Students' Use of Learning Tools and Tool Types

Solving Self-Study Assignments on an Online Platform

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Introduction

Despite the fact that the value of mathematics in society and economics is understood, in recent decades students' mathematics skills have deteriorated in western countries. The report "Mathematics for the European Engineer" by SEFI in 2002 [1] states that this phenomenon prevails in Europe. According to the SEFI report, universities in the western world have observed a decline in mathematical proficiency among new university students and have taken actions to remedy the situation.

For example, less than 60 % of BSc. students starting their studies in Finland at Tampere University of Technology (TUT) in 2010-2012 had completed all mandatory first and second year mathematics courses in their first two years at the university. Students who had progressed fastest in their studies had typically completed their first year mathematics courses according to the recommended schedule. Students who faced problems in studying mathematics more often progressed slowly with their studies in general.

To solve this kind of a problem, competent and skilled teachers should be engaged. However, human resources are limited, and universities around Europe have taken actions in order to battle this “mathematics problem” [2]. In a report by the European Commission in 2011 [3], some details are given on how different countries have taken action to improve the basic mathematics skills of their engineering students. A recent report ”A Framework for Mathematics Curricula in Engineering Education” by SEFI [4] proposes a pedagogical reform for engineering mathematics to put more emphasis on what students should know instead of what they have been taught. The learning goals should be described as competencies rather than learning contents. Contents should be embedded in a broader view of mathematical competencies that the mathematical education of engineers strives to achieve.

This paper aims to present the actions taken by TUT in order to bolster the skills of first year students in mathematics, and to describe the learning profiles demonstrated by different kinds of students when working with different learning tools on a self-study online platform. The data used in this paper has been collected from TUT courses Engineering Mathematics 1 and Mathematics 1, which were held in fall of 2015. The paper also presents some remarks on how studying remedial mathematics could be further developed, and how universities other than TUT could start to implement remedial mathematics in their curricula.

1 Problem-setting and theoretical background

1.1 The Basic Skills Test and the Remedial Instruction

Since 2002, a test titled Mathematics Basic Skills Test (BST) has been organized annually at Tampere University of Technology. The test is intended to be taken by first year students immediately after entering the university and is a mandatory part of completing the first mathematics courses at TUT. The test consists of 16 assignments from the Finnish high school math curricula. Since 2002, the original test has been modified, and today, the test is done using computers and the STACK system (System for Teaching and Assessment using a Computer Algebra Kernel [5]). The test developed at TUT has also been used at Aalto University [6]. The only tools allowed in the BST are pen and paper, and the students’ give their answers using a computer.

In order to pass the Basic Skills Test, a student should be able to complete a set amount out of the 16 assignments within 45 minutes (in fall of 2015, the passing limit was 6 for engineering students, 8 for science and mathematics students). Students who failed the test were directed to the Remedial Instruction (RI). The Remedial Instruction is a set of 71 high school mathematics problems designed to brush up the skills of engineering students. Students are able to work in the Remedial Instruction on their own time, since the system is available online on Math-Bridge learning platform. In fall of 2015, 169 students participated in the Remedial Instruction. Out of the 169, 164 were directed to the instruction from the BST, and 5 students participated voluntarily. The Remedial Instruction has been found to be a good way for students to get back on track in their mathematics studies, and the latest developments in learning technology have opened new ways to organize the Remedial Instruction [6].

1.2 Learner profiles at TUT

In 2006, by using cluster analysis, Pohjolainen et al. were able to create five different learning profiles that were used to divide all the TUT students into five different categories [8]. The categories are Surface Oriented Learners (SOL), Peer Learners (PL), Students Needing Support (SNS), Independent Learners (IL) and Skillful Students (SS). The profiling is done at the start of the Basic Skills Test by having the student choose from a five different statements the one that best suits them. A brief explanation of the profiles is given below. More detailed explanations can be found in [7,8].

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 a deep approach.

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.

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.

Independent Learners go more their own way than do students in other groups, at least in the study of mathematics 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.

Skillful 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. Skillful Students do not give up easily when doing their tasks.

1.3 Tools in teaching and learning mathematics

According to the OECD report [9], PISA results show no appreciable improvements in student achievement in reading, mathematics or science in the countries that have invested heavily in information and communication technology (ICT) for education. OECD reports that "ICT is linked to better student performance only in certain contexts" and that "technology can amplify great teaching, but great technology cannot replace poor teaching". This is closely tied in with the current way of using calculators in Finnish upper elementary schools and high schools.

Students enrolling in TUT have, excluding a few possible exceptions, all participated in the Finnish matriculation examination [10]. Thus, their use of different learning tools are often shaped by the possibilities allowed in the matriculation examination. The current most common tools include the Math formulary (the MAOL table book, Finnish: MAOL-taulukot) and calculators with computer algebra systems (CAS-calculators).

Since 2013, students in the matriculation have been allowed to use CAS-calculators. Before, only function or graphic calculators were allowed, and with the allowance of the CAS- calculator, the matriculation examination has had to change as well. The latest change is the ban of calculators for the first four problems of the exam.

Engineering students entering TUT often use calculators in their mathematics assignments. Since TUT does not allow calculators to be used in mathematics first year examinations, some students have had a hard time adjusting to studying university mathematics. Also, new kinds of online tools have been created, such as Wolfram Alpha, Symbolab, and others, which further remove the need for manipulation of mathematical expressions with pen and paper. Students can easily solve some of their their assignments with these new tools, but this may weaken their own learning. Hence, it is interesting to study how these tools are used in the Remedial Instruction.

1.4 MathBridge - an online platform for learning mathematics

In 2009, the European Commission's Information Society's eContentplus program started a project called Math-Bridge - its aim was to provide multilingual and multicultural semantic access to remedial mathematics content, which adapts to the requirements of a learner and the subject of study. After its completion in 2012, Math-Bridge has been a tool to be used in bridging the gap between secondary school and university mathematics. The final outcome of the project was the online learning platform Math-Bridge [11].

At TUT, the Remedial Instruction is implemented with Math-Bridge. The 71 problems are available online along with the study material and model answers for each problem. Since Math-Bridge is also calling STACK to randomize the problems, students can't simply look at a model answer and then copy the answer in their reattempt.

The use of an online platform combined with new learning technologies is not without problems. There is no way to efficiently control the way students solve the problems at home. A meaningful studying would include working on the problem itself, but with many tools, such as CAS calculators or Wolfram Alpha the problems can be solved without assigning the student to a mindful work. It is important to study how the online platform is used, and it is important to consider what actions - if any - should be taken to further increase the effectiveness of the Remedial Instruction.

2 Research methodology

2.1 Research questions

The research questions of this paper are linked to the use of different learning tools while self-studying on an online platform. There are two viewpoints: the use of learning tools and the student's learning profile, and the use of learning tools and the student's examination grade. The questions are:

1. Is there a connection between students' use of learning tools and their learner profile in Remedial Instruction on an online platform?
2. Is there a connection between use of learning tools and grades in the first mathematics course for students studying remedial mathematics on an online platform?

The means to answer these questions are presented below.

2.2 Remedial Instruction questionnaire

In Myllykoski's MSc thesis [7], 69 students in the TUT Remedial Instruction answered a questionnaire about the Remedial Instruction. Students participating in the Remedial Instruction were asked to answer the questionnaire which had 20 questions. 69 students out of the 169 (40.8%) gave answers. The most important questions in the questionnaire, related with this paper, were

> 14. The amount of hours I used on the instruction was approximately (choose one from 0-5; 5-10; 10-15; 15-20; 20-25; 25+)
>
> 15. Choose from the following all the tools you used to complete the Remedial Instruction: (Pen & paper (P&P); Wolfram Alpha (WA); CAS Calculator (CAS C); Function calculator (Func. C); High school books (Books); Remedial Instruction learning material (RI LM); Remedial Instruction model answers (RI MA); Remedial Instruction educational videos (RI EV).)

The answers to these questions were added together with the knowledge of the students' learning profiles, Basic Skills Test scores and their examination grades in the first mathematics course in their curriculum. By combining this information, it was possible to study relationships between students' use of learning tools with their learner profiles and course success.

3 Results and discussion

3.1 Questionnaire results and learner profiles

The results of the questionnaire questions and learner profiles are presented in Tables 1, 2 and 3. The contents of the tables are explained in detail in the sequent sections.

Table 1: Students' reported use of time in the Remedial Instruction, n = 69.

Hours	0-5 h	5-10 h	10-15 h	15-20 h	20-25 h	25+ h
No. stud.	14	25	15	6	6	3

Students' use of time in the Remedial Instruction is shown in Table 1. Each student chose the most appropriate time interval that best represented their time used to complete the Remedial Instruction. Most students had spent 0-15 hours on the problems, with only few spending over 15.

Table 2: Students' reported use of learning tools in the Remedial Instruction, n = 69.

Tool	P&P	WA	CAS C	Func. C	Books	RI LM	RI MA	RI EV
No. stud.	66	33	15	38	21	35	55	9

Table 2 contains the number of students that reported the amount of each learning tool used. The clear favourite is Pen & Paper, followed by RI Model Answers, Function calculators, RI Learning Material and Wolfram Alpha.

Table 3: The amount of students of different learner profiles, n = 69.

Profile	SOL	PL	SNS	IL	SS
No. stud.	14	26	6	7	16

Most students in the Remedial Instruction were profiled as Peer Learners as can be seen in Table 3. Skillful Students and Surface Oriented Learners are the second and third most represented groups.

Table 4: The average exam grade for each learner profile on a scale of 0-5.

Profile	SOL	PL	SNS	IL	SS
Grade avg.	0.929	1.731	1.500	1.429	2.313

The average grades of students of each learner profile group are shown in Table 4. Surface Oriented Learners seem to have achieved worse grades than the other groups.

3.2 Analysis of learning tools and their use

Students reported their use of learning tools according to Table 2. These reports came from different learner profiles and they show that on average a different amount of learning tools was used, as seen in Table 5.

Few differentiating patterns can be seen in the learning tool usage data. All groups have reported the rich use of pen and paper. This is natural, as pen and paper are the traditional tools of doing mathematics. When looking at the ordering of the most popular tools for each learner profile, differences are apparent. For Surface Oriented Learners, the most popular tools are Pen & Paper (P&P), RI Model Answers, RI Learning Material and Wolfram Alpha (WA)/Function Calculator (FC). For Peer Learners the order is Pen & Paper, RI Model Answers, Function Calculator, RI Learning Material. For Skillful Students, the order is Pen & Paper, RI Model Answers, Func. Calculator, Wolfram Alpha. On average, Skillful Students have reported less tools used than Surface Oriented of Peer Learners, and they have reported little use of the Remedial Instruction online learning material. Also, the percentage of Skillful Students that have used Wolfram Alpha is smaller than for Surface Oriented Learners (37.5% vs. 64.3%).

Table 5: Use of tools for each learner profile. In the bottom row the average number of tools for each learner profile is shown. Data is given in pairs of (n, % of group).

LT \ LP	SOL.	PL.	SNS.	IL	SS	Σ

P&P	14 (100%)	25 (96%)	6 (100%)	7 (100%)	14 (87.5%)	66 (95.7%)
WA	9 (64.3%)	11 (42.3%)	4 (66.7%)	3 (42.9%)	6 (37.5%)	23 (33.3%)
CAS C	4 (28.6%)	5 (19.2%)	1 (16.7%)	0 (0%)	5 (31.3%)	15 (21.7%)
Func. C	9 (64.3%)	15 (57.7%)	4 (66.7%)	3 (42.9%)	7 (43.8%)	38 (55.1%)
Books	6 (42.9%)	10 (38.5%)	2 (33.3%)	1 (14.3%)	2 (12.5%)	21 (30.4%)
RI LM	10 (71.4%)	13 (50%)	3 (50%)	4 (57.1%)	5 (31.3%)	35 (50.7%)
RI MA	12 (85.7%)	20 (76.9%)	4 (66.7%)	7 (100 %)	12 (75%)	55 (79.7%)
RI EV	2 (14.3%)	6 (23.1%)	0 (0%)	0 (0%)	1 (6.3%)	9 (13.0%)
Σ/(No. stud) The number of average number of used tools	4.714	4.038	4.000	3.571	3.250	3.942

There is a difference in the time spent working on the Remedial Instruction regarding learner profile. As time was reported in intervals, an approximation of time spent can be attained by summing up the total amount of different intervals, calculating the average for each learner profile and by multiplying the average by five. Different learner profiles spent approximately on average the following amounts of time on the Remedial Instruction:

Table 6: Average amount of hours spent for each learner profile.

Profile	SOL	PL	SNS	IL	SS
Hours avg.	17.1	12.3	15.8	15.0	9.1

As can be seen in Table 6, Skillful Students have spent much less time on the Remedial Instruction. When compared to the hours of Surface Oriented Learners and Students Needing Support, this difference is found to be statistically significant (t-test p-values of 3.8e-11 and 3.3e-13 respectively).

When the correlation of Basic Skills Test and examination grades from the students' first mathematics courses was studied, a positive correlation of 0.3291 was found (p-value 0.006). Similarly, a correlation was found between the sum of tools used and exam grades, but this correlation was negative, -0.1921, which is almost statistically significant. (p-value 0.117).

3.3 Discussion on effects of learning tool use

The research questions of this paper can be answered by using the data provided in Section 3.2. For the first question, there would appear to be a connection between using learning tools and students' learner profiles. The most tools are used by Surface Oriented Learners. Skillful Students use least amount of tools. Due to small sample size, Students Needing Support and Independent Learners are more difficult to analyze.

For the second question, correlation was found between the use of learning tools and examination grades. This correlation was negative. However, there is no proof of causality stating that if students use more tools, they will do worse in mathematics. It is actually more likely that weaker students tend to lean on tools, and therefore their examination grades are weaker, which explains the negative correlation. Either way, this information is interesting from the viewpoint of remedial mathematics.

Another interesting finding in this paper is the new information gained about Surface Oriented Learners. They, on average, spend more time and use more learning tools when working independently on an online platform. They also show significantly poorer exam results when compared to other learner profiles (see Table 4), especially Skillful Students (p-value 0.0166). This means that implementing learning tools shows no added benefit for Surface Oriented Learners, and for Skillful Students, these tools are not even necessary, since the group does not use them.

When this finding is considered from the viewpoint of the department that organizes mathematics teaching for the entire university (such as TUT), it becomes necessary to reconsider some of the actions taken to organize Remedial Instruction. The Remedial Instruction, as it now exists, does not seem to be as effective as it could be. Students, when working on their own, seem to tend to overuse learning tools and thus bypass and ignore the critical thinking involved in learning mathematics. This is a problem especially when the phenomenon seems to most apparent among the weakest students that would benefit most from training the basics in mathematics.

Based on this information, the Remedial Instruction should be developed. One possibility is that instead of only having the students work independently on the problems after a failed Basic Skills Test, students could be directed to a second test after their training, the Remedial Skills Test. This test would be similar to the BST. By enforcing students to take another test after their practice on an online platform, multiple beneficial effects could be reached: students would have to take their training more seriously, their training on an online platform would be more effective, and they could experience positive accomplishments from succeeding in the second test. Also, those that do not pass even the second test could be directed to further remedial actions, which would probably benefit them greatly. This is a cost-effective, modern approach to organizing help for students struggling in their studies.

4 SUMMARY AND ACKNOWLEDGMENTS

Different types of learners indicate that their self-study habits on an online platform are very different. Students that are surface oriented in their studies use a lot of different learning tools, but do not produce good examination results. Skillful students seem to do well even without using a lot of tools. Thus, the current way at TUT, where students work on their remedial mathematics problems on their own could be developed further. Some change is needed, and one suggestion is using testing to ensure that the remedial training has had the desired effect.

The ideas presented in this paper show the process of identifying mathematically weak students at TUT, as well as the steps that TUT takes to help these students in their studies. The research methods presented in this paper are ethically sound and in accordance with other publications in the field. The information presented in this paper can be used by TUT and other institutions in creating and modernizing their remedial mathematics. Some students need help in basic mathematics, and it is mutually beneficial for the university to answer the students' need for help by creating an environment where different kinds of students' needs are answered as well as possible.

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