IMPROVING THE TEACHING OF ENGINEERING MATHEMATICS: A RESEARCH PLAN AND WORK IN PROCESS REPORT

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Abstract: In this paper we present a research plan and work in process report about improving the teaching of engineering mathematics. In Aalto University School of Science and Technology (former Helsinki University of Technology) mathematics teaching has been an active field of development in the past few years. New engineering students have been tested by the basic skill test of mathematics in autumns of 2008 and 2009 and the test will be used also in autumn 2010. The test was based on a similar test used in Tampere University of Technology. It includes randomized questions covering the most important high school topics. Last autumn we also sent a link to a learning styles questionnaire to all students who made the basic skill test. The questionnaire was based on Felder's Index of Learning Styles Questionnaire. Results of the questionnaire were compared to the results of the basic skill test. In the future we will send an inquiry form to a sample of students who succeeded weakly in their mathematics studies and in the basic skill test. The questionnaire includes questions about their mathematics study experiences. After we have analysed the results of the questionnaire we will interview more precisely a few interesting cases. The results of the basic skill test have shown that students have some learning gaps in mathematics. Difficult topics are for example trigonometry and logarithms. However, while there was a significant correlation to the first year mathematics courses, many students seem to accomplish much better or worse than they succeeded in the basic skill test. According to the results of the learning styles questionnaire most of the first year students in Aalto University School of Science and Technology are visual and sensing learners. No correlation was found between the results of the basic skill test and the results of the learning styles questionnaire.

Keywords: engineering mathematics, teaching, basic skill test of mathematics, learning styles

1. Introduction
In the Aalto University School of Science and Technology (former Helsinki University of Technology) mathematics teaching has been an active field of development in the past few years. Our motivation is to increase the number of students passing of basic mathematics courses that are an obligatory part of studies for all engineering
students. The problems are, for example, first year students' varying level of knowledge in mathematics and low participation in teaching [1]. Aalto University has looked for solutions to these problems by actions that support students and improve flexibility. Another important project has been to gather data to gain understanding of the underlying reasons of problems. One of steps taken has been introduction of a basic skill test in mathematics for new students.

Success in the basic skill test does not ensure success in mathematics studies. Other things that also are believed to be important are, for example, motivation, ability to independently work and acclimatization to university studying environment. New students need also supportive actions for ensuring an improved level of achievement in mathematics. Actions taken to improve the situation are automatically assessed STACK-exercises ([2]-[3]), web-based review material concerning high school mathematics and voluntary mathematics exercise sessions for students who want to solve exercises by the help of an instructor or in a group.

2. Aim of the research
The aim of this research is to settle reasons why students do not pass the basic courses in mathematics, and determine whether the actions taken to date work. By using statistical analysis of the results, we try to find out how do the result of the basic test of mathematics compare to the results of the first year mathematics studies. We will also try to find out other things that contribute to failure and, if possible, measure how significant they are. Possible reasons can be for example unfamiliarity of the methodology required in university studying, social reasons and inappropriate teaching and learning styles. In this study we also try to propose methods that support weak students.

The main research questions are:
- What are the most important learning gaps for engineering students in first-year mathematics?
- How should we change mathematics teaching so that students' learning and success in studies improves?

The sub-questions are:
- How do already completed measures (STACK-exercises, e-learning material etc.) affect students' learning?
- What specific learning problems do students who succeed weakly have?
- What teaching methods are best for students who succeed very weakly?

3. Research methods
3.1. Basic skill test of mathematics
All new engineering students of Helsinki University of Technology made the basic skill test of mathematics in autumns 2008 and 2009 and the same test will also be used in autumn 2010. The test was a part of a compulsory (except architecture) course so nearly all students made the test. Students in architecture do not have to take basic courses in engineering mathematics. During the test there was an instructor in the class who answered to technical questions.
The test problems were originally created in Tampere University of Technology (TUT) but the assessment system used there was different because of software licence issues [4]. The test in Aalto University was implemented by STACK (System of Teaching and Assessment using Computer algebra Kernel) computer aided assessment system ([3] & [5]). STACK is a system which allows teachers to make personalized mathematics exercise assignments for students. Personalized questions are based on a technique where parameters are randomized. The test included 16 questions covering the most important high school mathematics topics including derivatives, logarithm and exponential function, inequalities, integrals, manipulation of algebraic expressions, arithmetics, trigonometry and equations. All questions were randomized so there were many variations of each question. However the problems were created so that the difficulty level did not vary significantly between different instances.

Problem assignments reduce the possibility of cheating in the test. The technique also enables universities to use the same test year after year. This makes it easier to compare the results of different years with each other.

3.2. Learning styles questionnaire
In October 2009 we sent a link to a learning style questionnaire to all students that made the basic skill test in the same autumn. The questionnaire is based on the North Carolina State University's Index of Learning Style Questionnaire (ILS) ([6] - [7]). It includes 44 questions about four different learning style dimensions (active-reflective, sensing-intuitive, visual-verbal and sequential-global). After answering the test the student gets the description of his/her placing in each dimension. The results of the questionnaire are saved to the system, and we will compare them to the results of the basic skill test.

Zywno measured the validation of the Index of Learning Styles questionnaire [8]. He found out that ILS is a suitable tool to access the learning of engineering students. However some evaluations should still be done. The questionnaire is very popular among engineering educators and it has been used in many universities.

3.3. Other research methods
Besides measuring students' basic mathematical skills and learning styles we will also send an inquiry form to a sample of the students who succeeded weakly in the basic skill test. The inquiry form includes questions about their earlier study success and learning styles and their opinions about the teaching in basic mathematics courses. After we have analysed the results, we will interview more precisely a few students. We will find out if we should change teaching so that students' learning would improve.

We will compare results to earlier research (for example [9]-[10]). We will also study relevant literature in order to find ways to improve mathematics teaching and to support weak students in their studies.
4. Preliminary results

4.1. Results of the basic skill test of mathematics
The mean of the basic skill test was 9.26 in 2008 (N=705) and 9.35 in 2009 (N=843). In Figure 1 you can see the distribution of the points students got from the test. The results from 2008 and 2009 were almost identical. The distribution is not Gaussian: there are quite many students who have got 15 or 16 points from the test. A reason for this is probably that in Aalto University School of Science and Technology there exists some very high profile programs which draw highly skilled and motivated students nation-wide. In Tampere University of Technology the distribution was more like the Gaussian distribution [11].

There were not many students who got less than three points from the test. There were couple of very easy questions in the test so students who are taken in to the Aalto University should be able to do them. About 17 % of the students have got five points or less from the test. One reason for weak success might be that many students have not come to university straight from the high school but they have been in work life, military service or had gap years before starting their studies. Unsurprisingly the results of the basic skill test in Aalto University are better for students who have come to the university straight from the high school.

![Figure 1: Distribution of the results of the basic skill test of mathematics in years 2008 (N=705) (white) and 2009 (N=843) (black). The length of the pillar describes the proportion.](image)

According to the results, in 2009 students have many gaps in mathematics in working with for example symbolic fractions, logarithms and trigonometric expressions (see Figure 2). These are the topics that are difficult in high school mathematics. Therefore more time should be dedicated to teaching these difficult topics in high school.
The correlation between the results of the basic skill test and the results of first year mathematics courses in 2008 were examined by using Spearman's rank correlation coefficient. This method does not require the Gaussian distribution of variables [12]. The correlation was not very high but statistically significant (\( \rho =0.3273; \rho =0.0000 \)). This can be affected by many reasons. In some study programs there are more advanced first year mathematics courses so the results are not directly comparable. Students who study more advanced courses may have gotten better scores from the basic skill test.

When examining students who got four points or less from the basic skill test we have found that this group fared weakly in basic courses of mathematics (see Figure 3). In Aalto University courses are graded by using the scale where 0 means that student fails the course, 1 is the lowest grade for passing the course and 5 is the highest grade. The most common grade was 0 and the mean grade was 1.66. It seems that it would be useful in the future to give these students some revision material or lessons of high school topics. In Tampere University of Technology such system has been used ([4],[11]). The remedial instruction has been there an obligatory part of weak successing students' (five points or less from the basic skill test) mathematics studies. In Aalto University we have created web-based remedial material but the use of it is voluntary for students at the moment.
4.2. Results of the learning styles questionnaire

During November 2009, 203 students who made the basic skill test in the same autumn answered the learning styles questionnaire. The total number of students taking the basic skill test was 843 so the sample was quite small (24%). Answering the learning styles questionnaire was voluntary but in the future we could connect the basic skill test and learning styles questionnaire with each other. Then we could get more reliable results.

In Figure 4 you can see the distributions of each four dimensions. The distributions of active/reflective and sequential/global scales are almost like normal distributions and the means are 0.66 for active/reflective scale and 0.59 for sequential/global scale. The distributions of sensing/intuitive and visual/verbal scales are negatively skewed so most of the students are sensing and visual learners. Means are 5.28 for sensing/intuitive scale and 4.52 for visual/verbal scale. According to earlier studies engineering students tend to be more active, sensing, visual and sequential learners ([9] – [10], [13]). The correlation between learning styles and results of the basic skill test of mathematics was also measured but no strong correlation was found.
Teaching in engineering mathematics in Aalto University is predominantly verbal (lectures) or visual presentation of verbal information (mathematical symbols written in texts and handouts) as Felder and Silverman described in [10]. Teachers should thus use more visual elements, for example pictures and interactive animations in their teaching.

5. Conclusions
The results of the basic skill test can be used when developing the teaching of engineering mathematics. For example all lecturers of the basic courses are given information about what to expect from their students. Thus lecturers are able to take into account this information when planning the content and the level of the course.
In addition to Aalto University and Tampere University of Technology the same basic skill test is nowadays used in many Finnish universities (for example in University of Tampere and University of Oulu). This makes it possible to compare the results between different universities.

The main purpose for the use of the learning styles questionnaire is to give students advices in their learning process. During summer 2010 we will write guide material for students about how to learn mathematics. It includes for example studying hints for students in different learning style dimensions.

References


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