Clustering and achievement of engineering students based on their attitudes, orientations, motivations and intentions

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Abstract: - Insufficient skills in basic mathematics cause problems for those majoring in engineering at university level. Learning entails the learner's own initiative in the achievement of learning objectives. Factors with bearing on what students do include attitudes: orientations, intentions and motivations. The present study ascertains how new undergraduates of Tampere University of Technology (TUT) differ in their attitudes to the study of mathematics. On the basis of their attitudes students are classified into different learner groups. The learner groups that were found were Surface Oriented Learners, Peer Learners, Students Needing Support, Independent Learners and Skilful Students.

In this paper we present a Basic Skills Test, a web-application which measures high school basic skills in mathematics and Remedial Instruction arrangement which is also a web-application intended to fill in gaps in students' basic skills in mathematics. The relation between the basic skills and further study achievement at university is investigated. The effect of learner groups on study achievement is also scrutinized. Results tell that basic skills predict quite well study achievement and that learner groups have influence on students' achievement. In this paper we also present some concrete teaching development based on the research carried out at Tampere University of Technology.

Key-Words: - attitudes, orientations, motivation, intention, clustering, engineering, mathematics, remedial study, achievement, higher education

1 Introduction and background

There has been public discussion about the learning of mathematics in Finnish schools and about the level of proficiency. In the Programme for International Student Assessment test (PISA) of 2003 the achievements of Finnish schoolchildren were good, yet at the same time over 200 teachers of mathematics at university level publicly expressed their concern regarding the decline in the level of proficiency in school mathematics – notably in basic algebraic routines. (see the special edition of the publication [in finnish] Matematiikkalehti Solmu at http://solmu.math.helsinki.fi.). A command of basic algebraic skills (calculating functions, cancelling, taking square roots, elementary functions, differentiation and integration) is indispensable for basic studies in mathematics at university level.

Poor skills in basic mathematics causes problems for those majoring in engineering in which mathematics plays an important role. Given that traditionally mathematics has been a major consideration in the entrance requirements to universities of technology, increased student intake has resulted in a wider variation in mathematics skills.

In the teaching of engineering mathematics engineering due note should be taken of the needs of engineering education. Mathematics is a logical-deductive science, in which established axiomatic logical deduction leads to new findings whose practical significance is frequently secondary. In the application of mathematics the problems must be dressed in the guise of the mathematical model: in order to solve the equations of the model suitable methods must be found, the goodness of the model and the precision of the solution need to be assessed. Solutions must generally be arrived at by computer, thus knowledge of mathematical software and programming skills are essential.

Learning outcomes in mathematics are not dependent solely on good teaching, sufficient resources and other external considerations with bearing on learning. Learning implies activity on the part of the learner in order to achieve learning objectives. Factors with bearing on what the student does include attitudes: orientations, intentions and motivations. Orientation describes the student's conscious and unconscious study habits, intention the student's own conscious objective-setting and motivation the power to achieve the objectives set.

The point of departure for the present study was the further development of teaching and learning in mathematics for engineering students. Also the lack of research from pedagogical viewpoint in the field of engineering education steered this study. The present study was started from a research of pedagogical theory and the development of teaching was made on the basis of theoretic framework contrary to many other engineering education studies. In autumn 2004 students beginning their studies at TUT completed a questionnaire. It contained questions intended to measure the attitudes of students to their studies.

Aim of the study was to ascertain how the students beginning their studies differ from each other with regard to their attitudes to the study of mathematics. Thus the study explores whether it is possible to classify students meaningfully on the basis of their attitudes into groups of different types of learners. What kinds of didactic adjustment should be made in order to take this diversity into account and develop measures supporting learning taking the different groups into consideration?

2 Concepts pertaining to learning

According to the constructivist view of learning, knowledge builds up in the learner's mind either by merging with existing knowledge structures or by adapting existing knowledge structures to fit new knowledge (Rauste-von Wright 1994). What was learned earlier is needed in order to assimilate what is still to come. The student's personal study habits, intention, motivation, orientation and other individual characteristics have bearing on achievement in studies.

2.1 Orientations, intentions and motivations

2.1.1 Intention and motivation

Intention refers to the purpose, aim or choice generated by an actor on initiating some action. (Yrjönsuuri, 2002). The intention may, for instance, be to obtain a good course grade, getting through a course or perhaps surviving on a minimum amount of effort. Intention describes the goal towards which the individual is moving. In studying mathematics the intention may, for example, be the application of the mathematics required in engineering sciences.

"Motivation refers to the power driving, directing and sustaining the actions of an individual (Tynjälä 1999.) Internal motivation is motivation which is not dependent on external rewards. External motivation refers to motivation which is influenced by external stimuli and rewards. Motivation may vary very considerably within a short period of time.

2.1.2 Orientations

Orientation refers to personal objectives, intentions, motives and expectations which govern how students study and learn. (Tynjälä, 1999.)

Orientations steer actions in study and learning. They constitute a holistic description of individual differences in the orientation towards learning and studying. (Tynjälä, 1999). Orientations can be divided, for example, into those of personal meaning, reproducing and achieving (Entwistle, 1986 adapting Biggs) and also non-academic orientation (Ramsden 1984). Personal meaning orientation is characterised by a search for the connections between matters, a critical and evaluative orientation to things and internal motivation (Ramsden 1984, Tynjälä, 1999). Personal meaning orientation is frequently considered a desirable orientation in studies. Reproducing orientation manifests itself in learning by rote and in a fear of failure. A student with a reproducing orientation does not seek correspondences between things (Ramsden 1984.) An achieving orientation for its part is characterised by a strategic approach, negative attitudes and achieving motivation. Achieving motivation drives the student to work for a course evaluation, credits or other comparable external accomplishments. (Ramsden, 1984; Tynjälä, 1999.) A non-academic orientation manifests in a negative attitude towards studies, an absence of systematicity in studies and a failure to be effective in studies (Ramsden, 1984).

Situational orientation is used to refer to an approach to studies which varies according to the situation. This may affect both intellectual and social activities. Actors may make use of several different situational orientations depending on the situation, varying these for the situation. Permanency in situational orientation is evidenced by the fact that situational orientation is primarily used in recurring situations (Yrjönsuuri, 2004)

2.2 On the orientation of university students

2.2.1 Situational orientations of undergraduates in technology

In autumn 2003 the situational orientation of undergraduates in technology of the Tampere University of Technology (TUT) was scrutinised. The study by Raija Yrjönsuuri (2004) was concerned with the situational orientations of students TUT information technology students of engineering mathematics. The study by Yrjönsuuri (2004) was based on four situational orientations in the learning of mathematics.

The situational orientations that were found were task orientation, dependency orientation, self orientation and defeatist orientation. Task orientation has characteristics features of

- taking responsibility and initiative in the task
- intention of learning mathematics
- tolerance of uncertainty
- evaluation of own learning
- contemplation of structures
- connections of content to be learned
- a precondition for deep processing of knowledge.

Dependency orientation has characteristics features of

- non-independent in task completion
- oriented towards remembering and learning by rote
- repetition of what has been learnt,
- adherence to external instructions and
- pursuit of social acceptance.

Self orientation has characteristics features of

- fear of failure,
- explanation of failure through external considerations,
- seeking means of survival,
- denying the value of study.

Defeatist orientation has characteristics features of

- consequence of failure situations,
- actor perceives task to lack significance,
- lack of dedication to studies and
- denial of value of studies.

(Yrjönsuuri, 2004 and 2002).

2.3 Research on learning approaches and learning patterns

2.3.1 Surface and deep learning approaches

Marton and Säljö (1984) researched how university students learn from text. It was observed in this study that there were two separate ways of processing information, referred to as surface and deep learning approaches. It was seen that those students who did not form a conception of the main notion in the text were unsuccessful because they did not even look for one. Such surface approach students paid attention to individual, unrelated matters which they deemed important and endeavoured to memorise them as such (Entwistle, 1986). Their study motivation appeared to be external and to emanate from the expectations and demands of others.

Deep approach students for their part endeavoured to understand the new matter and to connect it to their existing knowledge. They called the author's claims into question and monitored critically what conclusions the author drew on the basis of the research data. (Entwistle, 1986.) These students were characterised by adhering to the core issue and they perceived themselves to be some kind of generators of knowledge. For the deep approach students learning was meaningful and they were motivated internally, thus they were interested in the matters to be studied for their own sake. (Marton & Säljö, 1984.)

2.4 Learning patterns

Success in studies can be scrutinised through orientations and other educational concepts. Vermunt (1996) researched the study achievements of university students and Open University students and came to the conclusion that the differences in achievement between individuals was due to four components: cognitive processing strategy, metacognitive regulation strategies, conceptions of learning and study orientations. He calls this combination the learning pattern. (Vermunt, 2005.) The main characteristics of learning patterns are presented in Table 1.

Vermunt's (1996, 2005) idea is that the approach to studies is characteristic of each student at a certain time. He does not perceive this to be an immutable personal trait, but rather that the approach takes shape as a result of the interaction of the individual's personal characteristics and situation-related influences.

2.5 Interactivity in learning

There is in learning a strong element of interactivity between teacher and learner, and also of interaction between students in the group. It has been possible to divide interactive group learning into three different forms: peer tutoring, cooperative learning, and peer collaboration (Damon & Phelps, 1989).

In peer tutoring one or more of the learners in the group direct the other members. Within the group it is possible to separate those students with weaker skills and knowledge, novices and those who are teaching them, the dominant students with a better command of the matter, i.e. the experts. Cooperative learning as a term covers various approaches to learning supporting group work. In peer collaboration students having the same level of skills and knowledge work together in order to resolve some challenging task which they could not cope with using only their individual knowledge. (Damon & Phelps, 1989)

3 Implementation of the research

This study aimed to explore students' attitudes to the study of mathematics through orientation, intention and motivation, and also through learning patterns. The study was accomplished in autumn 2004 at the beginning of studies as an overall survey of all those students beginning their studies in engineering mathematics at that time.

A questionnaire eliciting students' attitudes (called attitude questionnaire) to mathematics which constitutes the data used in this research was implemented together with the test of basic skills (See more in Pohjolainen et. al., 2006 [in finnish]). A total of 860 students took the test and the same students responded to the attitude questionnaire. The attitude questionnaire contains 55 statements and was carried out computer aided. Except for the first two statements, students had five possible response options, the extremities of which were totally disagree and totally agree The attitude questionnaire is presented as a whole in the study by Pohjolainen et al. (2006).

3.1 Research questions and methods

The following research questions were formulated for the present study:

1. How do students differ in their attitudes (orientation, motivation, intention)?
2. How should students with different attitudes and modes/means of studying be taken into account in the teaching of mathematics?
3. What is the relation between basic skills, attitudes and study achievement?

Research methods included cross tabulation, comparison of averages, principal component analysis and cluster analysis. The data obtained from the attitude questionnaire were condensed using principal component analysis, after which observations were grouped using K-means clustering (Johnson & Wichern, 1998). The values for different sum variables corresponding principal components and for some single variables were interpreted. According to interpretations the clusters were meaningfully named.

3.2 Construction of questionnaire measures

The basis of the attitude questionnaire form was the orientation theory presented in the theory section (Ramsden 1984, Entwistle, 1986, Yrjönsuuri, 2002. The attitude questionnaire form was based on these orientation theories (personal meaning, reproducing, achieving, non-academic, task, dependent, self and defeatist orientation). In addition, questions designed to measure specifically intentions and motivations were added to the questionnaire.

More information on the construction of questionnaire measures can be found in research report of Pohjolainen et. al. (2006).

4 Analysis of the attitude questionnaire

4.1 Principal component analysis and sum variables formed on the basis thereof

First a principal component analysis of the attitude questionnaire data was performed using orthogonal Varimax rotation. The rotated component matrix resulting from the principal component analysis is presented as an appendix to Pohjolainen et al. (2006) The first 15 principal components obtained as a result of the principal component analysis explain 55.8% of the variance in the original variables.

Sum variables were formed of the variables that were strongly loaded on the first 11 principal components. Reliability of the sum variables was tested with reliability analysis. The value of the reliability coefficient (Cronbach's alpha) should be greater than 0.6, but due to their meaningfulness sum variables 5, 7 and 11 were included in the further analysis.

Factor	Learning pattern Undirected	Learning pattern Reproduction directed	Learning pattern Meaning directed	Learning pattern Application directed
Cognitive processing strategies	*** virtually no processing** * student has problems in almost all learning functions * problems in isolating essential matters * reads material again and again	*** processing by stages (operational)** * takes time to find important matters, but difficulty in selecting them * notes what must be learned by rote	*** deep processing** * internal interest *distinguishes important matters and tries to understand * tries to make connections to prior knowledge	*** concrete processing** * student pays attention to what can be applied in practice * makes concrete and applies what has been learned
Metacognitive regulation of learning	*** virtually no regulation of learning** * student find teacher's instructions unclear * student's way of studying does not change as studies progress	*** externally regulated** ***** student observes signs from teacher, e.g. test hints *student needs a lot of time for studies	*** mostly self-regulated** * if problems emerge, thinks why * also uses processing means to remedy situations	*** both self and externally regulated** * may sometimes find studies too theoretical * feels he has understood on understanding connection between theory and practice
Mental mode of learning	***co-operation and stimuli** ***** wants more external regulation * teacher needs to explain carefully, provide summary, draw together what needs to be learnt and what not, checks what students can do * students find co-operation with peers important * student's task is to study regularly and get things into his head	*** reception of knowledge and learning by rote** * main thing in studies is to scrape through * thinks studying is to digest information through repetitive practice * teacher must explain, show connection between things and overall picture, ensure that student has understood and say what is expected in test * no need for student to think critically	* **knowledge building** * perceives learning as a dialogue between people * learning is accommodating s.th. new into prior knowledge * teacher to explain things outside the book, give time for thought * good teaching puts student's frame and interest before tests * responsibility for learning with self	*** using knowledge** ***** teacher must ensure that matter does not remain too theoretical. encourage student to think for himself, stimulate curiosity * student must apply matter in practice, show interest by asking teacher
Learning orientation	*** uncertain attitude to studies** * wonders if the choice of field and courses was OK	*** degree oriented** * goal in studies is getting credits and competing degree	*** individual orientation** * studies out of interest, to develop as a person or from the joy of studying	* **professional orientation** * desire to acquire skills and knowledge for work or hobbies

Table 1. Learning patterns adapted from Vermunt
(Vermunt, 1996; Vermunt 2005)

The number of the sum variable indicates the number of the corresponding principal component. The sum variables were named as follows based on the strongly loaded variables on corresponding principal component [words in square brackets are abbreviations used in table 2] (the number in the parentheses is the coefficient of reliability):

1. [Uncert] Uncertainty of mathematical expertise (0.7545)
2. [Defeatist] Defeatist (0.7630)
3. [Posexp] Positive conception of own expertise (0.7545)
4. [Posmath] Positive attitude towards the study of mathematics (0.7038)
5. [Surface] Surface learning (0.5315)
6. [Rote] Learning by rote (0.6100)
7. [Deep] Deep learning (0.5216)
8. [Peer] Peer learning (0.6006)
9. [Weaklitrcy] Weakness in mathematical literacy (0.7673)
10. [Taskparall] Doing tasks in parallel (0.6149)
11. [Instrum] Instrumental learning (sufficient for the student for the task to look as if completed whether right or wrong) (0.5130)

The following statements were not strongly loaded on the former 11 principal components, thus they are processed in the following group analysis as they are (the number in front of the variable is the number on the questionnaire form/data):

4. [Effort] The fact that my efforts are appreciated inspired me to continue with my studies
5. [Byhand] When I am calculating I hope that someone will take me by the hand to advise me.
20. [Deduction] I learn best if I can use deduction in solving the task.
19. [Copying] I learn a lot by copying if I retain the thought with me
39. [Model] I succeed in solving the tasks when I take a model from the teacher
29. [Keepsols] I keep the solutions to the tasks strictly to myself.
42. [Fromdetails]I first learn the details then form a general conception of the matter.
3. [Depndsonme] Success in learning mathematics depends on me myself.

4.2 Grouping of students

The students were grouped into clusters according to the sum variables above (11) and the individual variables (Statements 3, 4, 5, 19, 20, 29, 39 and 42) using K-means cluster grouping. All variables used in the grouping into cluster centres were standardized (i.e. mean is zero and variance is one) prior to the analysis.

Next we present the solution of the five cluster centres identified by the researchers as informative. The solution of five cluster centres is presented in Table 2. The boxes in the table also show the average value of the standardised variable. If for some cluster centre the sum variable has a greater (smaller) value than in other cluster centres, the characteristic in more (less) common in the cluster centre concerned than in other cluster centres.

Final Cluster Centers					
	Cluster				
	1	**2**	**3**	**4**	**5**
Uncert	0.343	0.398	1.069	-0.187	-0.907
Defeatist	0.633	0.106	1.197	-0.101	-0.937
Posexp	-0.461	-0.247	-1.074	0.097	0.915
Posmath	-0.383	0.228	-1.236	-0.202	0.772
Surface	0.679	0.225	0.729	-0.239	-0.729
Rote	0.265	0.266	1.088	-0.251	-0.695
Deep	-0.637	0.296	-0.958	-0.275	0.784
Peer	-0.051	0.584	-0.024	-0.326	-0.213
Weaklitrcy	0.074	0.334	1.061	-0.129	-0.743
Taskparall	-0.140	0.469	0.696	-0.148	-0.556
Instrum	0.108	0.310	0.337	-0.230	-0.306
Effort	-0.323	0.529	-0.498	-0.383	0.266
Byhand	-0.158	0.669	0.805	-0.440	-0.528
Deduction	-0.336	0.248	-0.384	-0.422	0.512
Copying	0.463	0.261	0.191	-0.528	-0.131
Model	0.443	0.344	0.065	-0.640	-0.040
Keepsols	-0.376	0.010	0.449	0.249	-0.230
Fromdetails	-0.152	0.239	-0.026	-0.210	0.060
Depndsonme	0.390	0.108	-0.933	-0.326	0.411

Table 2. grouping of students on the basis of sum variables and individual variables into five cluster centres. Yellow indicates the greatest or greater variable for each cluster and blue the smallest or smaller values.

The clusters identified through K-means clustering are named were named as follows on the basis of the variables in Table 2: (1) Surface Oriented Learners (14.7%), (2) Peer Learners (24.0%), (3) Students Needing Support (12.5%), (4) Independent Learners (22.7%) and (5) Skilful Students (26.1%).

Surface Oriented Learners are uncertain about their own expertise. Their attitudes are not the most positive and their studying is characterised by copying or studying with the help of examples. However, they do take responsibility for their own learning and trust themselves, as it is their conception that their success in the study of mathematics depends on them. However, these students do not pursue deep approach. Compared to other groups they consider it less important to call what is taught into question. This is indeed understandable, since calling knowledge into question undermines the preconditions for learning by rote and surface approach. The intention in studies is to get through the course and take the degree, and the significance of studying mathematics is derived from the needs of their own respective degree programmes. Solving tasks is not kept strictly to themselves but may be shared with peers.

In this group Entwistle's (1986, adapted from Biggs) reproducing and achieving orientation and Yrjönsuuri's dependency orientation are emphasised. In Vermunt's learning patterns (Table 1) this is oriented towards reproduction. Students with an approach to reproduction perceive the teacher as a dispenser of knowledge and the student as its recipient. The student does not need to think critically.

Peer Learners are more social compared to the other groups and like to study together with their peers. Their attitude to the study of mathematics is positive. The teacher's support and attention and the example provided by the teacher are important. Copying, studying by means of examples and learning by rote are their methods of study, but there is also an attempt at deep learning.

In this group Entwistle's (1986, adapted from Biggs) reproducing orientation and Yrjönsuuri's dependency orientation are emphasised. Vermunt's approach to learning is directed towards reproduction, but also partly not directed and partly directed towards meaning. Peer Learners appear to make most use of use processing by stages (Table 1) since compared to other groups they study the details first and then build up entities from them.

Students Needing Support are extremely uncertain of their mathematical expertise compared to other groups and easily abandon their studies. Their attitudes towards the study of mathematics are moreover weak. These students in need of support study mathematics by learning by rote and they find the language of mathematics difficult to understand. They hope that someone will come and take them by the hand to advise them; the examples provided by the teacher are not sufficient. They do not take responsibility for their own learning. It suffices for them to get the tasks looking as if they had been completed (instrumental learning).

In the actions of this group we see Ramsden's (1984) non-academic orientation and Yrjönsuuri's defeatist and self orientations. The interest in mathematics of Students Needing Support is influenced by their degree programmes and possible completion of a degree. According to Vermunt their attitude to their studies is uncertain. They wonder if they have made the right choice of field of study.

Independent Learners go more their own way than do students in other groups, at least in the study of mathematics. According to the variables in the cluster analysis the group appeared more passive than the other groups, but its good achievements told a different story. Table 2 shows that the averages of the group ran parallel in several variables with those of the group of Skilful Students. Those classified as Independent Learners have a positive conception of their own capabilities and do not resort to learning by rote, reproducing orientation or surface approach. Compared to the Skilful Students group, however, Independent Learners are not as positive about studying mathematics, do not pursue deep study and do not find recognition of their efforts particularly important and do not use creative reasoning when solving tasks. They moreover study in their own way and the significance of other students in studying is not as strongly emphasised as in other groups. They also keep the solutions to their task to themselves. Examination of the original statements showed that in the opinion of this group the statements "Learning mathematical structures is unnecessary" was given the second highest ranking.

It appears somewhat contradictory that in the opinion of this group the average for the statement "Success in learning mathematics depends on me myself", was low, being lower only in the Students Needing Support group. Such a response may reflect the group's indifference to learning mathematics.

Examination of Vermunt's approaches suggests that some of the Independent Learners might be application directed. This group is characterised by believing that they understand the matter if they understand the relation between theory and practice. They may consider the study of mathematics too theoretical if the connection to the real world cannot immediately be demonstrated. Those who are application directed render what they learn concrete and apply it; their studying is both self-directed and externally directed. Application directed study includes professional orientation. The teachers can see that some of the TUT students of engineering are those who apply knowledge, considering practicality more important than theory. Theory is appreciated only if it provides immediately practical solutions.

Skilful Students have a positive attitude to studying mathematics and a positive conception of their own skills. Skilful Students pursued deep learning and used learning by rote least in their studies. Copying and examples were not as important to them as they were to other groups. Skilful Students do not give up easily when doing their tasks.

In Entwistle's terms Skilful Students are personal meaning oriented and for Yrjönsuuri they are task-oriented. In Vermunt's approach clearly meaning directed. The motivation of these students is internal and the strategies regulating studies are self-directed. Learning is the construction of knowledge and the teacher ought to recount matters not in the textbook and allow students time for their own thinking as they learn best if they can use creative reasoning and take responsibility for their own learning. The goal of studying is personal: interest, the joy of studying, developing as a person.

5. Analysis of students' study achievement

5.1 Basic Skills Test

The mathematical skills of all students of Engineering Mathematics course are assessed by means of a Basic Skills Test when their studies at TUT commence. The test measures the students' upper secondary level mathematical skills in basic algebraic routines.

The research data consists of the results of the test in basic skills in mathematics and of the learner group information. All students were moreover required to provide basic information: gender, degree programme, year of passing the matriculation examination. The research data also included the student's grade for the course Engineering Mathematics I, the number of practice assignments completed during the course and the student's score in the interim tests.

Basic Skills Test is a web-based application measuring upper secondary level mathematical skills. The Basic Skills Test was completed computer-aided in the A&O learning environment (Pohjolainen et al. 1999; Pohjolainen et al. 2003) with a software created for that purpose. The test included 16 tasks in eight different areas: numbers, expressions, equations, inequalities, logarithms, exponential expressions, trigonometry, derivatives and integrals.

A total of 60 minutes was set aside for testing. At the beginning each student registered in the A&O learning environment. Next the student was able to enter the personal ID and password using the test program. After logging in students had to respond to the attitude questionnaire containing 55 statements and implemented as a www questionnaire form. Approximately ten minutes was allowed for completing the form. The learner groups mentioned in chapter "Introduction and background" were found from the responses to these 55 questions.

Once the student had completed the attitude questionnaire the actual Basic Skills Test began. For this the time allowed was 45 minutes. Students did not need to complete the tasks in a given order but were free to look at the tasks in different subject areas and resolve them in whatever order they preferred. No pocket calculators or literature were permitted. Calculations were made with pencil and paper, after which the end result was entered into the field reserved for that purpose. The task was checked in real time and the student immediately received feedback from the program as to whether the solution entered was right or not. Each task could be attempted three times.

Students' comments on the test were mostly positive. However, a few candidates complained about the difficulty of coding answers correctly. This was because answers had to be entered into the test program according to Maple syntax. If the student did not do so correctly the response from the program was "syntax error". In such cases the student did not lose the opportunity to attempt the task and had the option of requesting assistance from the invigilator to achieve the right syntactic form.

The score from the test reflected the number of correctly solved tasks. The maximum score was 16 points, and the minimal pass mark was 6 points. If a student failed the test s/he was directed to Remedial Instruction, on which more detail will be found in Pohjolainen et al. (2006). The program allotted each respondent a task assignment. Thus the tasks of different users and attempts were of approximately the same degree of difficulty but had different numerical values.

5.2 Examination of study achievement and Basic Skills Test

In this chapter study achievement is examined together with the results of basic skills test. Study achievement is also investigated together with the learner groups.

Analysis of the Basic Skills Test and course grades
Examination of the year in which the students taking the skills test took the matriculation examination (Table 3) showed that as many as 64% of respondents took the matriculation examination in 2003 or earlier. Most TUT students had taken a year out (40.3%) and some even longer (23.7%) before commencing their studies at TUT.

Year matriculation	Frequency	Percent	Cumul. percent
-1999	38	4.4	4.4
2000	17	2.0	6.4
2001	32	3.7	10.1
2002	117	13.6	23.7
2003	347	40.3	64.1
2004	309	35.9	100.0
Total	860	100.0	

Table 3. Year of matriculation of Basic Skills Test candidates

Figure 1 presents the distribution of scores (0-16) achieved in the skills test. The distribution appears Gaussian and thus the level of the test questions appropriate. A total of 690 students passed the test (with scores of 6 or more).

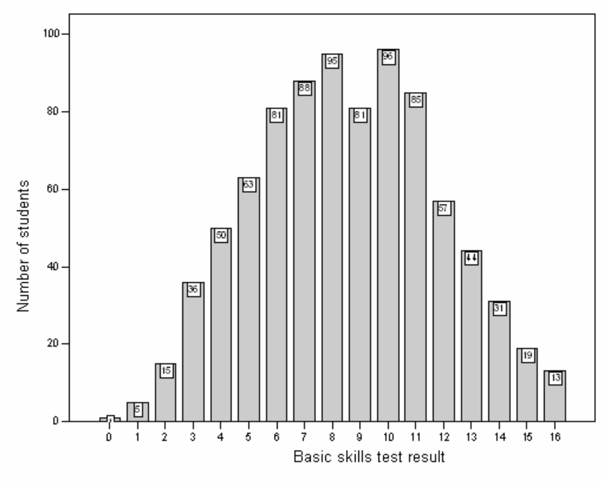

Figure 1. Distribution of Basic Skills Test scores

Examination of the grades of the students who did and did not pass the test showed that the students who failed did more poorly on the course. In total 65% of students failing the test also failed the course. Table 4 presents the grades for the course for those students who participated in at least one interim test (n=793). Grades: 0=fail, 1= satisfactory, 2= highly satisfactory, 3=good, 4=very good and 5= excellent.

Grade	0	1	2	3	4	5	Total
Passed test	145 22.2%	100 15.3%	120 18.4%	110 16.9%	91 14.0%	86 13.2%	652 100%
Did not pass test	91 64.5%	24 17.0%	15 10.6%	5 3.5%	5 3.5%	1 0.7%	141 100%
Total	236 29.8%	124 15.6%	135 17.0%	115 14.5%	96 12.1%	87 11.0%	793 100%

Table 4: Crosstabulation of course grade and passing Basic Skills Test

The success of the content of the basic skills test is evidenced by the fact that those students easily passing the test (9-16 points) had also done well on the course. Of these students, as many as 82.2% passed the course. Figure 2 presents the averages and standard deviations of course grades by the scores in the Basic Skills Test

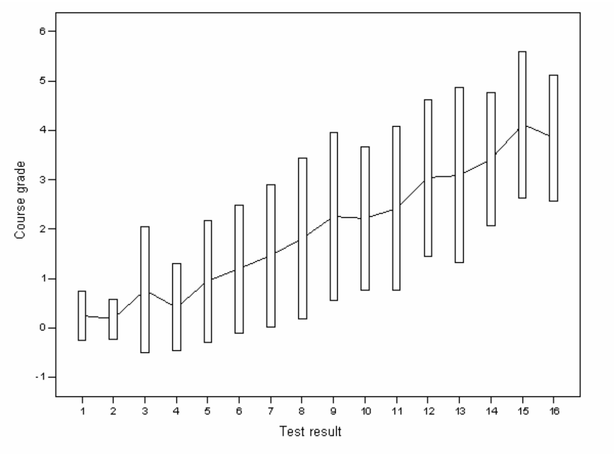

Figure 2. Average grades by test score. The bars illustrate the standard deviation of grades for each test result.

Learner group	Passed test	Did not pass test	Total
Surface Oriented Learners	97 77.0%	29 23.0%	126 100.0%
Peer Learners	156 75.7%	50 24.3%	206 100.0%
Students nee-ding support	74 69.2%	33 30.8%	107 100.0%
Independent Learners	163 83.6%	32 16.4%	195 100.0%
Skilful Students	200 89.3%	24 10.7%	224 100.0%
Total	690 80.4%	168 19.6%	858 100.0%

Table 5: Grades of those passing the test in the found learner groups.

It can be seen from Table 5 how great a share of the students in each group did not pass the test and were directed into Remedial Instruction. Of the Students Needing Support 30.8% and 10.7% of the Skilful Students were directed into Remedial Instruction.

Crosstabulation

	GRADE 0	1	2	3	4	5	Total
1 Surface Oriented Learners	38 34.9 %	20 18.3 %	14 12.8 %	18 16.5 %	7 6.4 %	12 11.0 %	109 100.0 %
2 Peer Learners	66 35.1 %	30 16.0 %	32 17.0 %	26 13.8 %	22 11.7 %	12 6.4 %	188 100.0 %
3 Students Needing Support	41 41.4 %	21 21.2 %	19 19.2 %	11 11.1 %	6 6.1 %	1 1.0 %	99 100.0 %
4 Independent Learners	47 25.4 %	32 17.3 %	35 18.9 %	22 11.9 %	26 14.1 %	23 12.4 %	185 100.0 %
5 Skilful Students	44 20.9 %	21 10.0 %	35 16.6 %	38 18.0 %	34 16.1 %	39 18.5 %	211 100.0 %
Total	236 29.8 %	124 15.7 %	135 17.0 %	115 14.5 %	95 12.0 %	87 11.0 %	792 100.0 %

Table 6: Distribution of course grades of the groups formed by cluster analysis. Grading scale 0= fail, 1 satisfactory, 2, highly satisfactory, 3, good, 4 very good, 5 excellent.

It can be seen from Table 6 that attitudes have effect on the students' achievement. This is further discussed below.

Examination of the grades obtained by the students on the course showed that most failures were among Students needing Support, of whom as many as 41% failed and only 7 (7.1%) obtained grades 4 or 5. Of the Skilful Students 20.9% failed and 34.6% obtained grades of 4 or 5. The achievements of the Surface Oriented Learners and Peer Learners were somewhere in between those of the first two groups. For the Surface Oriented Learners 34.9% failed while 17.4% of them obtained grades of 4 or 5. Of the Peer Learners 35.1% failed and 18.1% obtained grades of 4 or 5. Finally it should be noted that in all learner groups a considerable portion of students failed to complete the course. This may be due to several reasons. Non-completion of course may be due to reasons other than poor exam result. A student may have dropped out of TUT or decided to take some other TUT courses first. The main thing to recognize is that no matter what orientation student has, active work is needed to complete the course.

Independent Students' study achievement was relatively good. Failures amounted to 25.4% and grades of 4 or 5 were obtained by 26.5% of students in this group. As could be expected, the share of Students Needing Support of those directed to Remedial Instruction was largest, but not as large as might have been expected. Thus the group of those directed to Remedial Instruction was not very homogenous in terms of the attitudes.

We may roughly put the learner groups in order of positive conception of students' own capabilities. It is clear that Skilful Students have the most positive and the Students Needing Support the most negative conceptions of their own capabilities. The other groups are somewhere in between. It may be concluded that positive conceptions predict good achievement in further studies.

5.3 Years out and score

According to the findings of the chi-square test, taking a year out did not affect passing the course or the grade achieved. Supervised remedial study and studying mathematics served to refresh what students had already learned and the year out no longer had any major influence on the grade for the course.

6. Results

6.1 Students' attitudes and achievement

The research questions were presented in Section 3.2: Research Question 1 concerned how students differ in their attitudes (orientation, motivation, intention). As we saw in section 4.2, five learner groups were found, namely 1. Surface Oriented Learners, 2. Peer Learners, 3. Students Needing Support, 4. Independent Learners and 5. Skilful Students.

Research question 3 concerned relation between basic skills and study achievement. It was observed from the data collected on the students that the more years out a student has between the matriculation examination and studying mathematics at university the more likely that student is not to get through the test in basic skills. However, years out no longer have any effect on the students' course grades. Of the students having scores 9-16 in the Basic Skills Test as many as 82% passed the course. It may be concluded fairly well from a student's score in the Basic Skills Test how that student will do throughout the course. It may also be concluded that Remedial Instruction does help to bring back forgotten knowledge in mathematic. However, remedial study does not help to learn new things that student has not previously learned.

Research Question 3 also concerned the effects of attitudes on study achievement. It is evident that attitudes have effect on the students' achievement. So it is beneficial to give such teaching that is as close as possible to students' personal orientations. Of course not all the orientations are feasible in the sense of understanding the matter and it is also important to guide students towards more "recommendable" orientations. These aspects have been taken into account at TUT by providing in Engineering Mathematics courses two kinds of exercise groups which provide for most of the students a possibility to learn more close to their own learning orientation.

It can be generalized that those groups of students having a positive conception of their own capabilities also did best in their studies. Yet the distribution of the findings merits consideration. A considerable proportion of students in all groups failed to complete the course.

6.2 Development of teaching and further research

Research question 2 was about teaching alterations that should be made based on the current research.

The first thing to recognize is to tune in to fact that there are several different learner types among students. Also it is crucial to know different learner types so that one can know how and in which direction the teaching should be developed. After that it is possible to provide different learners special teaching arrangements. Also different students have different kinds of interests with respect to mathematics. (Pohjolainen et. al., 2007).

The most substantial intervention based on the results of the paper (Pohjolainen et. al., 2007) is the teaching arrangement that was made in 2006 and is still being used and developed in TUT. This arrangement is based on the found learner groups and concerns about one thousand students starting their engineering studies at TUT annually. In this arrangement two types of exercise classes were set up in all Engineering Mathematics implementations. These exercise groups are named as Supervised Classes and Independent Classes. Supervised Class is intended especially for Peer Learners, Surface Oriented Learners and Students needing support. In this Class it is possible to have guidance through the whole process of making exercises and to work collaboratively and cooperatively. In Supervised Classes it is possible to use more time in students' personal interests and deepening their knowledge. This enables for most of the students a possibility to learn more close to their own learning orientation than in traditional exercise group arrangement.

Because of the different characteristics of exercise groups, they also have different amounts of time in their use. Supervised Classes have 3 hours per week and Independent Classes have 2 hours per week. Although these groups are directed to certain learner groups, the students may freely choose an appropriate class based on their own conception which group will suit best. Approximately two thirds of students have chosen the Supervised

Classes. Also the feedback from the students has been positive about these Supervised Classes. The most positive feedback has probably been that students have proposed this teaching arrangement for other institutes as well.

Research continues and the further research is being carried into direction of analysing students' errors in mathematics. The idea is to systematically analyse the exams and classify the errors that occur in them. After classifying errors it is possible to understand and investigate whether the errors somehow predict errors in some other task. Also it is possible to evaluate whether these errors are in some way related to learner groups found in present study. This error analysis provides us to understand better engineering students' actual knowledge and the lack of knowledge in mathematics.

Present study has also led to write such material where different applications of mathematics are presented for the first-year engineering students. This material has been collected from the different departments from different fields of engineering such as electromagnetism, power electronics, electronics, industrial management etc. A co-operation between other departures was a fundamental idea when creating this material. Material enables engineering students to have some idea of the practical engineering applications at the phase in their studies where the subjects are mainly theoretical.

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