how it can be further handled. A common mistake is simplifying terms from the sum, for example $\frac{x+1}{x} = 1$. However, when numbers are used instead of x , students usually see the absurdity of their simplification. Some students have great difficulties in understanding the equality of expressions like $\frac{x}{2}$ and $\frac{1}{2}x$.

Learning at an individual level is a complex process, which involves pre-knowledge (cognitive structures), interest (motivation) and actions (self-regulation, self-efficacy). None of them should be omitted when discussing learning. *Motivation* is a key element. Many people engage in recreational activities in which they are ready to learn new things or practise a procedure continuously just to learn to do it correctly (Linja-aho, 2011). Because people are interested in their hobbies, they are prepared to spend time and make an effort to develop. *Self-regulation* is an essential part in adapting new knowledge. A learner takes personal responsibility for learning by setting goals and monitoring the learning. Self-regulated engineers can monitor and control their knowledge. All of these aspects are highlighted in online learning where focusing is easily disturbed by, for example, social media. The degree to which a student believes he or she is capable of performing mathematics, is referred to as *self-efficacy*. Although students may be motivated, if they do not believe in themselves, learning may be a struggle. With low self-efficacy, it is almost impossible to regulate one's learning: set goals, ask for help, etc. A student may be motivated but have low self-efficacy causing resistance to learning.

Many studies have been conducted on teaching and learning mathematics. For some reason or another, the studies mostly handle primary school mathematics, such as articles in the International Journal for Mathematics Teaching and Learning. When articles are searched with

keywords “teaching learning mathematics”, most of studies handles affective area of personality, like attitudes, self-efficacy beliefs, and anxiety: Mammarella, Hill, Devine, Caviola, and Szucs (2015), Cvencek, Kapur, and Meltzoff (2015), Aliasgari, Riahinia, and Mojdehavar (2010), Miller (2010), Gil Ignacio, Blanco Nieto, and Guerrero Barona (2006), Malmivuori (2002), etc. Few books could be found dealing with adults’ learning in mathematics, for example Fitzsimons (2002) Coben, O’Donoghue and Fitzsimons (2000), Evans (2000). Some studies address web-based learning in mathematics and requirements of technology for successful learning, like those by Novak and Tassel (2015), Martinovic, Freiman and Karadag (2013), and Mansoor (2008).

In the field of university mathematics, the International Commission on Mathematical Instruction (ICMI) has published several studies on different aspects such as teaching and learning mathematics in general or on particular topics, cultural aspects, challenges in classrooms, digital technology in teaching and learning, and educational interfaces between mathematics and industry (ICMI, n.d.). Some studies on university mathematics concern new teaching methods. For example, Westover and Westover (2014) used blended learning in their mathematics course and Sahin et al. (2015) employed flipped learning.

Today, teaching may be done in a more open context, such as problem based (Pehkonen, Hannula, & Björkqvist, 2007) and project based learning (Capraro, Capraro, & Morgan, 2013; Moursund, n.d.), or students are assumed to study new topics on their own and do exercises at school, as in flipped learning (or a flipped classroom) (Kivilahti, 2014; Sahin, Cavlozoglu, & Seytunuc, 2015; Hogarth, 2010). In blended learning, some part of learning happens with online material (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011). All these teaching methods have advantages and disadvantages (Xiuping, 2002; Freeman Herreid & Schiller, 2013; Fabris, 2015). Kilpatric et al. (2001) point out that despite the teaching methods used, students need both open and constrained opportunities to learn and to become proficient in mathematics. Combined, they will upgrade students’ understanding to the higher level needed in the technological world.

Every academic year, mathematics teachers in technology education confront new engineering students with different mathematical backgrounds and different levels of enthusiasm for studying mathematics. There are always mathematically weak and strong students, students highly interested in engineering and ones not knowing what they want to do in the future, and students belonging to none of these groups. As the resources for teaching are limited, recognising the enthusiastic and potentially graduating students is almost crucial. The challenge in recognising is that neither mathematical skills nor enthusiasm for engineering alone reveals the potential for success in engineering studies.

In Tampere University of Technology (Silius, Pohjolainen, Kangas, & Joutsenlahti, 2011), Finland, all freshmen participate in a computer-aided Mathematics Basic Skills test. The students with the lowest scores are directed to Mathematical Remedial Instruction to bridge the competency gap to university mathematics. In this Basic Skills test, students are also asked to select the profile best describing their learning habits. The profiles used are 1) skilful students

(positive attitudes and self-efficacy), 2) independent learners (study on their own), 3) surface level learners (do not take responsibility for their learning), 4) peer learners (study in groups), and 5) students needing support (attitudes are weak and give in easily). Based on the selected profile, the student is recommended an appropriate study method.

Although teachers feel that many students have poor skills in mathematics, not all those students drop out of or struggle with passing courses: this cannot be explained solely by the influence of previous education (Publication I). Some characteristics in students may explain why some of them cannot succeed in mathematics courses. These qualities might relate, for example, to students' learning styles, self-regulation and motivation.

The main focus of this thesis is on personality and intelligence: how they could predict progress in mathematics. In other words, is it possible to identify students who may struggle with their mathematics studies, but have potential to become engineers. Identifying alone is not enough, but it is also very important to support the student's learning. As Silius et al. (2011) point out, there is a need for student-centred methods to support learning. The second part of the thesis concentrates on course arrangements that support learning and can easily be taken into use. These methods should increase, or at least maintain, motivation and positive self-efficacy.

1.1 Introducing the chapters

This thesis is divided into main chapters and appendices. Chapter 2 presents the theoretical framework of this study. It includes psychological aspects (personality and intelligence) and teaching aspects (supporting) of learning theory. The process of the research is explained in Chapter 3. The motivation and self-regulation surveys are explained more deeply and the development of the prediction model is described. Chapter 4 includes a summary of publications. In Chapter 5, data is further analysed with information obtained in autumn 2014. The effects of actions to improve the passing rates of courses are presented. The study is concluded in Chapter 6 and some ideas for new research are introduced. Appendices contain surveys in Finnish, rules for forming the profiles, the final profiles in Finnish, and publications.

2 Theoretical framework

Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially. The process of learning has as its foundation the systemic, dynamic, and interactive relation between the nature of the learner and the object of the learning as ecologically situated in a given time and place as well as over time.

(Alexander, Schallert, & Reynolds, 2009)

The learning of an individual is affected by personality and intelligence (Kyrö, Mylläri, & Seikkula-Leino, 2008; Koiranen & Ruohotie, 2001). Figure 1 shows which psychological areas are involved. Personality influences through the affective area, which is attached to values and attitudes and appears as emotional reactions, and through the conative area, which is attached to motivation and conation. In learning, the affective area influences the motivation to perform, fear of failing, creating and utilising opportunities, and adventurism. The conative area is about the conscious facility to act (motivation) and aptitude for performing the task (e.g. self-efficacy). The cognitive area includes the ability for abstract thinking (declarative knowledge) and the ability to apply the knowledge (procedural knowledge). In this thesis, intelligence is restricted to knowledge and skills. (Kyrö, Mylläri, & Seikkula-Leino, 2008)

Alexander, Schallert, and Reynolds (2009) have studied learning from a slightly different point of view. Where Snow, Corno and Jackson (1996) concentrate on personality and intelligence, Alexander et al. see learning in four dimensions: *what*, *where*, *who*, and *when*. Whether the *what* in learning is about acquired habits (skills) or scientific conceptions (knowledge), it is affected by the social-cultural context *where* the learning occurs, the cognitive and biological context (*who*), and the time context (*when*). All these dimensions interact with each other. Maybe the fifth missing dimension could be *why* (motivational aspects), representing the

conative area. Alexander et al. (2009) present nine principles of learning (see Table 1). Closer study of principles shows, that all aspects of personality and intelligence (Figure 1) are included.

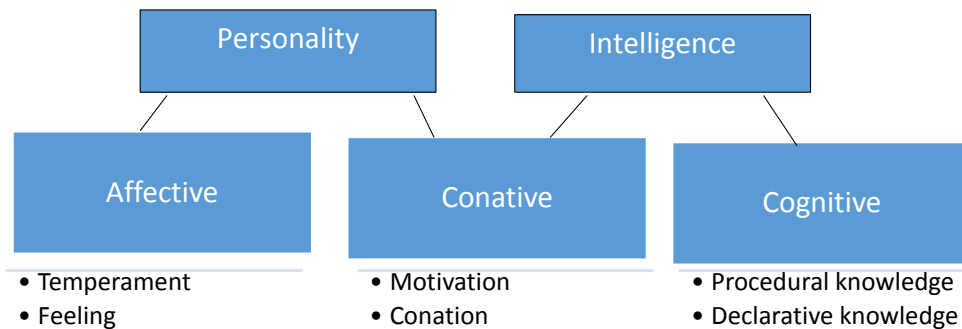


Figure 1. Construction of personality and intelligence (Koiranen & Ruohotie, 2001).

According to principle 1, learning is change that can range from imperceptible to dramatic, may occur instantly or over a long time, and is always systemic, that is, affects the learner's surroundings. The effect of learning is in all areas presented in Figure 1. The effect in cognitive area is obvious, but learning experiences will affect motivation, conation, and/or feelings either negatively or positively.

According to principle 3, learning can be resisted, which ensues from the affective area. Reasons for resisting learning may be that too much effort is required, the rewards are too small, or attaining the desired goal creates too much dissonance within the individual or the particular social system. All these are aspects of personality.

Epstein (2001) remarks that much learning happens subconsciously and without intent. Although a student is consciously studying a particular method in algebra, the student is also learning the language of mathematics, symbolic representations, etc. In education, usually both cases of principle 5 occur in learning.

Our humanness frames our learning in many ways (principle 6). Neurological and biological structures define how people experience the world: the tones they hear, how people reason, etc. All individuals are unique in their cognitive and non-cognitive factors, making us human.

Principle 7 states that learning should be thought both as a process and as a product. The process refers to the operations enabling learning and the product refers to the outcome. When the learning process is planned, also the product should be focused. Felder and Silverman (1988) handle learning and teaching from the individual's point of view to maximize learning.

Table 1. Principles of Learning (Alexander, Schallert, & Reynolds, 2009).

1. Learning is change.
2. Learning is inevitable, essential, and ubiquitous.
3. Learning can be resisted.
4. Learning may be disadvantageous.
5. Learning can be tacit and incidental as well as conscious and intentional.
6. Learning is framed by our humanness.
7. Learning refers to both a process and a product.
8. Learning is different at different points in time.
9. Learning is interactional.

According to principle 8, learning is affected by the stage of a learner (personality). Both the affective and conative area may change depending on the day but also based on the academic level achieved. The learning of a young child is different from that of an adult, as the life experience is not the same. Also, a novice does not learn in the same way as an expert.

Based on principle 9, learning is interactional, meaning that it is shaped by human culture and biology. In Finland, social class does not have so much effect on what kind of education is available, but the education perceived may have an effect on thinking. It may be that in lower educational classes the abstract thinking needed in higher education is not valued and practised very much, making academic lectures difficult to follow. If a student coming from a vocational college has always been surrounded by people who do not value theory, the student may not see the need for abstract thinking, and for that reason, unnecessarily restricts his or her learning. Thus, the social-cultural background affects one's learning: the will for change has not been strong enough. Also, the abstract thinking practised in upper secondary schools may undervalue the trial-and-error method that is sometimes needed in practical work, such as laboratory assignments.

Principles 2 and 4 are not of particular interest in the field of engineering and are thus omitted here.

2.1 Personality in learning

This section concentrates on the personality aspects of learning. The first subsection includes theories connected with motivation that have been used in formulating the motivation survey. The second subsection concentrates on self-regulation and self-efficacy, which are studied in the self-regulation survey.

2.1.1 Motivation

Motivation is the basis for learning. As principle 1 in Table 1 indicates, if there is no will for change, there is no learning, either. A student needs a motive (credits, graduating et cetera) to start studying, but actual studying is done with conation.

Naapila (2010) and Deci (Salmela-Aro & Nurmi, 2002, p. 16) state that a person modifies his or her motivation. External settings arouse extrinsic motivation onto suppositions, and little by little, intrinsic motivation starts to form. Figure 2 illustrates the forming of motivation in three phases: *extrinsic motivation*, *achievement (or autonomic) motivation*, and *intrinsic motivation*.

In the first phase (extrinsic motivation), a person acts, for example, in the hope of a reward. Homework is done because a teacher gives extra credit for it. Externally motivated students may lose their motivation quickly: a teacher is not nice, fellow students do not attend lectures, or lunch time is soon, etc. These students may be at risk in their studies.

Kauppila (2003) further divides extrinsic motivation into *avoidance motivation*, *diverged motivation*, and *escape motivation*. Students have *avoidance motivation* if they disregard or are reluctant toward the subject and have weak self-efficacy in learning achievements. Mathematics may also feel irrelevant to students, as they cannot relate to it personally (Guthrie, Coddington, & Wigfield, 2009). Ryan and Deci (2000) define amotivation as ‘the state of lacking an intention to act’. Sometimes, several failures may induce avoidance motivation (Förster, Grant, Idson, & Higgins, 2001).

Diverged motivated students have many other things on their mind, like work, hobbies or student union activity. The student is active but there does not have enough time to study. These students could excel in their studies if they concentrated on studying.

In *escape motivation*, a student simply tries to pass courses by memorising facts. The motive is to escape failure. Ryan and Deci (2000) define escape motivation as *external regulation*. These students do everything only for an external reward, such as extra credit for passing a course, or based on an external demand, such as ‘this must be done to pass the course’. The achievements of these students vary very much, and studying is at the surface level of learning, according to Kauppila (2003).

In the second phase (autonomic or achievement motivation), actions are performed for self-esteem: it a) to avoid guilt, anxiety or shame, b) to make an impression, or c) to appear to be better than the others. Grades are important to these students. Ryan and Deci (2000) refer to this as *introjected regulation*. These people act with a feeling of pressure. According to Bong (2009), they have performance-approach goals that often demonstrate positive association with self-efficacy and academic performance. Students with achievement motivation usually move forward in the curriculum. In some cases, high autonomic motivation may cause stress, and therefore, motivation may decrease or the student becomes exhausted. Ryan and Deci (2000) define the most autonomous motivation as *integrated regulation*. It is very close to intrinsic motivation, but is still extrinsic, as everything is done for 'its presumed instrumental value with respect to some outcome'.

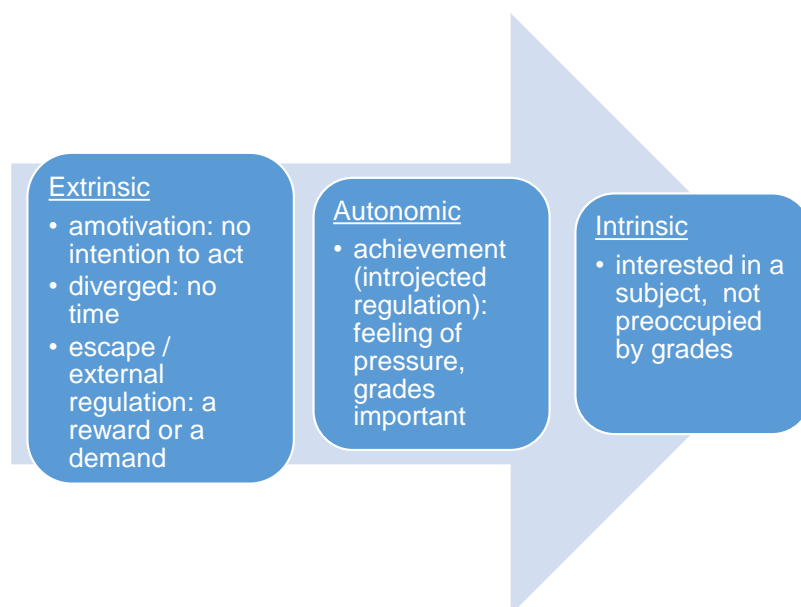


Figure 2. Phases of motivation.

In the third phase (intrinsic motivation), the learner understands the value of actions and/or is interested in the topic. Ryan and Deci (2000) define *intrinsic motivation* as 'doing the activity for its inherent satisfaction rather than for some separable consequence'. Intrinsically motivated students are interested in the subject and want to obtain deeper understanding; they spend a great deal of time on studying. The subject motivates them and grades may not be so important. In some cases, these students may be so fond of studying that they are not motivated to graduate (Lonka, Olkinuora, & Mäkinen, 2004). Ryan and Deci (2000) and Middleton and Spanias (1999) also state that all kinds of rewards, directives, deadlines and so forth diminish intrinsic motivation. Thus, autonomy seems to be important in intrinsic motivation. Ruohotie (1998) mentions that intrinsically motivated students may have high expectations and demands

for the curriculum and teaching. It could be said that most students apply for particular education spurred by extrinsic motivation, and it is the institution's duty to arouse intrinsic motivation.

According to the expectancy-value theory proposed by Wigfield and Eccles (2000), one's expectancies and values are assumed to influence achievement choices directly. Expectations are all beliefs one has about oneself and one's ability to perform the task (self-efficacy). Based on this theory, it is assumed that expectations of performing the task will affect one's motivation. Children who believe in their own abilities try hard despite difficulties and failures. They construe failure as not trying enough. Children who do not believe in their abilities expect failures and easily give up on tasks to avoid failure. This kind of behaviour in the long run leads to poor performance, and retaining a positive self-image becomes difficult. (Salmela-Aro & Nurmi, 2002)

Maslow (Madsen, 1974) introduced a motivation theory based on needs (see Figure 3). *Psychological needs* refer usually to man's system like hunger, thirst etc. Among students in universities of applied sciences, this could refer to the need for work. Many students have families and student grants may not be sufficient. Discussions with study advisors in Reflektori 2010 also revealed that many younger students who have just moved out of their childhood home, have problems in their everyday life, like shopping, eating, sleeping etc. When studying motivation for learning, the psychological needs could also include learning difficulties, such as dyslexia or Asperger's syndrome, or basic needs, such as fatigue and hunger. Psychological needs in this field are mostly not handled by a teacher. The only exceptions are learning difficulties, to which attention should be paid at least to some extent.

Safety needs refer to safety, the need for order and limits, protection etc. In this motivation study, they could be requirements for the courses, times of examinations, etc. All this basic information gives confidence to students as they know what should be done. These needs in learning do not differ from children's needs for order: they have to go to bed at a specific time decided by their parents. Similarly, students need to know what tasks must be done and when they should be done. Students may complain about requirements (like children), but keeping to them gives students a feeling of security.

Affiliative needs refer to the need for love, belonging, and affection. This can be seen as how well the student has affiliated to the study group and what the atmosphere is like in the lectures. It may also refer to an emotional anchor needed from other students and/or teachers. If affiliative needs are highlighted in student's motivation, a student may want to study with friends or in groups. (Rheinberg, Wollmeyer, & Rollett, 2000, p. 518)

Esteem needs refer to achievements and prestige. The student is concerned about grades and wants to be respected for his or her knowledge. *Self-actualisation needs* refer to 'man's desire for self-fulfilment, namely, to the tendency for him to become actualized in what he is potentially' (Madsen, 1974). The student is motivated by the subject, and other needs do not have such an impact.

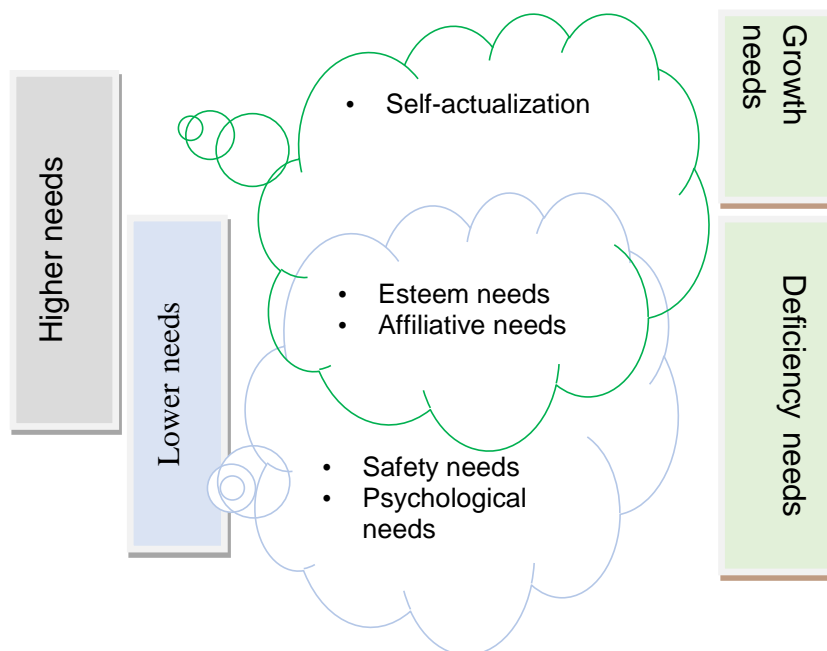


Figure 3. Maslow's hierarchy of needs (Madsen, 1974).

According to Maslow, the lower level needs must be satisfied before one is ready for higher level needs. Maslow based his theory on human life from infancy to old age, which makes the previous assumption logical. According to Leontjev (Salmela-Aro & Nurmi, 2002, p. 15), the hierarchy of motives is individual. The purpose of this study is not to find the correct hierarchy, but needs introduced by Maslow give us the basis for studying motivation among students. Obviously, motivation varies: if the student is tired or hungry, learning is not as good as it should be despite the student being highly motivated for the subject (Hannula, 2006).

These motivation theories were the basis for the motivation survey, which is handled more deeply in subsection 3.3.1. They all gave different aspects to the survey. Motivation psychology is a difficult field with various theories (Metsämuuronen, 2009). In this research, the theoretical background is studied as a *realistic theory*, i.e. as the assumed truth. The main idea is not to validate existing theories but to find factors indicating weak motivation. If these factors could be recognised, there may be a possibility to find methods for supporting students in their studies.

2.1.2 Self-Regulation

Self-regulation or self-regulated learning can be defined as a self-directive process where learning is viewed as an activity of learning in a proactive way. Zimmerman (2000a; 2002) and Schunk and Ertmer (2000) define self-regulation as self-generated thoughts, feelings and behaviours that are oriented to attaining goals. Self-regulated learning is said to be an academic skill, which matures alongside the studies (Pintrich, 1995; Svinicki, 2010). Students with high self-regulation skills also use skilful strategies (cognitive area in Figure 1) in their learning and they seem to obtain higher grades (Lewis, 2011; Bezzina, 2010; Zimmerman & Martinez-Pons, 1986).

These strategies can be taught in order for students to upgrade their self-regulation skills. Schunk and Ertmer (2000) point out that teaching of strategies does not guarantee that students will use them. If a student feels, that the strategy does not affect the results as much as the other factors such as time available, the student may reject the strategy.

Pintrich (2004; 2000) remarks that in self-regulated learning, learners are viewed as active participants in the learning process. Students not only attend lectures but also clarify matters by asking and discussing. Learners should be able to monitor, control, and regulate certain aspects of their own cognition, motivation, and behaviour as well as some features of their environments. Students may regulate their learning processes by attending lectures if they know that they might have difficulties in studying at home. There must also be some kind of goal, criterion or standard with which to compare learning. The goal can be a major or minor goal. A major goal might be passing the course or achieving a good average in all courses. A minor goal might be solving, for example, all of the given homework. After setting the goal, students can compare their learning to it. The advantage of minor goals is that they usually give feedback about learning during the course, and if needed, the learning strategy can be changed. The disadvantage of having only minor goals is that studying may not be proactive. Having only a major goal may not give feedback about learning during the studies. Thus, the best self-regulated students have both types of goals. There is evidence that learning environments can affect learning goals (Nasser-Abu Alhija & Amasha, 2012). If, for example, the importance of high grades is emphasised, students adopt performance goals and motivation diminishes. If understanding or student-focused teaching is emphasised, students are more probable to adopt mastery goals (Nasser-Abu Alhija & Amasha, 2012; Lonka, Olkinuora, & Mäkinen, 2004).

Self-regulation is a compromise between personal and contextual characteristics and actual achievement or performance. A student may be aware that because of previous mathematical studies, his or her knowledge may not be sufficient for the highest grades without very hard work. The student must decide how much effort he or she can or is willing to put into the studies. One component of self-regulation is the student's metacognition of performing the task (Labuhn, Zimmerman, & Hasselhorn, 2010). The better the students are able to evaluate their performance, the better studying habits they seem to have.

Phases of self-regulation by Zimmerman (2002) are shown in Figure 4. Zimmerman (2000, 2002) sees self-regulation in three phases, whereas Pintrich (2004, p. 390) divides it into four phases. The differences in the processes are not significant for this study, as both divisions consist of the situation before studying, while studying, and after studying.

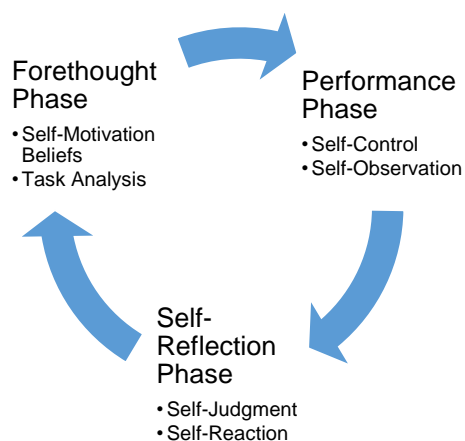


Figure 4. Phases of self-regulation (Zimmerman, 2002).

The first phase describes student forethoughts, planning and activation before studying (Zimmerman, 2002; 2000a; Pintrich, 2000). Zimmerman calls them task analysis and self-motivation beliefs. During this phase, students set and plan steps for achieving a goal according to perceptions of the task's difficulty, value and interest. When considering the task difficulty, student beliefs about personal capabilities for doing the task, e.g. self-efficacy, are also perceived. If students have low outcome expectations and no intrinsic interest in or value for a topic, not much can be expected for self-motivation or strategic planning. Students are motivated to learn in a self-regulated fashion if they are interested in the task, and value the learning for its own merits (intrinsic motivation).

The second phase consists of monitoring and controlling. Pintrich (2000) keeps them separate but Zimmerman combines them with self-observation and self-control. However, the basic idea is the same: deployment of the methods selected and control of efforts. During this phase, students become conscious, for example, of time use and the need for help (self-observing). When self-controlling, students increase or decrease effort, e.g. find some tutoring for help. Students may have higher assumptions of the time spent studying they actually spend if self-recording the time. One part of self-controlling is focusing attention spans. Pintrich (2004) also points out that self-observation and self-control are interpreted in much the same way in terms of people's experiences.

The third phase, self-reflection, is about reactions and reflections. Self-judgment has two forms: self-evaluation and causal attribution. In self-evaluation, students compare personal performance against some standard, for example, another student's performance. In causal attribution, students reflect on unsatisfactory results. Causal attribution is a very important phase for self-motivation. If students attribute unsatisfactory results to factors over which they have only little control, e.g. limited ability, luck, difficulty of the task (Schunk & Ertmer, 2000), it implies that they cannot improve their results, which may decrease motivation. On the other hand, if poor results are attributed to an incorrect strategy, it may sustain motivation.

Self-reaction involves feelings (self-satisfaction) and reactions (adaptive/defensive). Self-satisfaction levels affect the motivation level: high self-satisfaction may enhance motivation whereas low self-satisfaction may raise questions about the worth of studying. In adaptive reaction, a student increases the effectiveness of learning. Students may modify an ineffective learning strategy or completely discard it. In defensive reaction, students protect their self-image, perhaps by dropping a course or by being absent from a test. The student avoids opportunities to learn and perform better.

The last two phases may occur simultaneously and dynamically (Pintrich, 2004), although they are presented cyclically in Zimmerman's model. Students may change their goals and plans based on feedback from the monitoring, control, and reaction processes, during the study process. Students with low self-efficacy may change, after positive reactions, their plans in the hope of better grades, for example.

Because of diminishing resources, students are required to study more and more independently and with web-based materials. This kind of studying involves planning, monitoring learning and controlling behaviour and context. All these are important aspects of self-regulated learning (Zimmerman, 2008; Pintrich, 2000).

Self-efficacy is defined as 'students' beliefs about their academic capabilities' (Zimmerman, 2000b). Self-efficacy is in an important role in learning, as it influences motivation, and also in self-regulated actions. Self-efficacy is influenced by prior experiences, attitudes towards learning, instruction, the social context, and beliefs in abilities (Schunk, 1990). Self-efficacious students (Zimmerman, 2000b; Sullivan & McDonough, 2007) participate more willingly, persist longer in tasks, work harder, and have less negative emotional reactions when encountering difficulties. Self-efficacy is multidimensional, as beliefs in performing in, for example, algebra may be different from geometry.

A student's strength in self-efficacy seems to affect goal setting (Zimmerman, Bandura, & Martinez-Pons, 1992; Schunk, 1990): if a student's self-efficacy is at a high level, then the student embraces goals that are more challenging. Self-efficacious students are also better at monitoring their working time and at solving conceptual problems than less efficacious students (Zimmerman, 2000b; Bouffard-Bouchard, Parent, & Larivee, 1991).

Low self-efficacy may lead to mathematics anxiety. Students with mathematics anxiety feel tension, dread, helplessness, and mental disorganisation when they manipulate numbers or solve mathematical problems (Zakaria & Mohd Nordin, 2008). These students enjoy mathematics less and do not spend as much time on it as others. (Jameson & Fusco, 2014)

The survey in self-regulation was based on this theory. The survey is handled more deeply in 3.3.2.

2.2 Intelligence

According to Figure 1, the intelligence of a learner is formed by cognitive and conative areas. The conative area is handled in personality part and this part concentrates on cognitive knowledge. The cognitive area is about observing, recognition, imagination, evaluation, and reasoning (Kyrö, Mylläri, & Seikkula-Leino, 2008). Declarative knowledge is related to the ability to attribute concepts, and procedural knowledge is related to the ability to apply the knowledge.

In this thesis, the framework of intelligence is restricted to knowledge and skills. This is studied with the student's proficiency test and background information. The background information includes information on previous education (vocational college, upper secondary school) and also what kind of mathematics the student studied in upper secondary school (basic or advanced syllabus). This gives us information on what kind of knowledge the students should have. The actual proficiency test will tell the level of skills. It was also seen in the study by Schwenk and Kalus (2012), that previous education has a major role in basic mathematical skills.

The studies of mathematics curricula in Finnish vocational colleges show that the main target in mathematical studies is in the ability to work with numbers (Opetushallitus, 2014). For example, in Ahlman vocational college the curriculum (2010, p. 12) says:

A student uses basic calculations in solving professional and everyday problems. A student uses, for example, graphs, charts and statistics to solve professional duties and problems.

Students have two courses of mathematics, each worth one credit, on an average. Topics seem to include basic calculation (for example order of calculations, fraction numbers), percentages, measurement units, basic areas and volumes. In advanced courses, there was a note of using equations (Opetushallitus, 2014, p. 230). Although the example handles only basic degrees in machinery and metal technology, the idea is valid also in other basic degrees of vocational colleges. Ahlman's curriculum remarks on the same page (p.12) that the vocational basic degree guarantees eligibility for further studies in universities and universities of applied sciences.

For upper secondary schools, the curriculum is determined by the National Board of Education. The objectives of the basic mathematics syllabus (Opetushallitus, 2003, p. 117) are defined as to offer an ability to acquire, handle, and interpret mathematical knowledge and to use it in different situations of life and continuing studies. Students have eight compulsory courses, which handle for example linear and quadratic equations, systems of two linear equations, basic geometry, polynomial functions and their derivatives, power-law and exponential equations, and statistics. There are only two specialisation courses, from which one is about commercial mathematics the other is about trigonometrical functions and vectors.

The objective of the advanced mathematics syllabus (Opetushallitus, 2003, p. 110) is to give mathematical readiness needed in professional studies and universities. There are ten compulsory courses and three specialisation courses. Topics listed by the National Board of Education handle all aspects of mathematics needed in engineering studies. In addition to basic mathematics syllabus, it includes vectors, differentiation, integrals, numerical methods, etc.

As can be captured from curricula, the cognitive readiness in declarative knowledge in mathematics varies remarkably. Curricula only tell about declarative knowledge given in previous studies. Procedural knowledge, that is applying declarative knowledge, may not achieve the same level: a student knows the procedure but cannot apply the procedure correctly. For that reason, the previous education alone is not enough for determining intelligence. The proficiency test in mathematics and previous education together give better understanding of the situation.

The cognitive area includes, in addition to knowledge and skills, also beliefs (Koiranen & Ruohotie, 2001). Students may have beliefs, for example, regarding their need for mathematics (Houston, et al., 2010) or their ability to learn more abstract mathematics. This is included in the motivation and self-regulation surveys.

2.3 Learning instruments

A teacher's responsibility is to give instruments and lower the threshold for learning. One main point of this study was to find activities that would promote all aspects of learning: motivation, self-efficacy, and procedural knowledge. The idea was not to select the 'best' learning theory but to find activities that could easily be adopted by all teachers. Because this study concentrates on the learner, the different conceptions of learning are excluded as they mainly influence the teacher's way of thinking about course arrangements and other teaching-related matters. The following methods could be applied in all different conceptions of learning although they follow quite strongly the social-constructive conception. The first subsection handles promoting understanding and the second discusses the methods which could maintain or even raise conation and motivation to learn.

2.3.1 Understanding

Learning is a process, which starts at the knowledge already existing and develops gradually, until the new information is understood and, therefore, new knowledge is gained. (Bellmer, 2010)

Understanding in mathematics can be divided into three levels (Idris, 2009):

1. *Instrumental understanding*: a student can apply an appropriate rule to solve the problem ('how') without knowing 'why'.
2. *Relational understanding*: a student can deduce specific rules or procedures from mathematical relationships, that is, one knows 'how' and 'why'.
3. *Logical understanding*: a student can also convince others. Relational understanding is enough for convincing oneself, but not for convincing others.

The first level of understanding may be achieved by repeating the calculation procedure. This is done conventionally with a paper and pen, with interactive exercises in an e-learning environment, or with games or e-games. The last option may be more usable with young children. The main point is that despite the method used, the number of repetitions must be high.

The conventional homework, which may be checked later, gives feedback on learning retrospectively. If the student cannot even solve the first exercises, the motivation to continue may be low. Interactive e-learning exercises give feedback immediately, but producing them is time consuming and there may be problems with the compatibility of different systems.

As Idris (2009) remarks, a lack of understanding in mathematics can make students lose interest in the subject and affect their mathematics achievements. Upgrading the understanding requires good mathematical and professional vocabulary. Engineering problems are usually complex cases with verbal explanations. The low vocabulary proficiency for both engineering language and mathematics complicates the understanding of the problem. When this is combined with the need of logical understanding in math, students may be in trouble.

Language is usually defined as a system of symbols. It includes, besides verbal (written and spoken) language, also figures, expressions, gestures etc. Language is an instrument for thinking, acquiring knowledge, communication, influencing, social relations, expressing feelings, etc. (Joutsenlahti, 2003). Vocabulary is an essential part of a student's academic development (Kovarik, 2010; Kilpatrick, Swafford, & Findell, 2001).

People think and express themselves in their own language. When studying foreign languages, students are frequently requested to translate sentences from foreign language to their own language and vice versa. This helps in enhancing vocabulary, and also in understanding the nuances of the new language. If the mathematics notebook from any engineering is opened, there is usually not much verbal explanation, just mathematical expressions. The reasoning

behind the solution can only be guessed. However, the verbal explanations would help in deepening understanding both of the solver and of fellow students, not to mention the teacher.

Mathematics has its own language: symbols and grammar. This language is simply unlike other languages studied. However, the language of mathematics can be taught like any other languages, but it requires training in translating. *Languaging* helps students to organise their thinking and it also makes the thinking more perceptible (Kosko & Wilkins, 2010; Powell, 1997). As Adu-Gyamfi et al. (2010) state, languaging is a crucial component in the development of reasoning, communication and connections in mathematics. When a student is expressing the mathematical definition verbally, he or she must consider the most essential features of the concept and both reflect and analyse his or her mathematical thinking that helps in deepening the understanding (Whitin, 2004; Silius, Pohjolainen, Kangas, & Joutsenlahti, 2011). Although Idris (2009) discusses only writing, all verbal languaging helps students to recognise what they know and do not know, can and cannot do, raise questions about new ideas and summarise their knowledge.

2.3.2 Easy ways for teachers to promote learning

The way people capture information is mostly based on humanness (principle 6 in Table 1). Some of us prefer visual material (tables, charts, etc.), some prefer verbal material (textbooks, spoken words, etc.), and some learn by doing. There is evidence that people retain more information if they explain what they are doing (Felder & Silverman, 1988; Stice, 1987).

Felder and Silverman (1988) describe *inductive* and *deductive* learning styles. According to them, inductive learning is *the natural human learning style*, as it is based on observations, measurements, and data. However, deduction is *the natural human teaching style*, as it is based on governing principles and works down to applications. Felder (2002), although ignoring this division, made an interesting observation: *Inductive learners need motivation for learning* (p. 678). Inductive learners need to know why they need this information. As shown by Porras (Publication II), weaker students need applications from their professional field.

Felder and Silverman (1988) introduced four more scales to identify learners. They could be summarised as follows (Litzinger, Lee, Wise, & Felder, 2007; Felder & Spurlin, 2005):

- *sensors-intuitors*
- *active-reflective*
- *visual-verbal*
- *sequential-global*

The first two scales are closely related with Myers-Briggs Type Indicators. Where the sensors like facts and experiments, the intuitors prefer theories and principles. Where the active learners wants to try and experience, the reflective learners need some time to think. Neither active nor reflective learners benefit from passive lecturing. Sequential learners learn in small steps and the learning proceeds in a linear fashion. Global learners learn in large steps and the learning

proceeds in a holistic fashion (Felder & Spurlin, 2005). The study by Autio et al. (2010) suggests that young people are attracted to technology, as they like to work with their hands. This refers to the fact that engineering attracts active students. Felder and Silverman (1988) also suggest that most engineering students are active sensors.

A teacher can promote learning during the lectures by *reviewing, scaffolding, giving breaks for thinking, with working activities* and with *manipulatives*. During the review, the teacher binds the new content with students' pre-knowledge, shows the observable phenomena of the theory, and thus lowers the threshold for learning (inductive learners). Review is seen as a preliminary action before introducing the new content (Lemke, 1990; González & DeJarnette, 2012). González and DeJarnette (2012) argue that *the teacher makes explicit what mathematical content students need to know, and what mathematical procedures they should apply when solving specific problems*. Although they were studying the review process before an assessment, the same elements belong to introducing a new topic. When students know what they are assumed to know (also the pre-knowledge) and why they are learning it, they will be more motivated for learning (Felder & Silverman, 1988). Informal discussions with some non-scientists revealed that they may have been quite good at mathematics but they lost interest as they could not see the connection to real life. Unfortunately, they all mentioned upper secondary school in this connection.

Meyer and Turner (2002) define scaffolding as *an instructional process in which a teacher supports students cognitively, motivationally, and emotionally in learning while helping them to further develop autonomy*. Wood et al. (1978) describe scaffolding as enabling a novice to solve a problem that would be beyond his or her unassisted efforts. Scaffolding is about giving hints, posing open-ended questions and cueing questions or providing pieces of the solution (Meyer & Turner, 2002; Yelland & Masters, 2007), so that the scaffolder draws the learning into new areas with the learner's own intentions (Yelland & Masters, 2007). Scaffolding is a social process but not only between a teacher and student but also among students. At its best, scaffolding helps students to increase their understanding, engages students in learning, and helps students to build their autonomy as learners (Meyer & Turner, 2002).

Active learners need active experimentation for learning including discussing the topic, explaining it or trying it by themselves (Felder & Silverman, 1988). These kinds of learners also usually enjoy working in groups (Felder & Spurlin, 2005). For them, it is important to have some kind of action during the lectures: solving small problems, group work, etc. According to Felder and Silverman (1988), there is evidence that most of engineers are active learners.

Reflective learners, on the other hand, need breaks for thinking and usually want to work alone or at most with one other person (Felder & Silverman, 1988). Although they are more likely to be theoreticians, they are an important and needed part of engineering: good engineering requires a mix of theory and doing.

Visualising of mathematics with a piece of chalk is challenging. One or two graphs of a situation may not give the full idea. Nowadays, the Internet is full of free mathematical programmes (e.g. Geogebra, Wolfram Alpha) which help in visualising mathematics and solving the problems (Takaci, Stankov, & Milanovic, 2015). Technological power can also increase enthusiasm towards learning (Li, Zhang, & Yin, 2011; Challis & Gretton, 2008).

Manipulatives are typically concrete objects that help in representing mathematical concepts (Kosko & Wilkins, 2010). Bruner (Kosko & Wilkins, 2010) in their study used manipulatives to move students from concrete towards abstract thinking. Warrington and Kamii (1998; 1994) found that students using manipulatives were able to learn fraction calculations before the methods were taught symbolically. Although all these studies were done with young children, they would probably help also young adults. At least in my own lectures, the integration of volume seems to be easier to understand, when there is a concrete object involved.

Studies in learning mathematics show that level of motivation and self-regulation have an effect on achievement (Houston, et al., 2010; Miller, 2010; Hannula, Maijala, & Pehkonen, 2004; De Corte, Verschaffel, & Op't Eynde, 2000). However, a highly-motivated student may lose interest if the mathematical background is weak and no help and/or encouragement are available. Recognising the weaker but motivated students and encouraging them may be even more important than just recognising the motivated and self-regulated students.

Cognitive knowledge in mathematics varies based on the student's previous studies. Students from vocational colleges have not been taught the same knowledge as students from upper secondary schools. This means that their knowledge has to be upgraded to a sufficient level with, for example, bridge courses. Although students from upper secondary schools may have had access to the knowledge required, they may not be able to apply it. Some need more support in upgrading their procedural knowledge than others. Obviously, identifying students in need of support and selecting the sufficient level of support is not straightforward, as it involves aspects of affective, conation, and cognitive areas.

All different kinds of learners attend the same lectures, and attention must be paid to this during the planning of teaching: what fits me may not fit you. I have met students who want to know all existing theory before calculation, and students who did not do well at all in topic tests but obtained the highest scores in the applied tests. Balancing between sensors-intuitors, active-reflective, visual-verbal and sequential-global is not easy at all, paying sufficient attention to all learners and responding to their learning preferences. The learning instruments described previously may help in achieving that balance. Although the use of computers in mathematics teaching is disputed (Li, Zhang, & Yin, 2011; Challis & Gretton, 2008; Schwenk & Kalus, 2010), they are an essential part of engineers' work (not only for calculations but also for searching for new knowledge) and should not be omitted.

3 Research goal and methodology

The research questions are introduced first. The rest of this chapter explains the context of the study and the process.

3.1 The research problem

The study consists of three phases: 1) collecting information on motivation and self-regulation, 2) using this information together with cognitive information to form the psychological learning profiles, 3) forming the prediction model.

The main idea of this research is to identify students in need of extra support at the beginning of their engineering studies. The main research question in this thesis is:

How could the promising engineering students that are struggling in their learning of mathematics at the beginning of their studies be identified?

The learning of an individual is a complex issue. Thus, the main research question was divided into three sub-questions:

Question 1 Which factors in motivation and self-regulation could reveal the progress in mathematical studies?

The objective of this phase is to establish psychological learning profiles to portray students. At the beginning, teachers do not know freshmen's habits, actual knowledge in mathematics or commitment to engineering studies. On the other hand, freshmen do not know fellow students, the atmosphere in lectures, or how they will adjust to academic freedom. Therefore, the surveys are based on student's own view of motivational and self-regulation aspects.

Question 2 How could these personality factors be formulated as learning profiles to represent students generally enough?

Because motivation and self-regulation surveys are too large to be completed and analysed every year, it is essential to find a small number of learning profiles from which the students could select the best choice. The learning profiles must be connected with the actual progress but they must also be universal enough.

Finally, the personality and cognitive knowledge must be combined to prediction models.

Question 3 How should prediction models be formulated to take personality and intelligence aspects into account?

The fourth phase closely connected to this study experiments with different course arrangements to enhance learning. This is not included in the research problem as it is a continual process. However, this phase hopefully confirms the usefulness of the prediction model in the light of the decreased number of students failing and/or not completing courses.

3.2 Research process

This study was conducted at Saimaa University of Applied Sciences in 2011 – 2014. It involves all Finnish first-year students from the academic year 2010-2011 to the academic year 2014-2015. All students not answering the surveys in 2011 or not giving personal data were excluded from the analysis of the motivation and self-regulation surveys and from the formulation of the learning profiles. All students participating the proficiency test from autumn 2012 to autumn 2014 are included in the analysis of the prediction models.

This study uses mainly empirical quantitative research. The data consists of motivation and self-regulation surveys (later learning profiles), background information, results in the proficiency test, and the grades of the first mathematics course. The motivation survey is presented in subsection 3.3.1 and the self-regulation survey in subsection 3.3.2. Discussion about course arrangements is based on students' feedback, colleagues' opinion, and frequencies in percentages for passing the first mathematics course.

The phases and data used in different phases are shown in Figure 5. In phase 1, students entering in the academic years 2010-2011 (answered in spring 2011) and 2011-2012 (answered in autumn 2011) were asked to complete surveys concerning their motivation and self-regulation in mathematical studies. The answers in these surveys were combined with the results in the proficiency test, previous education, and the grades of the first mathematics course. This data was analysed with the IBM SPSS Decision tree®, as the information is mined from quantitative answers (Thomas & Galambos, 2004). This tool was selected as it makes categorising the grades (dependent factor) and independent factors on different criteria easy. All information could also be connected to the prediction model (called also student type in the articles) with syntax, enabling

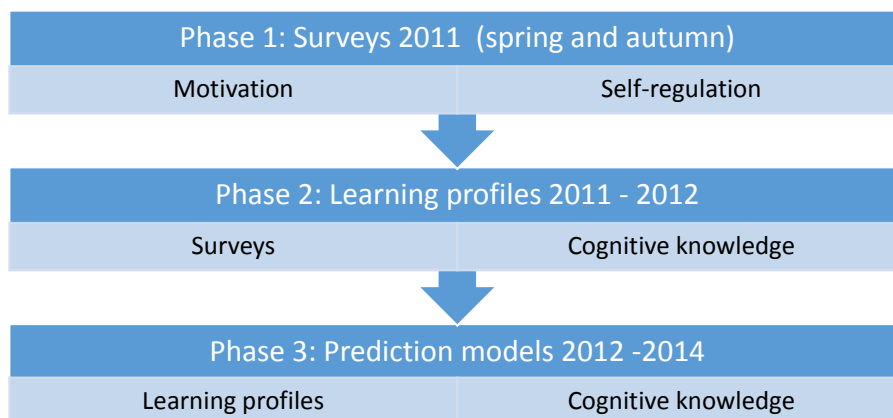


Figure 5. Phases of the study.

further analysis. In the prediction model, students are categorised into four groups: *at risk* (very likely to fail), *weak* (grades vary between 0 and 2), *ok* (grades vary on the whole scale), and *excellent* (grades are likely high). This phase gave answers to Question 1.

In phase 2, the learning profiles were formulated with the information received in phase 1. The first profiles based on answers in spring 2011 were not at all favourable. The new profiles were created when the surveys in autumn 2011 among new entering students were received (Question 2).

The final profiles are listed in Appendix D. Appendix C describes the reasoning behind the descriptions. Only one path to the conclusion is written in each case, although the same idea may have been reached through different paths. It should be remarked that most of reasoning is not based on only one decision tree but several of them. It can be noticed that weak students are at risk if they meet another criterion. Unfortunately, decision trees to this step are so large that it is not possible to include them, not even as an example. There is an example of the decision tree on profiles in section 5.1.

In phase 3, these learning profiles (personality aspects) were connected with students' cognitive knowledge (proficiency test, previous education, grades) to answer Question 3. At this point, students no longer responded to the surveys, so the selection of profiles is unknown, and therefore, the profiles must be combined with information on course grades. For profiles used in 2011 and 2012, only the total points of the proficiency test were used in preparing the prediction model. In the prediction models for 2013 and 2014, also individual results for each problem in the proficiency test were included in the decision tree. When the prediction models were created, all data gathered in preceding years were utilised. Phases 2 and 3 are done partly simultaneously.

3.3 Measuring the learning aspects

In this study, the students were asked to complete motivation and self-regulation questionnaires. The answers were not anonymous, enabling the grades of mathematical courses to be merged with the answers. No identification was included in the final data.

The validity of the surveys is contemplated in the light of internal validity. The surveys were answered in different years by different students, so the time may have affected the answers and conclusions. However, this method should be exploitable in the course of academic years. In that sense, time increases the validity. Students were asked to fill in their name or student number, so that the information could be connected with the grades. Although the surveys were answered during lectures, nobody was forced to fill in the personal data items. Only a few students answered anonymously. These answers were excluded from the data.

3.3.1 Motivation survey

The idea of the motivation survey (Appendix A) was to find factors in motivation indicating weak performance in mathematics. The survey was based on motivation theories described in subsection 2.1.1.

Although the number of questions was only fifteen, with four alternative endings in each question, the total number of different sentences was 60. These sentences ranged from psychological needs to self-actualisation needs, from avoidance motivation to intrinsic motivation, desire or fear, and from expectancy to value. Question 16 was included to establish about what types of arrangements would promote motivation for learning. Students could select at most five of these.

Three questions measured motivation towards the professional field. In a motivation study at Finnish universities of technologies (Erkkilä & Koivukangas, 2010), it was noticed that students motivated in their professional studies also succeeded in all of their studies. These questions handled

- the commitment to professional studies (question 1),
- why the student applied to this programme (question 2), and
- the importance of the studies at the time of answering the questionnaire (question 3).

The same kind of result was found (Publication I) among engineering students in Saimaa University of Applied Sciences. The rest of the questions concentrated on studying mathematics.

Table 2 shows how questions represent different motivation levels. In the first column, there are aspects of motivation mentioned in subsection 2.1.1. The first row displays the question number in the motivation survey. Alternatives (a – d) describing the case are mentioned in a cell. The minus sign before the alternative refers to an inverse meaning. For example, positive alternatives refer to desire and negative to fear.

Table 2. Motivation type vs. question.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
avoidant		d		d		d	d	c			d		d	a	d
diverged	d		c	d	a										
escaped	a	c	a	a		c	a	a, c			c		c	b	c
achievement	c	b	a, d	b, c		b	c	d			a		a	c	a
intrinsic	b	a	b	c		a	b	b	c		b		b	d	b
desire/fear					-b, d	a, b	-a, b, c, -d			-a, b, -c, d				-a, b, c, d	
expectation							-a, b, c, -d							-a, b, c, d	
value	b, c	a, b	b			a, b, -d		b, d			a, b, -c, -d		a, b, -c, -d		
psych. needs					b, c										
safety									b			c			
affiliative				a, b					a, d			b			a
esteem	c	b	a			b		d			a	a, d	a	c	
self-actualisation	b	a	b	c		a	b	b			b		b	d	b

Psychological needs are found only in question 5 in alternatives ‘b’ (I have a learning disability) and ‘c’ (I am often tired in lectures). The alternative ‘c’ was selected because it may indicate external difficulties. The reasons are not asked but could be anything from partying to a crying baby, or from working night shifts to sleeping difficulties. For example, sentence 3a ‘Studying at the moment helps in finding a well-paid job’ refers to esteem needs by Maslow and achievement motivation by Kauppila. As can be seen from Table 2, the same sentence could measure different things. The main reason for it is overlapping theories, which is not problematic for this study.

The reliability of the questionnaire is important when analysing its results. Reliability is commonly measured with Cronbach's alpha. For these questions, Cronbach's alpha is 77.8 %. It is quite high, and the questions can be said to be consistent (Metsämuuronen 2009).

Below is one example of a question and its alternative responses.

Question 1. It is important for me

- a) ___ to pass courses in accordance with the curriculum.
- b) ___ to learn as much mathematics as possible.
- c) ___ to get good grades.
- d) ___ to engage in hobbies/to work although it disturbs my studies.

Students were asked to give 1, 2 or 3 points for the alternatives in each question. The alternatives were not exclusive. In question one, a student may feel that alternatives from 'a' to 'c' represent him or her to some extent. If the student feels that passing the courses is more important than knowing the topic, the student should give the highest point for that alternative. The highest points should be given to the alternative best describing the student, the second highest to the next one, etc. Students did not need to use all of the points but at least one point had to be given. Within the question, the same points could not be given twice. At least one alternative was left empty in every question. This ranking of alternatives was used to know which of the alternatives motivated students the most and which the least. All other sentences were analysed in the same way as the one described above. Ranking was not used in question 16.

3.3.2 Self-regulation survey

This survey (see Appendix B) was used to find lacks in self-regulation habits and in self-efficacy. Low self-efficacy lowers motivation even to try, and that is usually seen in self-regulation. However, the high self-efficacy with weak self-regulation may not produce any better results, as seen in Publication IV.

A questionnaire for self-regulation was structured according to Pintrich (2000, 2004). Pintrich separates self-regulation into four phases:

1. *Forethought, planning, activation,*
2. *Monitoring,*
3. *Control,*
4. *Reaction, reflection.*

All of these are observed in the context of *cognition, motivation/affect, behaviour and context* (Pintrich, 2000; 2004). Table 3 provides a short explanation for the questions in matrix form.

Cognition includes all activities for regulating knowledge. It includes goal setting, activation of prior content and metacognitive knowledge, selection and adaption of strategies for learning and cognitive judgements. If a student sets goals for studying but does not monitor progress, learning and/or comprehension, the goals may not be achieved. Monitoring of learning could be, for example, checking which exercises the students could solve on their own. Control comprehends selection and use of strategies for learning, reasoning, problem solving, etc. In mathematics, one important part of solving problems is to know formulas. A student may decide to learn all formulas by heart or to use the help of formula books. Many Finnish students seem to select the use of formula books but do not take the time to understand written formulas. Most students do not reflect on their performance in this respect.

Table 3. Matrix of question types (Pintrich, 2004).

	Cognition	Motivation/Affect	Behaviour	Context
Forethought, Planning, Activation	Goals, prior knowledge	Interest in mathematics, self-efficacy	Time planning	Clarifying the course requirements
Monitoring	Asking for clarifications	Concentration	Time usage	Monitoring progress to grade requirements
Control	Solving given problems, getting more information	Getting feedback	Following plans, help-seeking	
Reaction, Reflection	Sense of responsibility	Feelings during and after the course	Reactions such as the student expressing that the topic is not very important after all	

Motivation includes a student's self-efficacy beliefs, reasons for performing tasks, personal interest in the tasks and beliefs about the importance, utility and relevance of the tasks (Pintrich, 2004). Monitoring motivation is awareness. Students may start solving the mathematical problems but after a while, find themselves thinking of other things. Examples of controlling the motivation are positive self-talk (self-efficacy beliefs), extrinsic rewards like meeting friends after finishing the task, or making the task more interesting or relevant personally. When completing the task, the student has different reactions to the outcome. The student may be

satisfied or dissatisfied with the outcome. This questionnaire explored, how much students rely on their competence after the mathematics courses.

Regulation of *behaviour* includes the planning and management of time and effort, and also help-seeking. Self-regulated students prepare schedules for leaving them time also for other activities, such as meeting friends or working. If a student plans to work on school assignments with friends at the beginning of the course, the friends may decide to change their plans (like doing something else instead of exercises). In such cases, the student can control his or her personal behaviour and decide not to work on assignments with these friends any longer. On the other hand, if the student cannot solve the assignments alone, he or she should ask teachers or assistants for help, not friends. A maladaptive way of help-seeking is asking for solutions without much work and/or learning.

The regulation of *context* involves efforts to control and regulate the tasks and contexts a student confronts in the course. Most of them are not in the hands of the student, e.g. classroom noise (environmental control), but students can often decide with whom they cooperate or how they perform particular tasks. Most of the time students are not studying in a classroom. Monitoring their place of study for distractions and making the place more encouraging for studying facilitates learning.

In self-regulation, regulation in different areas may be at the same level. For example, one can be equally regulated in terms of both minor and major goals. Consequently, the scale used in motivation was not utilised. The Likert-scale was considered to be the most suitable in this case. The scale was determined as

- 1 point: Not like me; I hardly ever feel like this.
- 2 points: I may sometimes feel like this.
- 3 points: I feel like this half of the time.
- 4 points: I feel like this quite often.
- 5 points: Like me; I often feel like this.

Cronbach's alpha for this questionnaire is 0.904, which is interpreted to be high and suggests good consistency of items. However, a high alpha value may suggest that some items are redundant. The number of items may also be increasing the value. (Tavakol & Dennick, 2011)

3.3.3 Mathematical knowledge

All first-year students should participate in the proficiency test before the courses start. The test deals only with basic mathematical skills (see Table 4) and is carried out without a calculator. Students have 90 minutes to complete the test, and the answers are marked either 0 (not correct) or 1 (correct). The use of the correct procedure was highlighted rather than the use of the correct figures. As can be captured from the topics listed in Table 4, almost all topics should be mastered by all students. The questions T3 and T4 are not in the curricula of vocational colleges.

Table 4. Topics of the proficiency test.

Question number	Declarative knowledge
T1	order of calculation
T2	calculation with fraction numbers
T3, T4	handling expressions
T5, T8	solving linear equations
T6, T7, T10	units of measurements
T9, T12	proportion
T11	system of two linear equations

The proficiency test was exactly same each year. No significant differences were found in the average scores (sig. > 0.05). Thus, we cannot report that during this time skills would have weakened, as Schwenk and Kalus (2012) suggest.

The same topics are covered also in the mathematics bridge course called *Introduction to Mathematics*. The main idea of the course is to upgrade the declarative knowledge on the mentioned topics but also equally importantly, to upgrade the procedural knowledge. The bridge course is graded as *passed* or *failed*. Passing the course requires that at least 90% of questions in tests are solved correctly.

The first course in mathematics is lectured by several teachers and the teachers may have changed between academic years. The content of the course involves trigonometry, two-dimensional geometry and vectors, polynomial functions and their derivation, inequalities, and special cases of higher order polynomial equations. All teachers prepare their own tests and have their own requirements for passing. Although the passing rates are not consistent in this light, this is the reality of where the prediction models are applied.

4 Summary of publications

This work is based on five publications out of which four are included in this dissertation. The only joint publication is Publication IV. The earlier version of Publication IV (Porrás, 2013) was accepted into the 41st SEFI Conference, 16-20 September 2013, Leuven.

4.1 Publication I: Motivation towards Mathematical Studies in Engineering

This paper was accepted into the *Conference of The International Community of Teachers of Mathematical Modelling and Applications* and was published in *Proceedings of ICTMA15* (2011), edited by Gloria Stillman, <http://www.ictma15.edu.au/>.

4.1.1 Research objectives and methods

This paper studies different motivation levels defined by Kauppila. Answers in the motivation survey are also combined with background information, overall results in the proficiency test and grades in the first mathematics course. The survey in motivation was conducted in Finnish engineering programmes in Saimaa University of Applied Sciences for students starting their studies in the academic year 2010 - 2011. The data consists of students participating in the proficiency test (N = 159) and was analysed with IBM SPSS Decision Tree®.

4.1.2 Results

It was verified that neither previous education nor the overall result in the proficiency test alone could be used for identifying students struggling in their mathematical studies. The number of intrinsically motivated students seemed to be quite high. However, not all of these students passed the course with high grades. Although grades and Kauppila's motivation levels were found to be connected, Kauppila's motivation levels were not accurate enough to identify students in need of help. When motivation in the professional field was compared with previous

education, it was found that students having studied in vocational colleges seemed to be more motivated in the field than students from upper secondary school. The first motivational factors for identifying the students were also found.

It must be noted that there are some mistakes in this paper. Directional measures of Somers' D were used with previous education, which is not in ordinal scale. However, these measures have no effect on later findings.

4.1.3 Relation to the whole

The first part of the study verified the pre-assumption that previous education does not explain progress in mathematics well enough. It was also found that we should not concentrate on motivation or later self-regulation levels but actual answers in surveys. Students' own conception would give more accurate information than psychological levels. The results of the second part were used later in defining the first profiles.

4.2 Publication II: Enthusiasm towards Mathematical Studies in Engineering

This paper was accepted into the *Conference of the International Group for the Psychology of Mathematics Education* and was published in the *Proceedings of the 36th Conference of the International Group for the Psychology of Mathematics Education* (2012), edited by Tai-Yih Tso, Volume 3, pp. 313-320.

4.2.1 Research objectives and methods

This paper studies motivation and self-regulation factors combined with background information, overall results in the proficiency test and grades in the first mathematics course. The surveys in motivation and self-regulation were conducted in Finnish engineering programmes in Saimaa University of Applied Sciences among students starting their studies in the academic year 2010 - 2011. The data consists of students participating in the proficiency test (N = 159) and was analysed with IBM SPSS Decision Tree®.

4.2.2 Results

Motivation seems to be the most important psychological factor in explaining success in mathematical studies. If students had no interest in mathematics, their grades were lower. Self-efficacy also plays an important role in mathematical studies. The knowledge of students coming from vocational colleges and from upper secondary schools having completed the basic mathematics syllabus seem to be at the same level. These results portray the situation after some months after starting, not necessarily at the beginning of the studies.

4.2.3 Relation to the whole

These results gave the first significant factors in recognising students struggling with mathematics. These findings were used to formulate the first profiles studied in Publication III.

4.3 Publication III: Profiles of Engineering Students in Mathematics

This paper was accepted into the *International Conference of Engineering Education 2012* and was published in *International Conference of Engineering Education 2012*, edited by M.-J. Björkvist et al., Vol 1, pp. 50-56.

4.3.1 Research objectives and methods

Factors describing struggling and passing in the first mathematics course (Publications I and II) were formulated into profiles. The purpose of this paper was to study the validity of the profiles. Students starting in engineering programmes in autumn 2011 also responded to the surveys in motivation and self-regulation. These answers were added to the data to obtain more information on psychological factors. The sample of the study was 223 students.

4.3.2 Results

It was found that the first profiles did not describe the students of the academic year 2011-2012 at all. There are two possible reasons:

1. The surveys in 2010-2011 were answered after the first mathematics course, and for that reason may not portray students at the beginning very well.
2. The sample was too small.

When samples of the academic years 2010-2011 and 2011-2012 were combined, it could be seen that weaker students were usually aware of their situation. Combining the data revealed that most students struggling in their studies know and acknowledge the need for support. It was also found that weak knowledge connected with the desire for a well-paid job suggests failing in math. Furthermore, some upper secondary school students having completed the advanced mathematics syllabus seemed to underestimate the need to work on courses, and for that reason, did not succeed as well as they could have.

4.3.3 Relation to the whole

After combining the data from the academic years 2010-2011 and 2011-2012, more accurate profiles were formulated. These profiles have been used as of 2012.

4.4 Publication IV: Students' conceptions of their learning may help in predicting their progress

This paper was published in the journal *Educational Alternatives*, Vol. 12, pp. 49-57. It is a joint publication with Jaakko Turunen, Mikkeli University of Applied Sciences.

4.4.1 Research objectives and methods

In this paper, the final profiles were studied in connection with answers to the proficiency test. The paper also studies the effect of some teaching techniques on success in mathematics. The data consists of students participating in the proficiency test in autumn 2012 and autumn 2013 (N = 156).

4.4.2 Results

Previous predictions were based on profiles, previous education (vocational college, upper secondary school with the basic or advanced mathematics syllabus) and categorised results in the proficiency test (weak, average, good). Now, the profiles were connected with previous education, all questions and total points in the proficiency test. The results confirm that low self-efficacy is a key element in struggling. On the other hand, high self-efficacy and weak knowledge is not a favourable combination, either. The prediction model for identifying students struggling seems to be accurate enough.

4.4.3 Relation to the whole

The prediction was more accurate after combining the profiles and answers in the proficiency test. This part of the study verified that combining student profiles with actual knowledge gives the most accurate prediction of progress.

5 Results and discussion

In this chapter, data is further analysed based on information received from students who started their studies in autumn 2014. Measures taken to support weaker students were also described, as well as how those measures and how those actions affected in passing the bridge course and the first mathematics course.

As mentioned in Publication IV, the course *Introduction to Mathematics* was traditionally lectured, and each programme had the same number of lectures. In 2012, first-year students were for the first time divided into groups in *Introduction to Mathematics* based on their predicted success instead of their degree programme. This division has been used ever since. Group A consisted of students who were predicted to fail in their first mathematics course, and ones who were anticipated to perform poorly and obtained the lowest scores in the proficiency test. Students whose skills were deemed sufficient were exempted from the course. All the other students were asked to join group B.

Students in group B were assumed to need only revision in basic mathematics. Therefore, one third of their lectures were allocated to group A. No other changes were made in the course arrangements for this group. In group A, some new teaching methods were adopted in 2012. This includes languaging, scaffolding, reviewing, and continuous feedback. In 2014, students were also assigned some online exercises for practising basic technical calculation. Teachers in both groups organised their own exercises. Both groups had exactly the same topic tests at the same time, so the results are comparable. All excellent students with good results in the proficiency test were exempted from this course.

5.1 Further analyses of prediction

The first profiles were developed based on surveys in the spring of 2011. The new profiles were formulated with supplemented data from autumn 2011 and are used from autumn 2012 forward. Every year the prediction model was checked and further developed by means of supplemented new data. Table 5 displays the percentages of grades successfully predicted based on the prediction model used that particular year. According to Somers' D, grades can be explained with the prediction. In 2012, the prediction explained 39.8% of the grades, in 2013 24.6%, and in 2014 37.4%. The results are statistically significant.

Table 5. Success of prediction in 2012-2014.

Year	Prediction	Grades of the first mathematics course					
		0	1	2	3	4	5
2012	at risk	75%	55%	54%	14%	16%	22%
	weak	19%	18%	12%	21%	17%	33%
	ok	6%	9%	17%	36%	17%	11%
	excellent		18%	17%	29%	50%	34%
2013	at risk	86%	57%	47%	50%	39%	17%
	weak		21%	11%	8%	46%	50%
	ok	14%	7%	16%	17%	15%	
	excellent		14%	26%	25%		33%
2014	at risk	56%	39%	43%	25%	25%	
	weak	44%	46%	29%	50%	25%	63%
	ok		15%	7%		25%	12%
	excellent			21%	25%	25%	25%

The problem with these prediction models is that too many good students were unsuccessfully predicted to be either weak or at risk. The idea at the beginning was that all weaker students should be identified and supporting them should not put the better students at a disadvantage. However, the number of students in need of support was too high and the support did not always reach the students who actually needed it.

Before constructing the new prediction model, the grades were checked with each profile separately in a box-plot graph. During the three years, no student selected profile 2 and only two students selected profile 6. These profiles can be excluded from the list from this point forward. The profiles are listed in Appendix D.

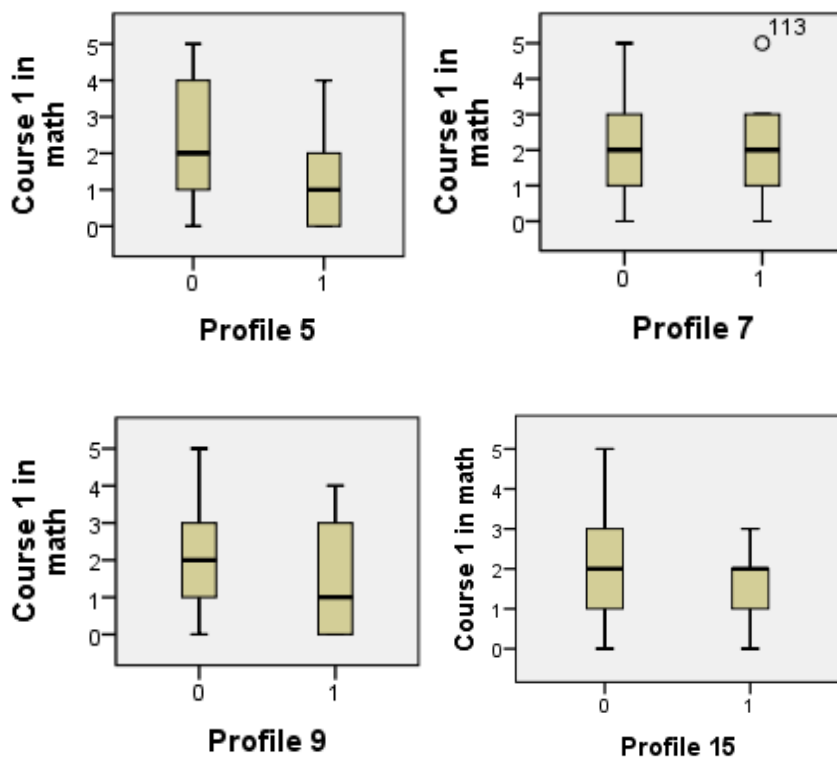


Figure 6. Box-plots of interesting profiles.

Figure 6 shows four interesting profiles. Value 1 means that the profile is selected by a student. Fifty per cent of students selecting either profile 5 or 9 either failed the course or received the lowest grade (1 out of 5). Profile 5 refers to a highly self-regulated student, but obviously only weaker students selected it. Profile 9 describes low self-regulation, where a student does not take responsibility for personal learning. Profiles 7 and 15 also refer to lower grades. Students

who selected profile 7 have worked or are working in the field of their studies. A long time may have elapsed since the student's previous studies and/or the student may have no time to study at home. Profile 15 reveals doubts about the education and students coming from upper secondary schools mainly selected it. The lower grades there are more obvious if profile 1 was also selected.

The decision tree in Figure 7 holds students only from two programmes. As can be seen, question 2 (marked as T2) is the main cornerstone for passing the first mathematics course. Fifty-three students answered correctly and only two of them failed the first mathematics course. Twelve students did not even attempt to respond to this question and ten of them failed the course. Thirty of the thirty-four students who answered incorrectly failed the course if they had not studied the advanced mathematics syllabus. The students with the advanced mathematics in upper secondary school failed the course if they did not attempt to answer question 4 (T4) about simplifying expression.

An analysis with the decision tree exposes that students who did not even try to solve problems concerning the order of calculations (T2) and the system of two equations (referred to subsequently as T11) in the proficiency test failed the first mathematics course. Moreover, if the student's total score in the proficiency test was not more than 2 and the student did not find the applied examples important, the student was likely to fail the course. However, interest in the applied examples raised grades mostly to 'passed'. Students coming from vocational colleges failed the course if they could not solve problems about formulas (T8) and the problem with time conversion (T7).

There are differences in passing the first mathematics course in degree programmes K and R. Students in programme R could be marked to be at risk if they did not even try to solve the problem T11 although they may have quite high total points. If a student tried to solve it but were unsuccessful, they could be marked as 'weak' even with low total points. Students from a vocational college having selected profile 5 seemed to be at risk in programme R. In programme R, students with more than 9 points out of 12 in the proficiency test could be marked as 'excellent'. Even with slightly lower points it is enough if the student's self-efficacy is high (profile 4).

In programme K, incorrect answers in basic calculation and in unit conversion indicated failure, as did not trying to solve T8. If the solution to T8 was incorrect and self-efficacy was low (profile 10 not selected), the student probably failed the course. Selecting profile 10 in this case refers to weaker students but not necessarily to students at risk. Attempting to solve T2 combined with profile 5 was also a sign of failure for students coming from vocational colleges. Unexpectedly, all students with the basic mathematics could be marked as weaker students in this programme.

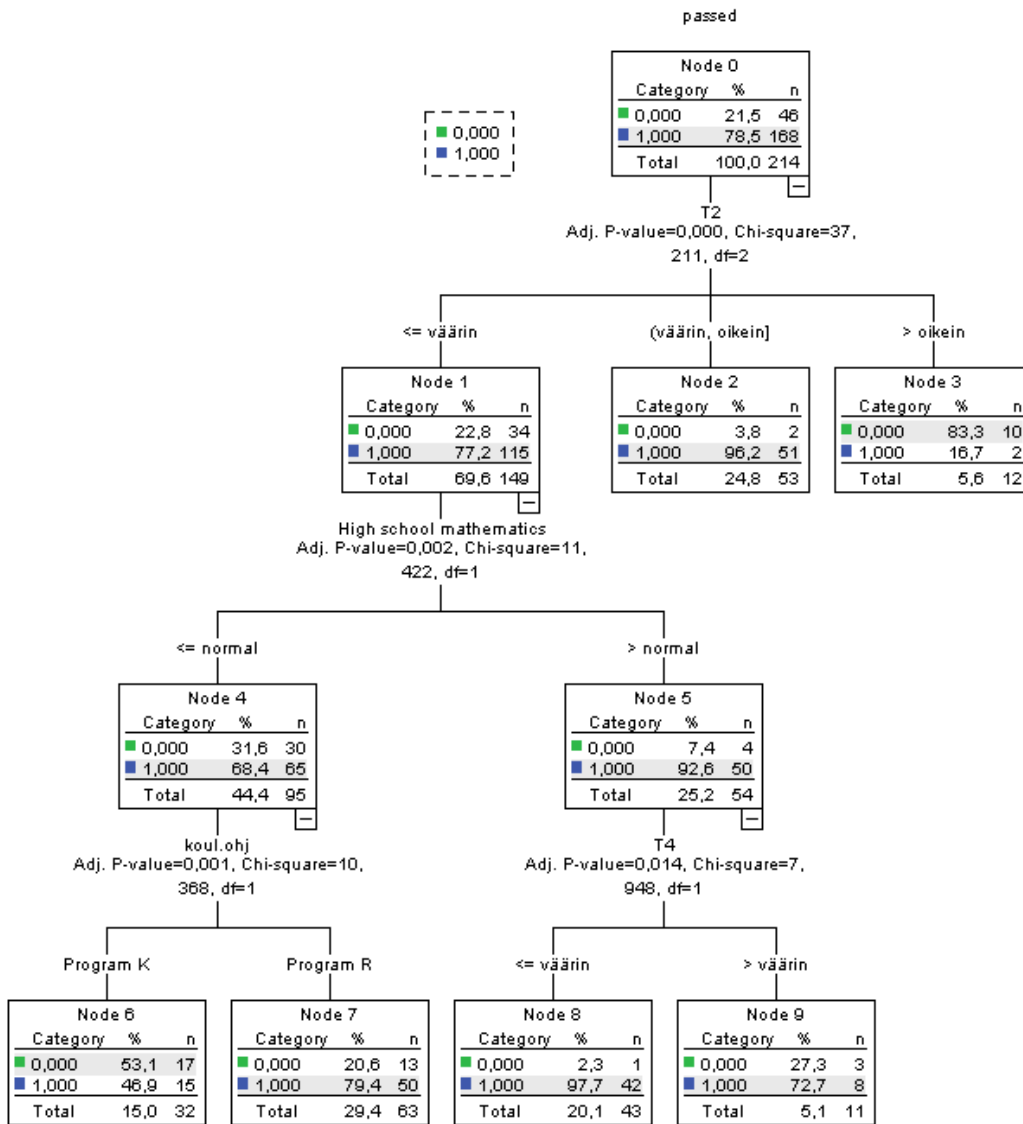


Figure 7. Decision tree for failing/passing the course during 2012 – 2014.

Table 6. Percentages in the new model.

Year		Course 1 in math					
		0	1	2	3	4	5
2012	at risk	100%	55%	35%	14%		
	weak		18%	30%	21%		33%
	ok		27%	35%	65%	67%	33%
	excellent					33%	33%
2013	at risk	79%	50%	16%	8%		
	weak	14%	14%	47%	25%	31%	17%
	ok	50%	57%	37%	59%	61%	50%
	excellent				8%	8%	33%
2014	at risk	81%	63%	20%	10%		
	weak	6%	13%	40%	23%	15%	21%
	ok	13%	24%	40%	64%	70%	48%
	excellent				3%	15%	30%

The newest prediction model is constructed based on previous findings. The percentages of the new prediction model can be seen in Table 6. The new model seems to explain the grades significantly better than the ones used before. According to Somers' D, this model would explain 67.8% (2012), 56.9% (2013) and 74.4% (2014) of grades with the average percentage of 66%. However, this model has not yet been tested.

5.2 Further actions on course arrangements

Some methods described earlier were already in use during *Introduction to Mathematics* with weaker students (Publication IV):

1. *Languaging*: students were allowed to solve exercises in small groups, compelling students to discuss methods and reasoning, and some exercises required written explanations.
2. *Reviewing and practical examples*: a new topic was presented with numbers and everyday mathematics and students mainly formulated calculation rules based on their pre-knowledge.
3. *Scaffolding*: when students had problems in solving the exercises, the teacher usually gave hints and students figured out the answer on their own.
4. *Continuous feedback*: smaller tests during the course tell students about their actual knowledge.

All these methods seem to have a positive influence on learning. In 2011, 37 out of 120 students failed this introduction course. From 2012 to 2014, there were only 23 failed students out of 211 altogether. The results are from the first attempt. However, there is still room for new arrangements.

Languaging exercises were the first exercises for the topic. As Idris (2009) remarks, understanding can be described at three levels. The first level is actually just ‘copying the solution method’ (‘how’) but languaging requires also understanding ‘why’ (level 2). The lack of interest in these exercises resulted from a lack of knowledge instead of laziness towards writing. Thus, these types of exercises should follow the basic calculation exercises.

Working in groups should also be encouraged (Perger, 2013; Angier & Povey, 1999). Students can help each other and may be able to finish more exercises together. Furthermore, when explaining their solutions to fellow students, they must have deeper understanding of the matter, as solutions must be explained more clearly to others. Progress may not be seen by the teacher so easily, but great deal of reasoning takes place. This may be the support that the weaker students need. It seems that students should be allowed select the groups by themselves as there must be mutual trust between all members: all members should be able to ask ‘dumb’ questions without fear of losing face.

If understanding is examined on a timeline, the more exercises are solved, the more understanding will be developed. As in Figure 8, the boundaries for different levels of understanding are not strict. Even instrumental understanding requires solving several basic but different cases. The normal way of giving exercises on paper does not always fulfil the

requirement: some students need to solve more of the same types of exercises than others even to know ‘how’. Automated exercises, for example in the Moodle platform, help here.

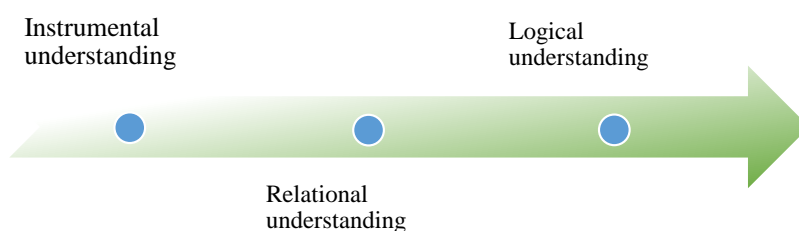


Figure 8. Timeline of understanding.

Hybrid courses (or blended learning) are one way of organising a course. They mix traditional face-to-face teaching and online teaching (Westover & Westover, 2014). Currently, many students want to have their material on the Internet, as a mobile phone or a tablet is so much easier to carry and all material is readily available. Online material also enables studying at one’s own pace. When this possibility is mixed with traditional lectures where students can ask questions and clarify material, learning outcomes could be assumed to improve. At least there are multiple learning pedagogies available for students for better understanding of topics (Li, Zhang, & Yin, 2011).

There is evidence (Westover & Westover, 2014; Clarebut, Horz, Schnotz, & Elen, 2010; Lindsay, 2004), that students’ self-regulating skills may not be sufficient for exercises online. In my online material for the first mathematics course, there are automated exercises on several topics. These automated exercises would promote understanding close to relational understanding. From thirty students starting in 2014, only five of the most enthusiastic ones solved them. Since in extrinsic motivation a person acts in the hope of reward or based on an external demand (Ryan & Deci, 2000), some kind of ‘must’ needs to be included. Giving extra points for passing the course might serve as motivation for solving online exercises. Intrinsically motivated students do not feel that they have to do it, and extrinsically motivated receive a reward.

The next step in developing the online course material is including exercises concentrating on relational understanding. There are some simple languaging exercises, like writing the correct word and selecting the correct case from options, which will promote instructional understanding closer to relational understanding. Although these types of exercises are quite easy to develop on paper, their online implementations needs tremendous work.

Students appreciated quizzes on limited topic areas during the introduction course. According to them, it was easier to prepare for smaller topic areas and the quiz did not feel so

overwhelming. The same idea was used in programme K for the first mathematics course in 2013 and 2014. In principle, students could pass the course with these quizzes but the higher grades need success in applied test at the end of the course. The quizzes check only the instrumental level of understanding and the lower level of relational understanding. Maybe because quite a small number of these exercises were available and the students did not solve them all, the requirements could not be fulfilled. The number of exercises can easily be increased and solving them could be motivated. The greater issue is that some students reacted negatively to the results and lost interest in participating in the applied test.

All this could be summarised as in Table 7. In lecturing, it is important to connect the topic with the prior topic. If students can do this, they do not feel that new knowledge is too difficult and they have higher self-efficacy. Practical examples show concretely why the topic is important. Students admitted that the numbers had meaning when the topic was taught in connection with the professional field (Porras & Toivanen, 2014). In some cases, manipulatives are enough for understanding the abstract information, as visualisation helps in realisation.

Table 7. Implications for course arrangements.

Lecturing	Exercises	Self-Efficacy
<ul style="list-style-type: none"> • Start lectures by reviewing the prior knowledge. If possible, let students figure out the new topic by themselves with help of scaffolding. • Show practical examples to give a motive for studying. • Use manipulatives to help understand of abstract theory. 	<ul style="list-style-type: none"> • Start easy exercises to improve self-efficacy. • Include many exercises to practise the solution technique. • Include some languaging exercises to upgrade understanding. • Let students solve exercises together. 	<ul style="list-style-type: none"> • Give positive feedback in solutions. • If positive feedback is impossible to give, use scaffolding instead of negative feedback. • Every correctly solved exercise gives positive feedback on abilities, and for that reason, improves self-efficacy.

Exercises are an important element in learning. There is evidence that the quality and quantity of exercises have an influence on achievement and motivation. Especially out-of-school exercises seem to have a greater effect on grades than in-school exercises (Kitsantas & Zimmerman, 2009). As homework is done only on demand or for a reward in extrinsic motivation (Naapila, 2010; Salmela-Aro & Nurmi, 2002), some kind of ‘catch’ should be included in course arrangements. On the other hand, external rewards and demands may lower

the motivation of intrinsically motivated students (Ryan & Deci, 2000; Middleton & Spanias, 1999), so the catch should be able to be ignored by these students. For example, the information that some exercises practising the mechanical use of a method is included in the test may give the needed boost for less motivated students, but could be ignored by ones not needing that kind of practise. In addition to instrumental exercises, relational exercises should not be neglected. They give the important know-how needed in solving engineering problems which require logical understanding. When students solve exercises together, they automatically explain the methods and their thinking verbally, which improves their understanding.

Self-efficacy is a motor in learning: if you do not believe in your abilities, why would you bother to try. For that reason, it is very important to give positive reactions to students' efforts. If there is almost nothing correct in student's solution, using scaffolding to help instead of saying 'it's incorrect' or 'do it again' will help with self-efficacy. The more a student can solve exercises correctly and independently, the higher self-efficacy the student will have and the more effort the student is willing to use.

All of these actions have had a positive impact on passing the introduction course and the first mathematics courses (see Table 8). It is worth pointing out that new course arrangements applied only to weaker students in the introduction course. The new arrangements for *the Introduction to Mathematics* are used from the academic year 2012 – 2013 onward.

Table 8. Percentages of failed students during 2011-2014.

Academic year	Introduction course	The first mathematics course	No engagement in the first mathematics course among students in the bridge course
2011-2012	41%	36%	10
2012-2013	7%	22%	0
2013-2014	7%	18%	2
2014-2015	19%	25%	1

When the percentages of different academic years are compared, the results from 2012 onward are statistically better ($\text{sig} < 0.01$) in both courses. Furthermore, ten students participating in the bridge course in the academic year 2011-2012 did not receive any mark in the first course in

mathematics. As both courses start in the same week, this indicates that they actually did not complete the course. This shows strong evidence that the prediction model and course arrangements perform well, as this number has decreased significantly over the years.

Poor results in the introduction course in 2014 can be partly explained with a good prediction and unfortunate circumstances. The prediction model seemed to work quite well and the possible struggling students were recognised, as 83% of failed students attended the introduction course with extra lectures and special teaching methods described earlier. The model was compared with the prediction model of the previous year, and the percentages of failing students were approximately the same. However, as the number of failing students was scattered more widely among the different student groups, the new prediction model seems to work better. The colleagues' comments gave the same indication.

Due to the teacher's business trips, the weaker students lost 12 hours of contact teaching during the first three weeks. Capturing this amount of knowledge requires a great deal of independent study, which was perhaps not the students' strongest area. Of course, this also had an effect on the first mathematics course. In programme K, students lost also normal lectures during the business trips, so the failure of weaker students is understandable. Nevertheless, failure in the courses is far from the level of 2011-2012. The percentages of failed students in group A and group B also suggest that allocating part of the lecturing time from group B to group A did not increase failures in group B.

6 Conclusions

This chapter presents a summary and the main contribution of this thesis. The limitations of this study and possible future research topics are also discussed.

6.1 Summary and contributions

This thesis developed a method for recognising students who are likely to struggle in their mathematical studies. In the first two phases, students were profiled based on their answers in the motivation and self-regulation surveys, previous education and results in proficiency test in relation to the grades in the first mathematics course. These results revealed that motivation in mathematics plays a significant role in learning, and sometimes motivation has been blocked by low self-efficacy. This part of the work gave essential knowledge not only for profiling but also for teaching.

In the third phase, these profiles were analysed together with previous education, results in the proficiency test and grades in the first mathematics course to predict students' success in mathematics. Although previous education has an impact on progress in mathematical studies, actual skills play a more important role. It does not matter as much whether a student studied in upper secondary school or in vocational school if they do not possess the required knowledge. Students learning better by hands-on methods seemed to need examples from their professional field to find motivation to study complicated theoretical topics. As the profiles are connected to actual knowledge, students cannot guess the outcome based on their selection of profiles in the proficiency test, and this decreases the distortion of the profiles.

In the fourth phase simultaneously with the third phase, some new course arrangements were tested to see whether they have value in promoting learning. The methods used were reviewing, scaffolding, languaging, practical examples and continuous feedback. Here the practical examples refer to examples from the students' professional field or from everyday life. This part was not easy for the teacher or the students. It is not easy for the teacher just to give hints instead of showing how the problem should be solved. Directing students' ideas by scaffolding in the right direction requires some practise and teachers must pay attention to it before

lecturing. The result of this method and reviewing in lecturing a new topic seems to be founded on the use of examples. If the examples are not well selected, the methods do not work. Creating languaging exercises and revising existing exercises are both time consuming for teachers.

Overall, students seem to like the new methods. However, the methods used differ from traditional lecturing so much that some students complained that 'you are not teaching us'. This usually happened when they asked for help (wanted the teacher to show how something is done) and only received hints about where the mistake is or what should be done next. Languaging is not the favourite part of learning among engineering students. The most common statements were 'Do I have to do this?' or 'I do not know what to write', and 'I am studying engineering as I do not like writing'. Obviously, they were not used to these types of mathematics exercises. However, they need the skill to promote their understanding in engineering to a logical level. The same kind of atmosphere was noticed also in the study by Van Dyke et al. (2015), although the advantages of writing in developing one's understanding were understood by students of this study.

The main contribution of this thesis is that students needing extra support can be recognised already at the beginning of their studies and the support given to them can be quite easily included in normal lecturing. Fortunately, there was no evidence of diminishing skills in mathematics at the beginning of studies during these years, contrary to the findings of Schwenk and Kalus (2012). However, their data covered a longer period (2000, 2005, and 2010) than this study.

The main difference to profiling in Tampere University of Technology (Huikola, Silius, & Pohjolainen, 2008; Silius, Pohjolainen, Kangas, & Joutsenlahti, 2011) is that they clustered the information to formulate the profiles. In this thesis, information was mined so that students at risk could be identified. This method gives more detailed information on the reasons behind the grades. When students needing extra support are identified at the beginning of their studies, it will decrease the frustration felt by students and prevent drop-outs if their learning is supported. This could be seen in the number of students who participate in the bridge course but were unable to complete the first mathematics course.

Silius et al. (2011) presented a list of weaker students' expectations regarding course arrangements: simple explanations on topics, time for thinking, inspiring students to think for themselves, a large number of examples, combining theory and solutions, and paying attention to students' skills. All of these aspects were taken into account also in the course arrangements of this study. According to this study, real-life examples/applications would also help the weaker students to understand the topic and would give an extra boost in conation.

In the light of other studies mentioned in the introduction, this study combines self-efficacy beliefs, motivational aspects, as well as self-regulation aspects with grades of Bachelor's level engineering students. This seems to be neglected in studies of learning psychology. Whether the teaching is performed with flipped or blended methods, with activating lecturing, or in an e-learning environment, the knowledge of students' behaviour will help in course arrangements.

6.2 Limitations of this study

This study is mainly based on opinions of freshmen. Answers in the motivation and self-regulation surveys may have differed depending on the day or the lecture and its teacher. This can never be fully avoided in surveys based on psychological questions. Furthermore, analyses were conducted with a decision tree, where the significance of branches is checked with a Chi test. In many cases, there was only one degree of freedom. Some statisticians think that the significance in this case is too weak and results should not be used. However, this study is not about validating a new theory in learning psychology; instead, it aims to provide ways to identify weak students. It is understood that nothing is certain when dealing with human beings.

This study has been conducted in the Technology Unit of the Saimaa University of Applied Sciences and handles only students in Finnish degree programmes. There is no evidence of any kind that results could be generalised to other universities of applied sciences even here in Finland.

6.3 Future research

This study has been a good opening for teaching engineering mathematics. It would be interesting to know how well the findings are suited for other engineering courses. This study did not make a distinction between students of production or designing because they had not yet chosen their field of specialisation when the surveys were conducted. The specialisation field might give more interesting information about learning.

One possible branch for research would be international students. Some of them have extremely good knowledge in calculation and calculus but applying that knowledge to practice seems to be problematic. One student told me once that 'we had to know all the formulas by heart but nobody told us where to use them'. It would be interesting to know whether such a background motivates or demotivates international students in Finnish universities.

Results in this experiment have been very promising. Thus, it is also worth exploring whether this profiling could be utilised in other courses where mathematics plays an important role. Other mathematics courses should definitely be organised in the same way.

It's the destination that matters, not the starting point. (Stuart, 2015)

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Appendix A. Motivation survey in Finnish

Motivaatiokysely

Nimi:

Opiskelijoiden valmiuksissa opiskella matemaattisia aineita on havaittu suuria eroja. Osa opiskelijoista omaa erittäin hyvät lähtötiedot ja osalla on suuriakin puutteita peruslaskutaidoissa. Opettajat eivät kuitenkaan ole havainneet, että kurssien hylätyt arvosanat olisivat suoraan verrannollisia aiempaan koulutukseen.

Tämä kysely on osa suurempaa tutkimusta, jossa pyritään kartoittamaan syitä matematiikan opintojen heikkoon etenemiseen. Asiaa tutkitaan myös itseohjautuvuuden ja havaintokanavien hyödyntämisen kannalta. Koska oma motivaatio on tärkein yksittäinen tekijä oppimiselle, aloitetaan tutkimus motivaatiokyselyllä. Jos kyselyn perusteella löydetään yhteisiä motivaatiotekijöitä heikolle suoriutumiseen, pyritään kurssien suunnittelussa huomioimaan nämä asiat.

Vastaa alla oleviin kysymyksiin mahdollisimman rehellisesti. **Voit jokaisessa kysymyksessä antaa kerran 3 pistettä, kerran 2 pistettä ja kerran yhden pisteen. Kaikkia ei ole pakko käyttää (saat valita vapaasti käyttämäsi pisteet) mutta vähintään yksi piste on annettava ja korkein pistemäärä parhaiten kuvaavalle vaihtoehdolle.** Voit siis antaa jossakin kysymyksessä yhteensä kuusi pistettä ja jossakin toisessa vaikkapa 3 + 1 pistettä.

Kirjoitathan nimesi tai opiskelijanumeron paperin ylälaitaan. Nimeäsi käytetään ainoastaan kyselyn ja suoritusten liittämiseksi. Mikäli emme tiedä nimeä, emme tiedä myöskään suorituksia, eikä vastauksia voida liittää kurssien suorittamiseen. Tällä lomakkeella ei tutkita yksittäisten opiskelijoiden motivaatiota vaan pienimmilläänkin yksittäisen koulutusohjelman sisällä olevia motivaatiotekijöitä. Tunnistetiedot (nimi tai opiskelijanumero) eivät ole mukana varsinaisessa datamatriisissa.

Halutessasi voit kysyä lisätietoja allekirjoittaneelta.

Yhteistyöstä kiittäen

Päivi Porras

Päivi Porras

Matematiikan ja fysiikan koordinaattori

Motivaatiokysely

1. Minulle on tärkeää
 - a. saada kurssit suoritetuksi opintosuunnitelman mukaisesti.
 - b. oppia matematiikasta mahdollisimman paljon.
 - c. saada kursseista hyviä arvosanoja.
 - d. harrastaa/käydä töissä, vaikka opiskelut jäisivät hieman varjoon.

2. Miksi hakeuduit alalle?
 - a. Ala kiinnostaa minua.
 - b. Olen jo työskennellyt alalla ja haluan edistää uraani.
 - c. Ala saattaisi kiinnostaa minua.
 - d. Tänne satuin pääsemään.

3. Opiskelu tällä hetkellä
 - a. mahdollistaa myöhemmin hyväpalkkaisen ammatin.
 - b. auttaa minua kehittymään.
 - c. häiritsee hieman harrastuksiani.
 - d. vie lähes kaiken aikani.

4. Jos huomiset tunnit yhtäkkiä peruttaisiin,
 - a. viettäisin aikaa ystäväni seurassa.
 - b. tekisin rästissä olevat kotitehtävät ensin ja sen jälkeen tapaisin ystäviäni.
 - c. saisin koko päivän harjoitustyön tekemiseen.
 - d. en edes huomaisi koko asiaa.

5. Keskittymiseeni vaikuttaa se, että
 - a. käyn töissä opiskelun ohessa.
 - b. minulla on todettu oppimishäiriö.
 - c. olen usein väsynyt tunneilla.
 - d. voin opiskella täysipainoisesti.

6. Matematiikan kursseihin
 - a. panostan, koska tiedän tarvitsevani asioita työelämässä.
 - b. panostan, koska niistä on hyötyä ammattiaineissa.
 - c. panostan, koska haluan päästä kursseista läpi.
 - d. en panosta, koska en tunne tarvitsevani opetettavia asioita missään.

7. Jos en pääse kursseista läpi,
- tärpit eivät osuneet kohdalleen.
 - en ollut opiskellut riittävästi.
 - kysymykset olivat ihan liian vaikeita.
 - niin enpä ole yllättynyt.
8. Lisätehtäviä tekisin
- saadakseni opintopisteet.
 - oppiakseni lisää.
 - jos olisi pakko.
 - saadakseni paremman arvosanan.
9. Opetuksessa on tärkeää, että
- tunneilla on hyvä ilmapiiri.
 - opettaja antaa henkilökohtaista ohjausta.
 - saan perehtyä asiaan rauhassa.
 - voin laskea halutessani tehtäviä yhdessä kavereitten kanssa.
10. Ohjausta matematiikassa
- tarvitsen, koska edellisistä opinnoistani on niin pitkä aika.
 - saatan mahdollisesti tarvita minulle uusien asioiden yhteydessä.
 - tarvitsen, koska osaamiseni ei ole mielestäni riittävää.
 - en luultavasti tarvitse, koska matematiikka on minulle helppoa.
11. Miten paljon aiot käyttää aikaa matematiikan opiskeluun?
- Niin paljon että saan annetut tehtävät tehtyä.
 - Niin paljon että osaan opiskeltavan asian.
 - Niin paljon että luulen saavani kurssit suoritetuksi.
 - Korkeintaan sen verran kuin lukujärjestykseen on merkitty.
12. Annetut tehtävät
- haluan ratkaista yksin.
 - voisin ratkaista pienryhmässä.
 - pitää ratkaista opettajan johdolla taululle.
 - ratkaisen itse kaverin neuvoessa.
13. Matematiikan kotitehtävät
- on tehtävä ennen seuraavaa tuntia.
 - pyrin tekemään lähes aina.
 - minun pitäisi tehdä oppiakseni.
 - jätän todennäköisesti tekemättä.

14. Miten paljon luulet panostavasi matematiikan kursseihin?
- Jätän suosiolla opintojen loppuvaiheeseen.
 - Teen töitä päästäkseni kursseista läpi.
 - Teen töitä saadakseni kursseista hyviä arvosanoja.
 - Teen töitä, koska matematiikka on mielenkiintoista/hyödyllistä.
15. Jos en osaa matematiikan kotitehtäviä,
- menen tarvittaessa klubille harjoittelemaan.
 - kysyn opettajalta.
 - kysyn kaverilta.
 - jätän tekemättä.

Rastita motivaatiosi parhaiten parantavat ideat (max. 5 rastia):

16. Minulle on tärkeää, että
- kotitehtävistä saa lisäpisteitä tenttiin.
 - opettaja laskee taululle riittävästi laskuesimerkkejä.
 - asiasta esitetään alaan liittyviä soveltavia esimerkkejä.
 - opettaja antaa palautetta ratkaisuksista.
 - opettaja selittää asian yksinkertaisesti.
 - opettaja alustaa asian jollakin alaan liittyvällä esimerkillä.
 - opettaja käy teorian lyhyesti ja esittää laskuesimerkkejä.
 - arvosanoihin vaadittavat pisterajat ovat tarkasti selvillä jo kurssin alussa.
 - voin halutessani laskea tehtäviä tuutorin ohjauksessa.
 - kotitehtäviä voi laskea jo tunnilla, jotta saan tarvittaessa apua opettajalta.
 - kotitehtävät ratkaistaan taululle oikeiden ratkaisujen saamiseksi.
 - opettaja kannustaa yrittämään.
 - saan näyttää osaamisen myös kirjallisten tehtävien (käsitekartta, essee) avulla.
 - voin halutessani opiskella kurssit itsenäisesti.
 - taululle lasketuista ja selitetyistä tehtävistä saa lisäpisteitä.
 - klubilla käymisestä saisi lisäpisteitä.
 - voisin suorittaa kurssin vertaisryhmän avulla.

Kirjoita alla oleville viivoille muita motivaatiota lisääviä ideoita:

KIITOS YHTEISTYÖSTÄ!

Appendix B. Self-regulation survey in Finnish

Itseohjautuvuus

Nimi:

Opiskelijoiden valmiuksissa opiskella matemaattisia aineita on havaittu suuria eroja. Osa opiskelijoista omaa erittäin hyvät lähtötiedot ja osalla on suuriakin puutteita peruslaskutaidoissa. Opettajat eivät kuitenkaan ole havainneet, että kurssien hylätyt arvosanat olisivat suoraan verrannollisia aiempaan koulutukseen.

Tämä kysely on osa suurempaa tutkimusta, jossa pyritään kartoittamaan syitä matematiikan opintojen heikkoon etenemiseen. Asiaa tutkitaan myös motivaation ja oppimistyylien kannalta.

Vastaa alla oleviin kysymyksiin mahdollisimman rehellisesti. Anna pisteitä seuraavasti:

1 piste: Ei kuvaa minua juuri ollenkaan; tuskin koskaan tunnen tällä tavalla.

2 pistettä: Ei kuvaa minua kovinkaan usein; joskus saatan tuntea näin.

3 pistettä: Kuvaa minua joskus; tunnen näin ehkä puolet ajasta.

4 pistettä: Kuvaa minua useimmiten; tunnen melko usein näin.

5 pistettä: Kuvaa minua lähes aina; tunnen usein näin.

Kirjoitathan nimesi tai opiskelijanumeron paperin ylälaitaan. Nimeäsi käytetään ainoastaan kyselyn ja suoritusten liittämiseksi. Mikäli emme tiedä nimeä, emme tiedä myöskään suorituksia, eikä vastauksia voida liittää kurssien suorittamiseen. Tällä lomakkeella ei tutkita yksittäisten opiskelijoiden itseohjautuvuutta vaan pienimmilläänkin yksittäisen koulutusohjelman sisällä olevia itseohjautuvuuden tasoja. Tunnistetiedot (nimi tai opiskelijanumero) eivät ole mukana varsinaisessa datamatriisissa.

Halutessasi voit kysyä lisätietoja allekirjoittaneelta.

Yhteistyöstä kiittäen

Päivi Porras

Päivi Porras

Matematiikan ja fysiikan koordinaattori

Itseohjautuvuus matematiikassa

1. Minä
 - a. ___ asetan itselleni oppimistavoitteita tutkinnon suorittamiseksi.
 - b. ___ asetan itselleni tavoitteet kurssi-arvosanoille.
 - c. ___ asetan itselleni pienempiä tavoitteita kurssien aikana tietäessäni vaatimukset paremmin.
 - d. ___ noudatan kurssin opetussuunnitelmassa olevia tavoitteita.
2. Valmistaudun kurssin suorittamiseen
 - a. ___ suunnittelemalla opiskeluaikatauluni viimeistään kurssin alkaessa.
 - b. ___ hahmottelemalla viikoittaista aikataulua.
 - c. ___ tutustumalla opettajan tapoihin ja vaatimuksiin.
 - d. ___ kertaamalla aiemmilla kursseilla käytyjä asioita.
3. Kurssin aikana
 - a. ___ en yleensä perehdy arvosanojen muodostumisperusteisiin.
 - b. ___ osallistun tunneille ja teen annetut kotitehtävät.
 - c. ___ kysyn opettajalta usein selvennyksiä.
 - d. ___ ihmettelen aineen tarpeellisuutta todellisessa elämässä.
4. Mielestäni matemaattisten aineiden opiskelu
 - a. ___ tuntuu turhauttavalta.
 - b. ___ onnistuu, jos yritän parhaani.
 - c. ___ on mielenkiintoista.
 - d. ___ ei ole tärkeää ammattiaineiden takia.
5. Opiskellessani matemaattisia aineita
 - a. ___ huomaan usein miettiväni muita asioita,
 - b. ___ kavereiden kanssa huomaan meidän keskustelevan enemmän muista aiheista kuin matematiikasta,
 - c. ___ haen tarvittaessa lisämateriaalia verkosta tai kirjastosta,
 - d. ___ käytän usein suunniteltua enemmän aikaa oppiakseni.
6. Opiskellessani matemaattisia aineita
 - a. ___ mietiskelen, kuinka hyvin teoria on sovellettavissa käytäntöön.
 - b. ___ yritän yhdistää asiat aiemmin oppimaani.
 - c. ___ pyrin opettelemaan ulkoa perusasiat.
 - d. ___ minulla on vaikeuksia ymmärtää matemaattisia kaavoja.

7. Minä

- a. ___ vastaan oppimisestani viime kädessä itse.
- b. ___ osaan aikatauluttaa opiskeluni ja noudattaa laatimiani aikatauluja.
- c. ___ osaan organisoida tekemiseni niin, että oppimiselle jää aikaa kiireistäni huolimatta.
- d. ___ tiedän, mitä kursseilla pitäisi osata, mitä osaan ja mitä minun pitää vielä harjoitella.

8. Huomatessani, että en osaa tai ymmärrä jotakin asiaa, niin

- a. ___ hakeudun klubille/tukikurssille laskemaan.
- b. ___ pyydän kaverilta ratkaisua nähtäville.
- c. ___ en yleensä kysy apua keneltäkään.
- d. ___ kysyn opettajalta täsmennyksiä.

9. Tehostaakseni opiskelua

- a. ___ pidän kirjaa kurssin suorittamiseen käytetystä ajasta.
- b. ___ pyrin mukauttamaan opiskelutapojani kurssivaatimuksia vastaaviksi.
- c. ___ pyrin saamaan palautetta edistymisestääni jo kurssin aikana.
- d. ___ etsin opiskeltavat kaavat heti kaavakirjasta ymmärtääkseni kaavakirjan merkinnät myös koetilanteissa.

10. Valmistautuessani matemaattisten aineiden kokeeseen

- a. ___ huomaan jättäväni valmistautumisen kesken, koska aihe ei kiinnosta.
- b. ___ motivoin itseäni pienillä palkkioilla (esim. kuppi kahvia), kun tietty määrä tehtäviä on laskettu oikein.
- c. ___ huomaan usein valmistautumisen tapahtuvan liian myöhään.
- d. ___ muistutan itselleni, että kurssi ei ole kovin tärkeä työelämää ajatellen.

11. Kurssin jälkeen

- a. ___ iloitsen suoritusmerkinnästä, kun sain kurssin pois mielestä.
- b. ___ luotan osaamiseeni enemmän kuin aiemmin.
- c. ___ mietin, kuinka voisin soveltaa oppimaani myöhemmin.
- d. ___ käyn katsomassa koepaperini oppiakseni tekemistäni virheistä.

12. Mikäli en saavuttanut tavoitteitani kursilla, niin syy on

- a. ___ huonoissa opetusmenetelmissä,
- b. ___ huonosta keskittymisestääni,
- c. ___ heikoista matematiikan taidoistani,
- d. ___ opiskeluun käyttämäni ajan vähäisyydestä.

Appendix C. Forming profiles

Question marks starting with a number refers to the motivation survey and question marks starting with 'i' refers to the self-regulation survey.

G refers to points in the proficiency test, where 1 refers to the points 0 - 4, 2 to points 5 – 8, and 3 to points 9 – 12.

E refers to previous education, where 1 refers to students from vocational colleges, 2 to upper secondary schools students with the basic mathematics syllabus, and 3 to upper secondary school students with the advanced mathematics syllabus.

Profile	Surveys	Cognitive	Prediction
P1	$14d \leq 2$ and $c10 > 0$	$G \geq 2$	weak
P2	$14a > 0$	$E \leq 2$	at risk
P3	$i10b > 3$ and $b14 > 2$		at risk
P4	$14b = 0$ and $i10c \leq 2$		excellent
P5	$i5c > 2$	$G = 1$	at risk
P6	$i4d > 2$ and $12a \leq 1$	$G = 1$	weak
P7	$b2 > 2$ and $c10 = 0$ and $8d \leq 2$	$E \leq 2$	at risk
P8	$3a > 2$ and $i2c > 1$	$G = 1$	weak

Profile	Surveys	Cognitive	Prediction
P9	$c_{10} \leq 2$ and $c_7 > 1$	$E \leq 2$	at risk
P10	$c_{10} \leq 1$ and $i_{8c} > 1$ and $i_{7c} \leq 2$		weak
P11	$11b \geq 0$ and $i_{4c} > 3$ and $i_{9c} \geq 3$	$E = 3$	excellent
P12	$10d > 0$ and $12a > 1$	$G = 1$	excellent
P13	$10c > 0$ and ($i_{11a} > 4$ and $E = 3$)		at risk
P14	$10c > 2$	$E \leq 2$	weak
P15	$2d > 1$		doubts
P16	$16c = 1$		lowers grades universally

Appendix D. Final profiles in Finnish

- P1. Koen matematiikan tärkeäksi mutta taitoni eivät välttämättä riitä.
- P2. Voi olla, että suoritan matematiikan kurssit myöhemmin.
- P3. En yleensä motivoi itseäni palkkioilla (esim. kuppi kahvia) mutta hankalien kurssien kohdalla saatan niin tehdäkin.
- P4. En usko kamppailevani kurssien läpäisemisen kanssa ja yleensäkin valmistaudun kokeisiin ajoissa.
- P5. Etsin verkosta ja kirjastosta lisätietoa.
- P6. En koe matematiikka kovinkaan tärkeäksi ja tekisin tehtävät mielellään toisten kanssa.
- P7. Olen työskennellyt alalla ja haluan kouluttautua lisää. Mielestäni osaan matematiikkaa mutta aika ei välttämättä riitä lisätehtävien tekemiseen.
- P8. Haluan mahdollisimman nopeasti työelämään, joten otan selvää opettajan tavoista ja vaatimuksista.
- P9. Jos en läpäise kursseja, niin syy on luultavammin liian vaikeissa koetehtävissä kuin tarpeessani saada ohjausta.
- P10. Osaan mielestäni hyvin matematiikka enkä helposti pyydä apua. Joskus saattaa olla ongelmia ajankäytön kanssa.
- P11. Mielestäni matematiikka on mielenkiintoista. Pysin ymmärtämään opiskeltavan asian ja yritän saada palautetta osaamisestani jo kurssin aikana.
- P12. Minulle matematiikka on helppoa ja haluan ratkaista tehtävät yksin.
- P13. Kurssin suorittamisen jälkeen olen vain iloinen saavutuksesta enkä liiemmin mietiskele kurssin asioita sen jälkeen.
- P14. En vain osaa.
- P15. En ole ihan varma, onko tämä juuri minulle sopiva ala.
- P16. Minusta on tärkeää esittää käytännön esimerkkejä siitä, mihin matematiikkaa tarvitaan.

Appendix E. Publications

Publication I

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Motivation towards Mathematical Studies in Engineering

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Abstract Despite the good results of Finnish pupils in PISA, there are more and more students in engineering struggling in their mathematical studies. The main idea of the study was to recognize those freshmen in engineering who are at risk in their mathematical studies, i.e., they drop out courses or do not pass them (*critical students*). If they were recognized at the beginning of their studies, teachers could support their learning from the day one and, hopefully, they would graduate in time. This particular study was focused on students' motivation as one's own motivation is essential for learning. Students were asked to fill in questionnaire with statements about studying mathematical courses. According to the results, some critical students could be identified based on their motivation but extra information is also needed.

Key words: motivation, avoidant, extrinsic, achievement, intrinsic

Introduction

Technology has always been based on mathematics and physics. Without any mathematical knowledge it is impossible to work as a professional in the field although programs and computers do most of the calculations. Mathematics also helps in logical thinking that is essential in the field of technology. In Finnish universities of applied sciences, there are more and more students who have difficulties in passing mathematics courses despite the good results of Finnish students in PISA. There are several articles dealing with the same phenomenon all around the world, e.g. in the United Kingdom (Engineeringtalk, 2001) and Canada (University Affairs, 2010). In both of these articles a concern for mathematical skills in engineering can be perceived.

Engineering students have studied either in a high school or in a technical college before entering UAS engineering studies. For several years, freshmen in our university of applied sciences have participated in a proficiency test at the beginning of their studies. Results of these proficiency tests are mainly used for comparing freshmen to students of previous years and for comparing freshmen in different programmes. The best freshmen do not need to participate in the introduction course of mathematics, which is meant for refreshing students' memories in basic algebra.

Mathematical knowledge for students coming from high schools is beyond the knowledge of students coming from technical colleges. Cross-tabulation of categorised points of the proficiency test versus previous education is presented in Table 1. The more students have studied mathematical courses the better points they have gotten. Although this dependency is statistically significant (approx. sig = 0.000), only 34 per cent of the points (value = 0.337) can be explained with previous education.

Table 1 Previous education vs. results in the proficiency test

Previous studies * Points_class Crosstabulation

Count

		Points_class			Total
		bad	average	ok	
Previous studies	college	37	1	0	38
	college + high school	5	0	2	7
	high school	49	30	9	88
	not known	1	0	0	1
Total		92	31	11	134

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	,343	,057	5,394	,000
		Previous studies Dependent	,349	,062	5,394	,000
		Points_class Dependent	,337	,061	5,394	,000

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

When comparing the grades of the first mathematical course with previous education, it is found that previous education does not explain the grades very well. According Table 2, only about 27 per cent of the grades (value = 0.271) can be explained with previous education. This knowledge, at the latest, should stop categorizing students to weak and good students by their previous education.

Table 2 Previous education vs. grades of the first course in mathematics

Count

		Course 1 in math						Total
		0	1	2	3	4	5	
Previous studies	college	12	2	8	5	3	4	34
	college + high school	4	0	0	2	0	0	6
	high school	13	11	11	11	21	13	80
	not known	0	0	0	0	1	0	1
Total		29	13	19	18	25	17	121

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	,200	,072	2,759	,006
		Previous studies Dependent	,159	,058	2,759	,006
		Course 1 in math Dependent	,271	,097	2,759	,006

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

The general assumption has been that students with poor points in the proficiency test are usually struggling with their mathematical courses. In Table 3, a cross-tabulation of categorised points in the

proficiency test and grades of the first course in mathematics are presented. Although 56 per cent of the grades (value = 0.557) can be explained with the results in the proficiency test, the proficiency test alone is not enough for finding critical students. As it can be seen, there are several students getting high grades despite the poor results in the proficiency test. On the other hand, the high points in the proficiency test do not guarantee good grades.

Table 3 Results in proficiency test vs. grades in the first mathematical course

Count		Course 1 in math						Total
		0	1	2	3	4	5	
Points_class	bad	28	11	15	11	9	7	81
	average	0	2	3	6	14	5	30
	ok	1	0	1	1	2	5	10
Total		29	13	19	18	25	17	121

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	,413	,062	6,124	,000
		Points_class Dependent	,328	,054	6,124	,000
		Course 1 in math Dependent	,557	,082	6,124	,000

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

The main idea of the study is to find those students who have difficulties in passing courses in mathematics. We are focusing on motivation in this first part. We are interested in whether students' motivation towards mathematical studies could give hints about performing in those courses.

Theoretical Framework

Motivation is the base for learning. If there is no earthly motivation, there is no learning either. According to Waitley (1990), motivation cannot be pumped in with incentives, pep talks or diatribes. People can be encouraged and inspired with those but only if they want it by themselves.

There is an affecting *motive* before a decision and a *will* after the decision (Ruohotie 1998). A motive gives impetus for making the decision and the will helps attaining goals. Separating the motive and the will is almost impossible. In this study, *motivation* means both the motive and the will. A student needs a motive (credits, graduating etc) to start studying but do it by an effort of will. It is teacher's responsibility to give these impetus for a student and, also, to maintain the will.

Kauppila (2003) separates learning motivation into five groups: *avoidance motivation*, *diverged motivation*, *escape motivation*, *achievement (or performance) motivation* and *intrinsic motivation*.

A student has *avoidance motivation* if they are disregard or reluctant toward the subject and they have a weak self-efficacy in learning achievements. There are subconscious and, maybe, also conscious processes which prevent learning. For example, a student with dyslexia may have gotten incorrect results in mathematical problems because of miswriting. These failures may induce avoidance motivation (Förster et al. 2001). It may also be that mathematics is irrelevant to a student as they cannot relate to it

personally (Guthrie et.al 2009). Ryan and Deci (2000) define amotivation as ‘the state of lacking an intention to act’.

Diverged motivated students have lots of other things in their mind like working, hobbies or acting in a student union. A student is active but there is not enough time to study. These students could be excellent in their studies if they were concentrating on studying.

In *escape motivation*, a student just tries to pass courses with learning by heart. The motive is to escape failures. Ryan and Deci (2000) define escape motivation as *external regulation*. These students do everything only for external reward, such as extra points for passing the course, or for external demand, like ‘it must be done to pass the course’. According to Ryan and Deci, these students experience behaviour as alienated or controlled. Bong (2009) states that these students have *performance-avoidance goals*. These kinds of goals are usually demonstrated by negative associations with self-efficacy and academic performance. Achievements for these students vary very much and studying is surface level learning according to Kaupila (2003).

Achievement motivated students want to do courses well (esteem needs). They may do it

1. to avoid guilt, anxiety or shame
2. for effect, or
3. to appear to be better than the others.

Grades are important to these students. Ryan and Deci (2000) call this as *introjected regulation*. These people act with the feeling of pressure. According to Bong (2009), they have performance-approach goals that often demonstrate positive association with self-efficacy and academic performance.

Ryan and Deci (2000) define *intrinsic motivation* as ‘the doing the activity for its inherent satisfaction rather than for some separable consequence’. Intrinsically motivated students are interested in the subject and want to get deeper understanding: they use a lot of time for studying. They are motivated by the subject and grades are not so important to them. Ryan & Deci (2000) and Middleton & Spanias (1999) also state that all kinds of rewards, directives, deadlines etc. diminish intrinsic motivation. Thus, autonomy seems to be important in intrinsic motivation. Intrinsic motivation can also be problematic in academic studies if a student does not graduate because of being fond of studying (Lonka et al. 2004).

According to Waitley (1990), motivation is an emotion. It is dominated by *fear* or *desire*. Fear can sometimes even prevent to reach one’s goals: it reminds of failures. A student may not even have expectations for success (avoidance motivation, escape motivation). It can also be perceived in achievement motivation if studying is, for example, done to influence one’s parents. If fear roots from earlier experiences, it may take a long time to get fear out of one’s system. If fear roots from lack of self-confidence (e.g. weak base, long time from previous studies), the supportive feedback may defuse it. These students use lots of phrases like *I cannot, I have to or I must try*. If motivation roots from desire, it encourages reaching one’s goals. These students have lots of expectations and may not even have thought about failure. They use phrases like *I want, I can or I do*. (Waitley 1990)

By the expectancy-value theory, one’s expectancies and values are assumed to influence directly achievement choices (Wigfield and Eccles 2000). Expectations are all beliefs one has about oneself and one’s ability to perform the task. By this theory, it is assumed that expectations of performing the task will affect on one’s motivation. A child, who believes in his own abilities, tries hard despite the difficulties and failures. A child construes failure as not trying enough. A child, who does not believe in his abilities, expects failures and easily gives up on tasks to avoid failure. This kind of behaviour in the long run leads to poor performance and retaining the positive self-concept becomes difficult. (Salmela-Aro et al., 2002).

Motivation psychology is a difficult field with various theories (Metsämuuronen 2009, p. 116). In this study, the theoretical background is studied as *realistic theory*, i.e., as assumed truth. The main idea is

not to validate existing theories but to find factors indicating amotivation (lack of motivation). If these factors can be recognized, there may be a possibility to find methods for supporting students in their studies.

In this study, the students were asked to complete a motivation questionnaire and they were categorised according to their answers to different motivation groups according to Kauppila. Kauppila (2003) groups motivation in studying as *avoidance*, *diverged*, *escape*, *achievement* and *intrinsic motivation*. Except for diverged motivation (acting in a student union, working etc), the groups adapt motivation defined by Ryan and Deci (2000). Answering was not done anonymously so that the students' grades in mathematical courses (mathematics and physics) and results of the proficiency test could be included in the same data.

Results of the motivation study

Kauppila's motivation categories were chosen for grouping the students. As critical students were to be found, it is enough to know whether students are avoidance, diverged, escaped, achievement or intrinsic motivated towards mathematical studies. In Table 4, the observed percentages of different motivation groups are presented. As can be seen, most students are escape-motivated (49.3 %). This result was expected but not hoped. By Kauppila (2003), these students just try to pass courses with learning by heart. Their motive is to escape failures. Although this is not a recommended way of studying, it may not be seen as a problem in this study, if students can pass the courses without any problems. The second largest group (19.6 %) seems to be the intrinsic motivated students. If a student has an intrinsic motivation either towards mathematical studies or professional field, the student is likely to graduate without any problems.

Table 4 Percentages in Kauppila's motivation

		Percent	Valid Percent	Cumulative Percent
Valid	avoidant	1,4	1,9	1,9
	diverged	2,9	3,7	5,6
	escaped	49,3	63,0	68,5
	achievement	5,1	6,5	75,0
	intrinsic	19,6	25,0	100,0
	Total	78,3	100,0	
Missing	System	21,7		
Total		100,0		

Table 5 Motivation level by Kauppila vs. grades of the first mathematical course

		Course 1 in math						Total
		0	1	2	3	4	5	
Kauppila's motivation groups	avoidant	0	0	1	0	1	0	2
	diverged	2	0	1	1	0	0	4
	escaped	12	12	14	8	14	8	68
	achievement	0	0	1	1	3	2	7
	intrinsic	1	1	1	9	7	7	26
Total		15	13	18	19	25	17	107

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	,297	,065	4,351	,000
		Kauppila's motivation groups Dependent	,244	,056	4,351	,000
		Course 1 in math Dependent	,379	,083	4,351	,000

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

A cross-tabulation between Kauppila's groups and the grades of the first course in mathematics (see Table 5) shows that grades seem to be lower for weakly motivated than for highly motivated. This was also tested with Somer's d-test. Somer's d-test is used if variables are in ordinal scale but a property does not disappear with the value zero as weak motivation does not mean that there is not any kind of motivation. According to the test, 38 % of grades (value = 0.379) could be explained by motivation toward mathematical studies. The result is statistically significant (sig. = 0.000) and higher than for previous education and for the proficiency test but, still, quite low.

Erkkilä and Koivukangas (2010) found correlation between the interest in professional field and progress in studies. According to them, if a student is interested in the professional field, then the student is also motivated to study. Also, if the student is motivated in studies, the student will progress in their studies. All these dependencies were statistically significant. Four questions in the motivation questionnaire handled the motivation in the student's professional field. When results of them and mathematical studies were cross-tabulated, the same kind of dependency was also found among students in engineering. As it can be seen from Table 6, the dependency between motivation in the professional field and mathematical studies is statistically significant (sig. = 0.000). However, no statistical dependency was found in motivation in the professional field and grades of the first course in mathematics.

Table 6 Kauppila's motivation groups vs. motivation in the professional field

		Motivation in professional field			Total
		weak	normal	high	
Kauppila's motivation groups	avoidant	2	0	0	2
	diverged	2	1	1	4
	escaped	31	23	14	68
	achievement	1	3	3	7
	intrinsic	1	13	13	27
Total		37	40	31	108

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	,368	,070	4,964	,000
		Kauppila's motivation groups Dependent	,333	,067	4,964	,000
		Motivation in professional field Dependent	,412	,078	4,964	,000

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

It was also studied how motivation towards the professional field is affected by previous education. From Table 7, it can be seen that students from technical colleges are more motivated in their professional field than students coming from high school. It seems to be logical as these students have already studied in their professional field and they can envisage working in the field.

Table 7 Motivation in professional field vs. previous education

		Motivation in professional field			Total
		weak	normal	high	
Previous studies	college	5	10	12	27
	college + high school	0	1	2	3
	high school	31	26	16	73
	not known	0	1	0	1
Total		36	38	30	104

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	-,243	,081	-2,916	,004
		Previous studies Dependent	-,202	,069	-2,916	,004
		Motivation in professional field Dependent	-,305	,102	-2,916	,004

a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

Most of the students are escape-motivated meaning they try to avoid failures. It was also further studied whether expectance or value could explain grades on Kauppila's motivation levels and, especially, the grades of escape-motivated students. Expectance did explain them to some extent but value was not statistically significant. Hopefully, self-regulated learning would explain grades more among this group.

Hannula (2006) found that subgoals may support motivation. For example, intrinsically motivated student with a subgoal in performing well (achievement motivation), did support the students studying. When motivation levels were analysed, some of the results were very close to each other or even exactly the same, whereas, for some students, the first motivation was to stand out from the others. The second best motivation level was determined to be checked if it will have influence on performance. No statistical dependency was found.

There is a positive correlation between expectancy and value given to mathematical studies by students. When the grades of the first course in mathematics are cross-tabulated with expectancy and value separately, both of them are statistically significant in explaining grades. Expectance is very significant (sig. = 0.000) in explaining the grades and value is explaining the grades quite significantly (sig. = 0.005). It has been shown in many studies that students' expectation of their own learning has a great impact on performance (Watt et al 2006).

The grades of the first course in mathematics were also classified with the decision tree in IBM SPSS. Grades were first categorized so that 1 stands for the original grade zero or one, 2 for the grade two of three and 3 for the grades four and five. The dependent variable was these categorized grades and independent variables were previous mathematical education, categorized points of the proficiency test and all statements of the motivation questionnaire. The categorized grades are used as we were concerned of finding the critical students. If we were able to classify the lowest grades correctly, we could identify the critical students (the ones struggling with their mathematical courses).

First, classifying was forced to do by previous education in mathematics. Almost 71 per cent of grades could be classified correctly to categorized grades and ten of 41 from the lowest category were misclassified. Students from technical colleges or with normal high school mathematics were mostly classified by the statement: 'I work to pass courses'. If a student had even a little doubt of need for working, the student was quite likely to belong to the category 1 in grades. The students with extensive mathematics in high school did not have this feature.

The categorized grades were also classified with the same variables but forced by categorized points of the proficiency test. Now, almost 74 per cent of categorized grades could be classified correctly and only five of 41 from the lowest category were misclassified. If a student's points in the proficiency test belonged to the category one or two and the student gave points to the statement 'I work to pass courses', the student was more likely to belong to the lowest grade category. If a student's points were in the highest category but the student did not give points to the statement 'I may need guidance in mathematics when studying new topics', the student was more likely to belong to the possible critical students. If, furthermore, the student did not give the maximum points to the statement 'I am interested in my professional field', the probability of being a critical student was almost 53 percent (9 out of 17).

Conclusion

The idea of this study was to find some traits in students explaining students' performance in mathematical courses. Because of the weaker mathematical knowledge of students coming from technical colleges it would be easy to use that as an explanation. Although these students may have more technical difficulties in solving the mathematical problems, it does not mean that they would not pass the courses or would more easily drop out studying them. It was thought at the beginning of this study

that these students must be more motivated in their studies as they must have known the difference in mathematical studies already when applying.

Motivation towards the professional field was studied too. Although motivation towards the professional field alone does not explain the grades, it will give valuable information for further studies. In the research of Martin and Marsh (accessed 2011), greater variances in motivation from student to student than between the school levels or schools was detected. Martin and Marsh studied motivation inside different schools and did not find great variances. In this study, students came from different schools to study engineering. This may explain why there was seen dependency between the previous education and motivation level.

The motivation level explained about 36 per cent of grades of the first course in mathematics. The higher the motivation level is the better grades students seem to get. Only for escaped motivated students the grades were varying a lot. Most students belong to this group and, obviously, there is need for studying these students more.

Motivation explains progress in studies to some extent but not all of it. Self-regulation could give some more information about students. When we have information about self-regulation among engineering students, we can form portraits of students. If portraits are good enough and freshmen select the portrait describing them the best honestly, we could identify critical students at the beginning of their studies. It would allow us teachers to plan personal curriculum for these students or, at least, to watch their mathematical studies and, if needed, to discuss with them before it is too late.

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ENTHUSIASM TOWARDS MATHEMATICAL STUDIES IN ENGINEERING

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There are more and more students in engineering struggling in their mathematical studies. The main idea of the study was to recognize those freshmen in engineering who are at risk in their mathematical studies, i.e., they drop out courses or do not pass them (critical students). If these students were recognized at the beginning of their studies, teachers could support their learning from the day one and, hopefully, they would graduate in time. This particular study was focused on students' motivation and self-regulation as they are essential for learning in the universities. Students were asked to fill in two questionnaires with statements about studying mathematical courses. Some critical students could be identified based on their motivation and self-regulation but extra information may also be needed.

INTRODUCTION

Mathematics and physics are the basis for engineering studies. Without mathematical knowledge, it is impossible to work as a professional in the field although programs and computers do most of the calculations. Mathematics also helps in logical thinking that is essential in the field of technology. In Finnish universities of applied sciences, there are more and more students who have difficulties in passing mathematics courses despite the good results of Finnish students in PISA.

In the previous study (Porras 2011), it is shown that freshmen's previous education does not give enough information for progressing in mathematical studies. Proficiency test at the beginning of their studies gives a better hint but much more information is needed. Neither motivation nor self-regulation alone helped much more. In this study, it is analysed whether they together could help in profiling students. The main concern is that factors found should be easily checked by teachers and, also, easy to recognize by freshmen.

THEORETICAL FRAMEWORK

Motivation

Motivation is the base for learning. If there is no earthly motivation, there is no learning either. According to Waitley (1990), motivation cannot be pumped in with incentives, pep talks or diatribes. People can be encouraged and inspired with those but only if they want it by themselves.

Kauppila (2003) separates learning motivation into five groups: *avoidance motivation, diverged motivation, escape motivation, achievement (or performance) motivation and intrinsic motivation.*

A student has avoidance motivation if they are disregard or reluctant toward the subject and they have a weak self-efficacy in learning achievements. There are subconscious and, maybe, also conscious processes which prevent learning. For example, a student with dyslexia may have gotten incorrect results in mathematical problems because of miswriting. These failures may induce avoidance motivation (Förster et al. 2001). It may also be that mathematics is irrelevant to a student as they cannot relate to it personally (Guthrie et.al 2009). Ryan and Deci (2000) define amotivation as “the state of lacking an intention to act”.

Diverged motivated students have lots of other things in their mind such as working, hobbies or acting in a student union. A student is active but there is not enough time to study. These students could be excellent in their studies if they were concentrating on studying.

In escape motivation, a student just tries to pass courses with learning by heart. The motive is to escape failures. Ryan and Deci (2000) define escape motivation as external regulation. These students do everything only for external reward, such as extra points for passing the course, or for external demand, like “it must be done to pass the course”. According to Ryan and Deci, these students experience behaviour as alienated or controlled. Bong (2009) states that these students have performance-avoidance goals. These kinds of goals are usually demonstrated by negative associations with self-efficacy and academic performance. Achievements for these students vary very much and studying is surface level learning according to Kauppila (2003).

Achievement motivated students want to do courses well. They may do this to avoid guilt, anxiety or shame, for effect or to appear to be better than the others. Grades are important to these students. Ryan and Deci (2000) call this as *introjected regulation*. These people act with the feeling of pressure. According to Bong (2009), they have performance-approach goals that often demonstrate positive association with self-efficacy and academic performance.

Ryan and Deci (2000) define intrinsic motivation as “the doing the activity for its inherent satisfaction rather than for some separable consequence”. Intrinsically motivated students are interested in the subject and want to get deeper understanding: they use a lot of time for studying. They are motivated by the subject and grades are not so important to them. Ryan & Deci (2000) and Middleton & Spanias (1999) also state that all kinds of rewards, directives, deadlines etc. diminish intrinsic motivation. Thus, autonomy seems to be important in intrinsic motivation. Intrinsic motivation can also be problematic in academic studies if a student does not graduate because of being fond of studying (Lonka et al. 2004).

According to Waitley (1990), motivation is an emotion. It is dominated by fear or desire. Fear can sometimes even prevent to reach one's goals: it reminds of failures. A student may not even have expectations for success (avoidance motivation, escape motivation). These students use lots of phrases like *I cannot, I have to* or *I must try*. If motivation roots from desire, it encourages reaching one's goals. These students have lots of expectations and may not even have thought about failure. They use phrases like *I want, I can* or *I do* (Waitley 1990).

Self-Regulation

Self-regulation or self-regulated learning (SRL) may be seen as the self-directive process where learning is viewed as an activity of learning in a proactive way. Zimmerman (2000, 2002), Shunk and Ertmer (2000) define self-regulation as self-generated thoughts, feelings and behaviour that are oriented to attaining goals. Self-regulated learning is learnt by experience and reflection. It could be said to be an academic skill, which matures along the studies (Pintrich 1995).

Four *general assumptions* in SRL (Pintrich 2000, 2004) are that

- a. students are active participants,
- b. they are able to monitor, control and regulate certain aspects of their cognition,
- c. they can reflect their learning to some criteria, goal or standard and
- d. self-regulation is a compromise between personal, contextual characteristics and actual performance.

All these assumptions are also present in the phases of self-regulation by Zimmerman (2002). Zimmerman sees self-regulation in three phases, whereas Pintrich (2004) sees it in four phases. Differences in processes are not significant, as both consist of the situation before studies, during the studies and after studying.

The first phase describes a student's forethoughts, planning and activation before studying (Zimmerman 2000, 2002). Zimmerman calls them task analysis and self-motivation beliefs. At this phase, a student sets and plans steps for achieving a goal according to perceptions of task difficulty, value and interest. When considering the task difficulty, the student's beliefs about personal capability for doing the task, e.g. self-efficacy, are also perceived. If the student has low outcome expectations and no intrinsic interest or value for a topic, very much cannot be expected either for self-motivation or strategic planning. Students have motivation to learn in a self-regulated fashion, if they are interested in the task and value the learning for its own merits.

The second phase in Zimmerman's self-regulation process consists of self-observation and self-control. Pintrich (2004) separates them into two phases but the basic idea is the same: deployment the methods selected and controlling one's effort. At this phase, a student becomes conscious, for example, of time use and need for help

(self-observing). When self-controlling, the student increases or decreases the effort, e.g. finds some tutoring for help. Students may have higher assumptions of actual time spent on studying than it turns out to be if self-recording the time. One part of self-controlling is focusing one's attention. Pintrich (2004) also points out that self-observation and self-control are not distinguished in terms of people's experiences.

The third phase called self-reflection is about reactions and reflections. Self-judgment has two kinds of forms: self-evaluation and causal attribution. In self-evaluation, a student is comparing one's performance against some standard, for example, another person's performance. In causal attribution, a student reasons unsatisfactory results. Causal attribution is very important phase for self-motivation. If a student is attributing unsatisfactory results to factors over which they have only a little control, e.g. limited ability, luck, easy task, (Shunk and Ertmer 2000), it implies that the student cannot improve their results and it may decrease their motivation. On the other hand, if poor results are attributed to a wrong strategy, it may sustain motivation.

The self-reaction involves feelings (self-satisfaction) and reactions (adaptive/defensive). Self-satisfaction level affect the motivation level: high self-satisfaction may enhance motivation whereas low satisfaction may question the worth of studying. In adaptive reaction, a student increases the effectiveness of learning. The student may modify an ineffective learning strategy or totally discard it. In defensive reaction, a student protects their self-image. It may happen by dropping a course or by being absent from a test. The student is avoiding the opportunities to learn and perform better.

In many models of self-regulation, although Zimmerman presents the phases to be cyclic, the last two phases may occur simultaneously and dynamically (Pintrich 2004). During the study process, a student may change their goals and plans on the basis of the feedback from the monitoring, control and reaction processes. A student with low self-efficacy may after positive reactions change their plans in the hope of, for example, better grades.

QUESTIONNAIRES

In this study, the students were asked to complete motivation and self-regulation questionnaires. Answering was not done anonymously so that grades of mathematical courses could be merged with answers. No identification is included to the final data.

The motivation questionnaire consists of 15 questions with four alternatives in each question. Those 60 alternatives altogether handle all motivation groups presented by Kauppila (2003). Students were asked to give 1, 2 or 3 points for alternatives in each question. The highest points should be given to the alternative best describing the student, the second highest to the next one etc. They did not need to use all points but at least one point must be given. Inside the question, the points could not be given twice.

At least one alternative was left empty in every question. This kind of ordering for alternatives was used to know which of the alternatives motivated students most. For example, the question 14 is as follows:

How much do you think to devote to mathematics courses?

- a. I will put off till the end of studies.
- b. I work to pass courses.
- c. I work to get high grades.
- d. I work because mathematics is interesting/useful.

For example in the question 14, the alternative ‘a’ refers to a lack of motivation, the alternative ‘b’ refers to extrinsic motivation, the alternative ‘c’ to performance motivation and the alternative ‘d’ for intrinsic motivation. Furthermore, the question 16 includes 17 alternatives, how teachers could increase students’ motivation. The student could tag at most five of them but no ordering was asked. These questions were also included in analyses although they were originally meant for giving ideas for further studies. In fact, they give a lot of extra information about enthusiasm.

In the questionnaire of self-regulation, there are 12 questions with four alternatives in each question. Contrary to the motivation questionnaire, students were asked to use five-level Likert scale in self-regulation questionnaire. One point referred that *it does not describe me at all or I hardly ever feel like this*. Five points referred *it describes me or I feel like this almost all the time*.

MOTIVATIONAL AND SELF-REGULATIONAL FACTORS EXPLAINING THE GRADES

The data is analyzed with IBM SPSS Decision Tree®. The data consists of all those Finnish students who started their studies in the academic year 2010 – 2011. The number of data is 138 but it can change in different cases if all information did not exist. Not all students answered the proficiency test but they answered the questionnaires. These students were also included in the data as questionnaires are more important to this study.

The first factor found when classifying grades by the results in the proficiency test was that 28 of 29 failed students got bad results in the proficiency test. It is worth of bearing in mind as the decision tree does not remind about this information at every stage. Unfortunately, the data does not have the information whether the one failing student with at least average result in the proficiency test dropped out of university or for some other reason was not attending the examination. All grades used in the data are from the first examination. Any following attempts to pass or to raise the grade are not included.

When the grades of the first course in mathematics were classified with background knowledge and questions in motivation and self-regulation questionnaires, the cornerstone seems to be the student's own beliefs in easiness of mathematics. All students strongly feeling that they probably do not need guidance in mathematics as they have always learnt mathematics easily seem to get higher grades in their first mathematics course. None of these students failed the course and the most grades were either 4 or 5. Grades 4 and 5 were gotten by the students who were using so much time for studying mathematics that they can solve all given problems or did not feel studying mathematics frustrating at all.

If the student gave at most 1 point to the need of guidance and did not give any points to the alternative *I work to pass the courses*, they were more likely to get high grades. These students neither gave points to the alternative *I will put off my mathematics till the end of studies* suggesting they have a good self-esteem. The more points were given to these statements the lower grades students got from their course in general.

When students were categorized according to the results in the proficiency test ('bad', 'average' or 'good'), all those students, who got bad results and marked that they would not probably even notice suddenly cancelled lectures, were failing the course (17 of 19 students). These students seem to neglect the lectures so failing is not a surprise. This study does not tell whether these students drop out of university.

It was also studied whether there can be seen any common factors among those students who failed the course or just squeak through it with the grade 1 or 2. If students got the bad results in the proficiency test and gave any points to *I need guidance as my knowledge in mathematics is not sufficient*, they were getting low grades (42 students of 57 students). It was also found that the less points given to the statement *I work as mathematics is interesting/useful* the lower grades they got, although students did not feel their knowledge in mathematics would be insufficient. In overall, if students gave any points to the statement *I need guidance as my knowledge in mathematics is not sufficient* but did not give high points to *When I am studying mathematical courses I often use more time than I scheduled*, they were marked as critical students.

After these findings, students were categorized to *critical*, *weak*, *average* and *excellent* ones. At the beginning of categorizing, all students were assumed to be average students. Students were categorized differently only if they matched the criteria mentioned earlier. When this factor called *student type* was included to the decision tree, more information could be found. Students, who were categorized to be weak in mathematics and did not feel they should do given problems for learning and, furthermore, did not adjust their learning to meet the course requirements, could be marked as average. These students were probably not studying just to please teachers.

When previous knowledge was included in the student type, it was noticed that students, who were not working for to get high grades but were hoping for well-paid

job, were failing the course more often than other weak students. The grades of weaker students were higher, if they were at least slightly working for high grades and wanted to have time to read up about the topic. When this new knowledge was included to the student type all those average students, who were interested in learning as much as possible, could be marked as excellent. The decision tree showed after this that those students marked as excellent at this point got the grade 5 if they did not mind how the grades were determined or solved all the given problems before the next lecture.

It was also found that weaker students seem to miss applied examples from their professional field in mathematical courses. The intuition among mathematics teachers was that applied examples are asked by qualified students. It seems that these applied examples from students' professional fields give motives for weaker students; they know why they should study the topic.

These results are only from students, who started their studies in the academic year 2010 and only from the first mathematic course. The filling data from the next academic years will either confirm the results or supplement them. The first mathematic course was selected because students' motivation to study mathematics after the first course is crucial for advanced courses. If students do not see the importance of the mathematics during the first course or they are getting stale with too easy topics, they are losing their motivation to study.

CONCLUSION

Several factors revealing progress in mathematical studies could be identified. Motivation seems to play a major role compared to self-regulation. According to Miller (2010), motivated students seem to be better in self-regulating their studies. It is not clear whether it is because they are knowingly regulating or because they are just interested in the topic and/or they focus in achieving their goals. Ryan and Deci (2000) define amotivation as "the state of lacking an intention to act". Is it even realistic to assume any self-regulating from weakly motivated students?

The next step is profiling the students. The factors of motivation and self-regulation with the background information (e.g. previous studies, results in the proficiency test) should form a base for profiles. Writing profiles into a form, from which freshmen would recognize themselves, may be hard. Although written profiles might be good enough, the lack of freshmen's self-knowledge may cause misinterpretations. We have to remember that freshmen may not have earlier studies in any university, so they may not know how they act in an academic freedom.

However, results presented here show that most of the critical students and, as well as, the excellent students could be recognized. When critical students are recognized, their studies can be supported from the beginning. It gives confidence for students and saves resources. On the other hand, excellent students could have different forms to study the courses to maintain or even to increase their motivation.

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Publication III

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16 Profiles of Engineering Students in Mathematics

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ABSTRACT

For some time mathematics teachers of Finnish universities of applied sciences in engineering have been talking about students who struggle in passing the courses. It is quite usual that last courses before graduating are the first year mathematics, physics or statics. Amount of these students is growing at the same time when resources are diminishing. It is easy to point the finger at students coming from technical colleges because of their lesser education in mathematics. In this study, freshmen of two academic years were profiled according to their background information, motivation and self-regulation. The profiles of the first year were used to recognize students at risk from freshmen entering next academic year. The recognition was done not only by questionnaires but, also, by students' self-knowledge. Although mathematical background is affecting the grades, there were more common characteristics in students found explaining the grades.

Keywords: Motivation, Self-Regulated Learning, Profiling.

1 INTRODUCTION

Students struggling in their mathematical courses is a growing group in the field of engineering. Because of the demands for graduating in time, this group should be trailed through curriculum as smoothly as possible. In some cases, it may mean not holding out the requirements that is not rational in the sense of the other courses and working in engineering field.

Although students with lesser mathematical education seem to get lower grades, some of them are getting higher grades. On the other hand, some students with extensive mathematics in high school are struggling with engineering mathematics. This can be seen by analyzing grades of the first mathematics course in 2010 at Saimaa UAS. The same kind of diverging can also be found when grades are classified according to the results in the proficiency test, which was hold at the beginning of their studies.

We asked the students to fill in questionnaires about motivation and self-regulation towards mathematical studies. Answers were classified according to the grades with background information like previous education, mathematics studied in a high school and result in the proficiency test. Classification was done with IBM SPSS® Decision Tree. Results show that the same motivational and self-regulating factors are either lowering or raising the grades despite the previous education or results in the proficiency test.

These factors were used to get profiles of different kinds of students. In the autumn 2011, freshmen were asked to select the profile best describing them. The selection was done during the proficiency test. The same students also filled in the motivation and self-regulation

questionnaires. In this paper, it is analysed how well students' selection from profiles and their actual mathematical profile according to the questionnaires matched and how, if necessary, the profiles should be improved. When profiles are selected correctly enough by students, their mathematical studies could be supported from the beginning. It would lower frustration felt by students and the diminishing resources could be used efficiently.

2 THEORETICAL FRAMEWORK

Motivation and self-regulated learning are key components in all engineering education. If a student is not interested, i.e. motivated, in engineering, it is almost impossible to drag oneself through studies. On the other hand, motivation is not enough. Diminishing resources requires students to study by themselves. If a student is not self-regulated in learning, studying in a proactive way may be impossible.

Kauppila [1] separates motivation in learning into five groups: *avoidance*, *diverged*, *escape*, *achievement* and *intrinsic motivation*. Avoidant motivated students usually are indifferent or reluctant towards subject or they may just find mathematics irrelevant to themselves. Diverged motivated students have much other things, like hobbies or working, in their mind that they do not have time in studying. Escape motivated students try to pass courses with learning by heart. They are just trying to escape failures, and they may be doing everything for external rewards (extra points to pass) or demands (it must be done). Achievement or performance motivated students do everything for good grades. It may help them to get a well-paid job or they avoid shame of not being the best. Intrinsically motivated students are interested in the subject and are keen to know as much as possible. Grades are not important to them. ([2], [3]).

Self-regulation can be defined as self-generated thoughts, feelings and behavior that are oriented to attaining the goals ([4], [5]). Self-regulation is a skill which matures along the studies ([6]). Self-regulation consists of three phases ([7]) and all phases are equally important. In phase 1, a student activates oneself. A student schedules studies and set goals for achievement. It has to be remembered that self-efficacy beliefs affects in perception of success. Part of this phase is also cognition of prior knowledge. In phase 2, a student is monitoring and controlling e.g. selective strategies for learning and time use and need for help. Decisions made in phase 1 are not beneficial if they are not controlled. Students, for example, have more positive perception of the time used than they actually do if monitored. Although the time used would be the same as scheduled, it is also important to be conscious of focusing. Just sitting beside the books is not an effective way. In phase 3, a student should reflect the learning to the actual studying. One should reflect success to some standards, like success of peers, requirements of the course, etc. A student should "cycle" the phases during the course. If learning is not good enough, a student might schedule studying again or seek for help. On the other hand, if learning has been better than goals, a student could set goals higher.

All these phases should be observed in context of *cognition*, *motivation/affect*, *behavior* and *context*. Cognition embodies all activities for regulating learning. It is, for example, scheduling, selecting learning strategies and activating prior knowledge. Motivation consists of self-efficacy beliefs, reasons for doing the task, personal interest, etc. Regulation of behavior consists of those actions that a student may change if needed. When controlling the behavior, a student may find out that one is doing other things instead of studying in a scheduled time or a student finds out that one cannot solve the problems alone. Regulating behavior also includes action like

seeking for help. Regulating the context is not always in the hands of students. It includes the noise of the dormitory or with whom they are doing the group works.

3 PROFILING STUDENTS

When freshmen start their studies, teachers may only know their background information of previous education and, of course, the result of proficiency test taken in the beginning of their UAS studies. The proficiency test includes some basic problems concerning order of calculations, equation solving, trigonometric questions etc. Because recognizing should be done immediately at the beginning of the studies, profiles must base on previous education and the proficiency test more than mere psychological factors. We have to also remember that freshmen may not even know their studying habits in an academic freedom due to lack of experience.

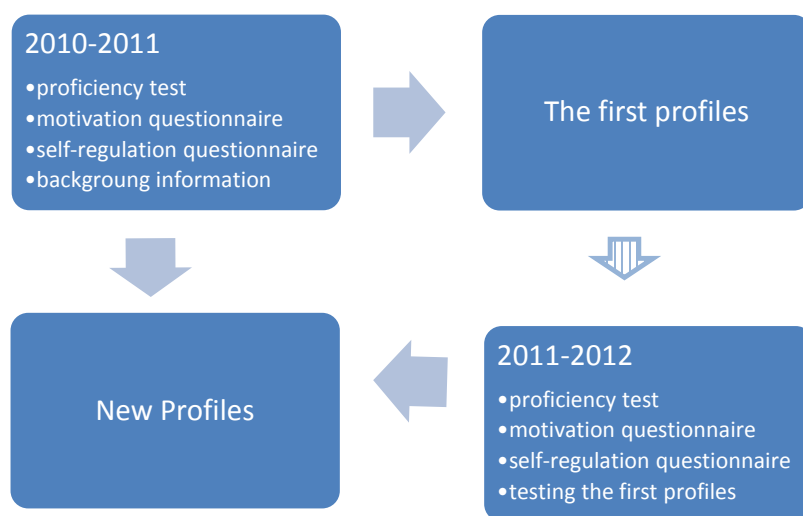


Figure 1. Process of profiling.

The main steps of the research are shown in Figure 1. The questionnaires filled in 2010 – 2011 were used to get the first profiles. These profiles were tested with freshmen starting at the beginning of the academic year 2011 – 2012. The freshmen of the academic year also filled in the questionnaires. This data is included to the original data to improve profiles (new profiles).

3.1. Results of the academic year 2010 - 2011

The null hypothesis is that all students are *average* in their mathematical studies. If evidence of something else was found, students would be classified as *at risk*, *weak* or *excellent*. As it is shown in [3] and [8], the easiness of mathematics seems to be the cornerstone in studies. All those students, who at least quite strongly felt that there is no need for guidance in mathematics as they have always learnt mathematics easily, passed the first course in mathematics. For these students, most of the grades were 4 or 5 (20 of 26). If these students were solving all the given problems, they probably got the grade 5 (6 of 7). The grades are usually given from 0 to 5 where 0 refers to failing and 5 is the highest grade. Students also seem to get high grades if they did

not feel mathematics as frustrating at all although they were not necessarily solving all the problems. All these students could be marked as excellent students. When factors were analysed according to the results in the proficiency test, it could be seen that freshmen, who got at least average results in the proficiency test and were solving all the given exercises, were getting the grades 4 and 5.

It was also found that students with bad results in the proficiency test were failing the course if they would not even notice the suddenly cancelled lectures as well as did not answer the questionnaires. This refers to the fact that those students are not attending the lectures. When knowledge in mathematics is already weak, attending lectures is very important. It was also found that students with bad results in the proficiency test seem to get lower grades if they felt they have to work to pass the courses.

During the next steps the characteristics of students were further defined. Students with at least average results in the proficiency test could be marked as excellent students if they were not preparing to the examinations too late nor did they mind about applied examples from their professional field. In fact, it was found in many stages that applied examples were important to the weaker students. Applied examples may motivate weaker students to studying the topic as they would know why they need it. Teachers' pre-assumption was that applied problems were important to the better students, as they are not struggling with technical skills anymore.

If students felt that they should do home exercises for learning, they were getting lower grades. If the base was already weak (bad results in the proficiency test), these students could be marked as critical. According to the [9], the word 'should' refer to fear and probably nothing is done: the student knows that they need to do them but for the reason or the other is not able to do them. Of course, all students, who were not sure that they are in the right place, were getting lower grades (no motivation to study) and bad results in the proficiency test referred them to be at risk. On the other hand, if students were hoping to learn as much as possible from mathematics and were also adapting their studying habits to course requirements, they could be marked as excellent students.

3.2. Predicting Success in Mathematics

In the proficiency test, students were asked their previous education, mathematical studies and the grade in matriculation examination with some information of minor importance. When features described in the previous section are combined with the background information and the result in the proficiency test, we can form *student types* to predict their success in mathematics.

Grades in the first course of mathematics were classified according to the student type for students, who started their studies in the academic year 2010 – 2011. According to the results, about 60% of grades could be explained with the determined student type. All students at risk could be recognized quite well but some average students were also marked to be at risk.

Profiles were given in a written form at the beginning of an academic year 2011 – 2012 as follows.

1. I think mathematics easy to me. I try to do all exercises given and I do not feel studying frustrating at all.
2. I prepare to examinations well in time and I do not necessarily need any applied examples from my professional field during the math lessons.
3. I want to study as much as possible from mathematics. I also try to adapt my studying to the course requirements.
4. I know my knowledge in mathematics is not were strong. I consult my formula book as much as possible, although, understanding the formulas is not easy to me at all.
5. I know that I should do home exercises for to learn.
6. I am not quite sure that this is the right place to me and I am not very interested in mathematics either. I should do lot of work to pass the courses but I am probably not attending the lectures because I just do not feel like attending or I have so much other hurries.
7. None of above describes me at all.

Students were asked to select only one profile describing them the best although it would not be exact.

All students, who chose profile 4 or 6 and got bad results in the proficiency test, were marked as critical (at risk). The profile 6 also refers to a critical student if the student had not studied high school at all or had studied only normal mathematics in the high school. Profile 5 referred to weaker grades. Therefore, they were marked as weak students if they got average results in the proficiency test. All profiles from 1 to 4 refer to the better students. Profile 1 seems to refer to the excellent students despite the background but all profiles 2 – 4 need the results in the proficiency test to be at least average. Furthermore, it was found in the analysis that students studying extensive mathematics in the high school could be marked as excellent, if they got good results in the proficiency test.

3.3. Academic year 2011 – 2012

Previous findings and the results are from the same academic year 2010 – 2011. It is interesting to see how well they portray students entering engineering programs during the academic year 2011 – 2012. When student types and grades were cross-tabulated, it was found that student types did not portray new freshmen well at all. Only 1.5% of the grades could be explained with determined student types. After this, it is not surprising that profiles selected by students combined with background information did not give any better results.

Analysing data of the academic year 2011 – 2012 revealed that the main classifying statement was *I need guidance in mathematics as my knowledge is not good enough* in the motivation questionnaire. Thirteen of 25 failed students admitted their weak knowledge in mathematics. Twelve of those 13 students did not usually ask clarifications from a teacher. It was also studied how well profiles selected by students reflect grades. Students, who did not find any matching profile, mainly failed the course.

Like mentioned earlier, some students seem to get high grades despite their lesser education in mathematics. According to this data, if students neither needed to work to pass the course nor they mind about grades, they seem to get high grades although not studied the extensive mathematics in high school. Probably, these students were intrinsic motivated. Also, all students

feeling that 1) mathematics is easy, 2) studying is helping them to mature, and 3) they would solve extra exercises to learn more, were found to be excellent.

Combining the data of both academic years should reveal some common features of students. It was found that 27 of 38 failed students admitted their weak knowledge in mathematics. Furthermore, 26 of those 27 students felt that they need guidance in mathematics because of their weak knowledge. Eleven failed students did not admit the weak knowledge but ten of them admit that they have to work to pass the courses. The interesting information is that nine of those 10 students were mainly motivated by a well-paid job.

It was found that students with extensive mathematics seem to be at risk if they usually do not mind about the requirements for grades and they just want to pass the course. The risk is also present if students with extensive mathematics admit the need for guidance but they do not revise their knowledge at the beginning of a course. If students with extensive mathematics seem to omit home exercises, they were getting lower grades. Maybe, these students were either not actually interested in studying or they were presuming on their mathematical skills.

The other students seem to be at risk if they admit their weak knowledge and they are working hard to pass the courses. Even the strong motivation for a well-paid job combined with the weak knowledge refers students to be at risk. Also, preparing to tests too late and neglecting lectures were bad signs.

Table 1. Student types vs. grades in mathematics.

		Course 1 in math						Total
		0	1	2	3	4	5	
student_type	at risk	25	13	5	2	4	0	49
	weak	7	9	11	12	10	7	56
	average	6	4	10	15	19	10	64
	excellent	0	0	0	0	2	8	10
Total		38	26	26	29	35	25	179

Directional Measures

			Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.
Ordinal	Somers' d	Symmetric	0,478	0,051	9,189	0,000
by		student_type Dependent	0,440	0,048	9,189	0,000
Ordinal		Course 1 in math Dependent	0,524	0,054	9,189	0,000

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

This new classification explained 52.4% of grades in combined data (see Table 1). The more important information is that 25 failed students out of 38 could be recognised with it. Seven of

remaining unrecognized there marked as weak students, so they would not be forgotten. Of course, classification could be more exact but it would make profiles too complicated. If there were many profiles to choose from or profiles were too complicated, freshmen would have difficulties in recognising the best describing profile.

4 CONCLUSION

Some motivational and self-regulating characteristics could be found for profiling the students. Motivation seems to be the key element in predicting the progress. Motivational factors were more clearly perceived among freshmen of the academic year 2010 – 2011 although they did not predict the progress for next year freshmen very well. As mentioned in [8], self-regulating goes hand in hand with motivation. Thus, it is unreasonable to assume high self-regulating for weakly motivated students.

The results of two academic years were different. Freshmen of the academic year 2010 – 2011 answered questionnaires after several months of studies, whereas freshmen of the academic year 2011 – 2012 did it at the beginning of their studies. The lack of experience in academic studies may have affect in answers for the latter group. On the other hand, student types based on the academic year 2010 – 2011 and profile selected by a student matched quite well. Thus, the self-knowledge of learning habits was recognized by freshmen.

The next step will be finding further information about motivational and self-regulating characteristics. It is also important to find methods for motivating and supporting weaker students. As weaker students seem to neglect lectures and they also have some problems in focusing, one solution might be compulsory lectures and exercises. It is also shown in the literature ([10], [10]) that essays in mathematics or writing formulas in written form by students will improve understanding and, in consequence, may motivate students more.

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Publication IV

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STUDENTS' CONCEPTIONS OF THEIR LEARNING MAY HELP IN PREDICTING THEIR PROGRESS

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Abstract

Students struggling in their mathematical studies in the department of Technology in universities of applied sciences have been a concern for several years. In 2010 and 2011, new students in Saimaa UAS were asked to fill in two surveys concerning their motivational and self-regulation aspects. Based on these surveys and the proficiency test held at the beginning of their studies, we formed profiles to predict their progress in math courses. Furthermore, teaching methods were developed to support motivated but weak students in their mathematical studies. This article will describe the process of profiling and how well the progress could be predicted by student's own conception of studying habits. It also describes new teaching methods used and their influence on progress.

Keywords: *motivation, self-regulation, self-confidence*

1. INTRODUCTION

Universities of applied sciences in Finland receive funds primarily from the Ministry of Education and Culture. One key issue in budgetary appropriation is the number of students graduating from the institution. Especially in engineering, the problem is dropouts. During the first year or just after it, many students drop their engineering studies and, unfortunately, these students seem to also have struggled in their mathematics courses.

Young people under 25 are obligated to apply for a study place in Finland if they are out of work. Without applying for a study place, they have no rights to allowances paid by social welfare. This may partly explain the lack of motivation in beginning students and the resultant dropout rate. On the other hand, some of the struggling students have already been working in their chosen field, so motivation should not be the problem. This article studies the profiles of beginning students in mathematics and how these profiles might be factored into the course arrangements, so that more students would graduate.

The educational backgrounds of engineering students at universities of applied sciences (UAS) include those from both vocational colleges and high schools. Some of them have studied only a little math after primary school, while others would qualify for a degree programme in mathematics. Normally, the progress of university students is observed in the results of the final exam, meaning that a student may have been struggling for several weeks or even months before being notified by a lecturer. Although the lecturer would give the extra help at that time, the student may already have dropped out. The idea of profiling the students at the beginning of their studies is that extra help could be provided during the course to the motivated weaker students. Because of time resources this help cannot usually be provided to all students.

For that reason, beginning students in Saimaa UAS were asked to participate in a proficiency test to reveal their actual calculation skills (Porras 2012a, 2012b). During 2010 and 2011, new students at Saimaa UAS, Finland, filled in the surveys about motivational and self-regulating aspects of learning. Combining the two data of 2010 and 2011, appropriate information was found and profiles were formed. These profiles were used with the beginning students of 2012 and 2013. In 2013 the same profiles were also used in Mikkeli UAS for predicting students' progress.

2. PROGRESS IN MATHEMATICS

As described previously, students from academic years 2010 and 2011 filled in the surveys about motivation and self-regulation. The motivation questionnaire consisted of 15 questions with four alternatives in each question. Those 60 alternatives altogether handle all motivation groups presented by Kauppila (2003). Students were asked to give 1, 2 or 3 points for alternatives in each question. The highest points should be given to the alternative best describing the student, the second highest to the next one etc. They did not need to use all points but at least one point must be given in every question. Inside the question, the points could not be given twice. At least one alternative was left empty for every question. This kind of ordering for alternatives was used to know which of the alternatives motivated students most. In the questionnaire of self-regulation, there were 12 questions with four alternatives in each question. Contrary to the motivation questionnaire, students were asked to use five-level Likert scale for the self-regulation questionnaire. One point meant that “it does not describe me at all” or “I hardly ever feel like this”. Five points meant “it describes me” or “I feel like this almost all the time”.

These answers, students’ background information like previous education, mathematics studied in a high school as well as results on the proficiency test were used for analysing progress in mathematics based on grades. Students could not answer the surveys anonymously because their grades in math courses were included in the data. Analyses were mainly done with Decision Tree in IBM SPSS, as it shows which questions in surveys highlight features the best. IBM SPSS also enables syntax programming. When a new significant feature was found, it was included to a variable called student type to classify students. Little by little students were categorised into four types:

1. Students at risk
2. Weak students
3. Average students
4. Excellent students

For example, it could be seen that students giving more than one point to the choice “I probably do not need supervising in mathematics as it has always been easy to me” are passing the courses with good grades. On the other hand, giving at most one point to that sentence and the highest points to the sentence “I have to work to pass the courses” refer to the struggling student. Both these sentences describe self-esteem, and the weaker students seem to have significantly weaker self-esteem. It has been shown that students’ expectation of their own learning has a great impact on performance (Lewis 2011, Porrás 2012a). This suggests that elevating weaker students’ self-esteem may positively affect in their progress.

One surprising sentence was “When studying the math courses, I look for extra material from the Internet or a library if needed”. This sentence was originally meant for finding self-regulated students. However, high points here, combined with weak results in the proficiency test, is suggesting that the student is struggling with math. According to Clarebout et.al (2010), no evidence is found that weaker students even benefit from the use of support devices such as e-learning materials. It would be interesting to know whether these students are not capable of recognizing good material, do not understand the material they are reading, or are just trying to copy-paste solutions for their exercises.

Results of analysis were compressed to sixteen profiles. The number of profiles is quite high and it may be decreased after further analysis. Remember that the profiles should describe also the average students, as not all students are excellent, or struggling in their studies. During the academic year 2011-2012, there was also included the last choice “None above describes me”. This choice was only selected by the students, who failed their first course in math. Does it infer that some weak students do not even recognize their customs and thoughts during the studies?

One interesting profile was “I want to graduate as fast as possible, so I find out a lecturer’s requirements and custom.” Although the profile seems to be encouraging and self-regulated, it was selected mainly by weaker students. It seems that these students selected engineering based on status. Students are not ready to work to gain the good grades, but they are doing lot of work to avoid actual

studying. More detailed information in surveys and results of motivation and self-regulation as well as profiling may be found in Porras (2012a, 2012b).

3. FIRST SEMESTER IN SAIMAA UAS

3.1 Introduction into Mathematics

Students for this course are selected by the proficiency test. Because of the wide range in math skills, students participated in the proficiency test at the beginning of studies. If a student got at least 90% of the maximum points in the proficiency test, the student did not need to take the course. All the others were directed to the course.

All main topics of basic calculation are gone through during the course. This includes everything from basic arithmetic calculation and handling expressions to solving polynomial equations. All the topics should be understood before entering the engineering studies, but for one reason or another, they are not.

As the topics are so essential for all mathematics, students are required to answer all test questions correctly. There are several smaller tests during the course, where students can show their skills. If the student makes a mistake on the test, the test may be taken again on the failed part. Failing a test did not prevent attending the next test.

3.2 Profiles in course arrangements

According to Table 1, the number of high school students in both programs is significantly higher than the number of students from vocational colleges. As the high school students are considered to be better in theoretical subjects, these students should not have big problems in math courses. Furthermore, the proportion of students with extended math in program “K” is higher than in program “R”. Students with extended math should not have any difficulties in their first year math studies, so passing the math courses should not be a problem in program K.

Table 1. Basic information on students in Saimaa UAS

	2012		2013	
	Program K	Program R	Program K	Program R
High school	80.0%	71.4%	82.7%	79.3%
- extended math	56.0%	34.7%	51.7%	47.2%
- normal math	24.0%	36.7%	31.0%	32.1%
Vocational college	20.0%	28.6%	17.2%	20.8%

When students are profiled based on their results in the proficiency test and suspected student type, the progress does not look so obvious anymore. As seen in Table 2, the number of students struggling in their math studies is about 60 per cent. One part of this can be explained with the will to recognize all the struggling students: even a slight doubt will cause a mark of being under observation. However, this cannot explain the tremendous lack of calculation skills these students have. Further analysis showed that almost all students from vocational colleges were classified to be at risk. These students usually are very motivated in their professional hands-on studies but theoretical subjects cause difficulties: maybe avoiding theoretical studies was the reason for applying to vocational college. Motivating these students will produce skilled engineers for the field.

The bigger issue is that high school students with normal math are also mainly classified to be struggling. After studying in high school, these students should be familiar with theoretical subjects and mathematics. If we look at history, we find that the normal math was originally meant for students

not applying natural or technological fields. These students were keen on languages, social care, law etc. After reform of tertiary level education in Finland, more and more of these students are applying in universities of applied sciences to study engineering. Many of these students have not actually wanted to join the field but descended into the field. Thus, these students may lack the professional motivation and mathematical skills.

Table 2. Predicted progress

	2012		2013	
	Program K	Program R	Program K	Program R
at risk	52.0%	40.8%	48.3%	54.7%
weak	16.0%	20.4%	13.8%	22.6%
average	12.0%	18.4%	10.3%	13.2%
excellent	20.0%	20.4%	27.6%	9.4%

3.3 INTRODUCTION INTO MATHEMATICS

The course Introduction into Mathematics was traditionally lectured separately in programs with same amount of lectures. In 2012 and 2013, the decision was made to separate the course according to student types and results in the proficiency test. The group called *A* consisted of the weakest students. These students had major problems in their calculation skills. The group called *B* did not have excellent results but they were assumed to benefit from revision in basic calculation. For this reason, one third of their lectures were allocated to the group *A*. All excellent students with good results in the proficiency test were exempted from this course.

Both groups had their own lectures and lecturers, meaning that lectures were planned independently. However, weekly topics were decided on in advance as topic tests every other week were the same for both groups. The same topic tests were used, as it made comparison of progress possible.

Lectures of the group *B* followed the lecturer's traditional way of teaching. These students got the lecture on the topic with examples and solved most of the exercises after the lectures. The lectures of the group *A* were totally redeveloped. It was thought that if these students did not benefit from the traditional teaching in their previous education, the method would not be any better for current studies. It must be noted that this lecturer also had more lecturing time for every topic. These students should reach the calculation skills needed in engineering in a very short time.

Instead of the topic being lectured, all topics were started by thinking about it together. Not all students had even studied some topics and some of these students had enormous deficits in calculation skills, so it was very important to relate topics to pre-known basic calculation instead of just writing

the formula on the board. For example, writing $\frac{x}{2}$ in the form $\frac{1}{2}x$ was not always understood. This was explained as "If a banana is bisected, then one gets half of the banana". At this level, it would have been waste of time to derive the formulae in theory only.

During the discussion section, students related the topic to their pre-knowledge from the previous education and previous lectures and tried to find new solution methods. The lecturer only started the lecture with a problem and led the discussion by giving some hints or by asking questions.

After the "lecturing", students got their exercises. The main idea was that students could solve all exercises during the lectures. As mentioned earlier, these students were very weak in their math skills, so the lecturer wanted to keep abreast of progress. This kind of teaching also enabled correction of mistakes in notations before they became automatic. If many students struggled with the same problem, it was solved on the board together with the discussion method; the lecturer was a secretary

and the students told what should be written. The lecturer wrote also the notation mistakes, expecting that somebody would remark on them. The lecturer had to correct the mistakes without prompting from the students only a few times.

Part of the exercises were changed from traditional “solve the problem” or “simplify” kinds of problems. As found in literature (Kovarick 2010, Powell 1997), writing, e.g. essays, in mathematics helps in deepening understanding. The method, called “linguaging”, compels a person to understand the topic as it must be explained on paper. These students were not asked to write essays but to explain the solution method. Without the linguaging, students may have only dipped into the calculation and tried to copy the method in upcoming exercises without thinking. With this problem they were forced to explain to themselves why a particular step is done.

In some problems, the solution included common mistakes. Students were asked to find the mistakes and also solve the problem without them. All mistakes were usually found easily by students. The catch in this problem was that when solving the traditional exercises, students may have made exactly the same mistakes. The light on a student’s face at the moment of realization that the same mistake had been corrected just five minutes ago, revealed the learning.

Students were allowed to do exercises in groups. Most of students formed groups of 2 - 4 students in whose they were working. Only some students worked alone. There were lots of discussions about exercises and their solutions in groups. Although one student may have been a little bit better than the others, this student’s solutions were not just copy-pasted: questions were asked and solution methods were questioned. Students were told at the beginning of the course, that they are equally good at mathematics. This may explain why they did not take anything on trust.

3.4 Feedback from the course

The feedback in the group A was great. Students liked the pace during the lectures and that the help was always available. One student wrote that “Lectures were easy to follow and even me, who have never before studied these topics, could understand and learn them. Do not change anything in the course arrangements”.

Students also liked the small topic tests. According to them, it gave them motivation to study as the number of topics was not too big to handle. With small topic tests, students became alerted quickly if they had misunderstandings in the topic.

Although the overall feedback was excellent, there is still room for improvements. Students did not receive the correct answers, but the problems were always solved on the board. Answers were intentionally not given in order to prevent misbehaviour: some students check the answer first and then start to think how it was obtained. In real-life engineering, this kind of method does not work. However, the missing answers impede studying at home.

The relaxed atmosphere during the lectures was a complex issue. Students easily approached the lecturer and asked for help. They also discussed the exercises in small groups. Overall, students were active in learning. At the same time, some students suffered from the noise. Some kind of balance must be found in the future.

4. INFLUENCES ON PROGRESS OF MATH STUDIES

Results of the introduction course are promising. As shown in Table 3, only a few students from the group A failed the course.

Table 3. Results of the introduction course

	2012		2013	
	failed	total	failed	total
Group A	4	28	3	31
Group B	1	29	3	31

As the results and background of students from program *K* were so promising, the expectations for the first mathematical course were high. However, forty per cent of the students failed the course in 2012 and 28% in 2013. In program *R*, the proportion of the failed students was about 12.5 per cent in both years. There are many reasons for this terrible result in the program *K*, and it can never be explained thoroughly. The teacher of the group *A* lectured the first professional math course in the program *K* and the teacher of the group *B* lectured in the program *R*. Content of the courses is basically the same but, of course, different topics of the special interests in the field were highlighted. Both lecturers had done well with the introduction course. However, some kind of reflection about the teaching is needed.

The lecturer *A* had worked at the university level for ten years before teaching at Saimaa UAS, whereas the lecturer *B* had previously worked at the high school level. Perhaps the demands of the lecturer *A* for passing the course were too high. Although the lecturers may have influenced the passing with their demands, it cannot be the only reason. When the introduction course was given, group *A* had 8 lectures a week and the group *B* had 4 lectures a week. At the same time both groups were studying 3 lectures a week for the first math course as well, along with all the other courses. The demand of “no mistakes” for passing the introduction course may have caused great pressure for the students. When the course ended, they just broke down and could not concentrate on math anymore.

The lecturer *A* did not have so much time for teaching the first math course as for the introduction course. There was no time to reform the exercises taking the languaging into account, nor was there time to check all exercises. As a result, the lecturer *A* reverted to old habits in teaching, though knowing that the new way had brought promising results.

The students of program *K* start their first year project at the same time when the introduction course ends. In their project, they have to design and manufacture a man-powered vehicle with three wheels. At the end of the academic year, they have a time trial where the best vehicle is selected. This project takes considerable time and effort. Because students find it interesting, they take the time from not so interesting topics, e.g. mathematic, and the tailspin begins.

5. FURTHER ANALYSIS OF PROFILES

As the profiles were originally formed based on surveys on motivation and self-regulation, it is worth checking their validity. Each profile was selected as classifying profile in decision tree, where the grades of the first math course classified. Other independent variables were the rest of the profiles, total points in the proficiency test, and scores of individual questions in the proficiency test. The interesting profiles are listed in Table 4. Students selected the profile during their first week of studies, so they represent students’ preconception at the moment. Students could select three profiles best describing themselves.

Table 4. Interesting profiles

Code	Explanation
P1	I feel mathematics is important but my skills may not suffice.
P3	I do not usually motivate myself with rewards (like a cup of coffee) but I may do it with difficult courses.
P5	I look for extra help from the Internet or the library.
P10	I think that I am good at mathematics and I do not easily ask for help. Sometimes, I may have issues with the time.
P11	I think that mathematics is interesting. I try to understand the topic and to get feedback already during the course.
P15	I am not sure that this professional field is suitable for me.
P16	It is important to show practical examples, how mathematics is used.

If a student selected the profile P1 and did not even try to solve the problem concerning rational expressions, the student was marked to be at risk. Those students, who did not even try to solve the problem concerning formulas and did not select this profile, can be marked to be at risk. In both problems, concerning expressions or formulae, there are “letters” in variables and parameters. Thus, it seems that working with mathematical expressions is not handled.

The students, who selected the profile P3 and could not solve the problem concerning basic algebraic operations, mostly failed the first math course. These students have fundamental lacks in calculation skills and, obviously, they are not very keen on math studies. In the entrance examination, students are allowed to use a calculator but not in the proficiency test. Despite their lacks in calculation skills, they passed the entrance examination. Is it possible, that these students trust so much in their calculators that they do not actually solve anything without them?

Profile P5 was already in the motivation survey in the same form. The main idea was to find self-regulated students. Already in surveys and also later in profiles, this sentence combined with weak results in the proficiency test, revealed that the student was at risk in math studies. This could be seen especially among students from vocational colleges.

Profile P10 describes a student with a good self-esteem. However, a good self-esteem with weak knowledge may not be the best combination. Some students selecting this profile could not solve linear equation correctly. Obviously, these students could be predicted to be weak. The students neither selecting this profile nor solving the rational expressions could be marked to be at risk.

Profile 11 and the problem concerning formulae seem to be one cornerstone. Although students selecting this profile are self-regulated students, it is not enough. If these students did not even try to solve the formulae, they failed the first course. If they solved it incorrectly, they could be predicted to be weak students. Students, who did not select this one and could not solve the basic arithmetic problems, can be predicted to be at risk. Obviously, these students do not understand the need for mathematics in engineering.

Selecting the profile P15 at the first week of their studies is a warning sign. Although these students would not drop out, motivating them is not easy at all. All these students got lower grades in their first math course.

When profiles were formed based on surveys, it was found that students needing practical examples received lower grades than the other students at the same level. For example, a student with extensive math in high school may not have the highest grades but the grades in the middle. Still, the students selecting this profile were not the excellent students, but it revealed the motivation for learning among weak students. After finding this result, I checked the information on two known students. Both of

them were predicted to be at risk as their results in the proficiency test were extremely low and profiles were not very promising. One of them asked a lot of questions already during the introduction course. This student is now above the average in that group. The other student is always in lectures and quietly listens to the teaching. Results in tests have not been very promising. During the discussion with this student, it was easy to see that there exists a desire to learn. There seems to be perceptual problems combined with lack of knowledge delaying the learning. The student thankfully accepted the extra help for catching up in knowledge.

Overall, handling the expressions seems to be the main problem for weaker students. Although these skills can be taught, the bigger issue is in student's self-esteem and desire to learn. Strong self-esteem with weak knowledge is not always a good thing, but then, low self-esteem seems to lower grades also for good students.

6. SUMMARY

There are many studies of learning mathematics (e.g. Houston et.al 2010, Corte et.al 2009, Hannula et.al 2004). According to the studies the more motivated and/or self-regulated students are, the better grades they achieve. However, the highly-motivated student may lose interest if the mathematical background is weak and no help and/or encouragement are available. Recognizing the weaker but motivated students and encouraging these students may be even more important than just recognizing the motivated and self-regulated students.

Languaging gave promising results during the introduction. However, rewriting all or even some exercises in this form requires time that is not readily available to the lecturer. Hopefully, languaging will come into common use with time. Also, starting the new topic by refreshing previous knowledge of the subject should help students in understanding. This could be seen in the introduction course with weaker students. At this point, it is very important that the lecturer speaks the same language as students. The examples must be easy to understand for all students.

Although re-organizing the lectures from traditional lecturing to discussion-based format requires time and effort, it is worth it. Obviously, attempting to address all learning styles during classes, also in mathematics, promotes understanding. At least in Saimaa UAS, this method will continue and be developed further in mathematics.

Studying with others should also be encouraged (Perger 2013, Angier & Povey 1999). It allows students to help each other, and they may get more exercises done. Furthermore, when explaining their solutions to the others they must have deeper understanding as solutions must be explained more clearly for fellow students. Like in languaging, progress may not be seen by the teacher so easily, but there is a lot of reasoning done. This is probably the support that the weaker students need. It seems that students should select groups by themselves as there must be mutual trust between all members: all members should be able to ask 'dumb' questions without fear of losing face.

Without a doubt, profiling the students gives more information and helps out with course arrangements. It revealed the students who should be tutored more thoroughly. If students' self-esteem in mathematics can be improved, skills do improve. In the long run, this produces more graduates and decreases frustration felt by students.

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