Mathematics Remedial Instruction with Math-Bridge e-learning system

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Abstract

Mathematics is important in science, technology and economics. Unfortunately, in recent decades students' mathematical skills seem to have deteriorated in western countries.

Tampere University of Technology (TUT) has an extensive set of measures to support and help freshmen with their mathematics skills. At the start of their studies, all students have to take the Basic Skills Test (BST) in Mathematics. Students who do not pass the BST must participate in the Mathematics Remedial Instruction (MRI). MRI is carried out with a new e-learning system, Math-Bridge.

Keywords: Mathematics, learning support, remedial studying, e-learning, Math-Bridge

Introduction

Good competency in mathematics is important in science, technology and economy as mathematics can be considered not only as a language of nature and technology but also an important methodology in economics and social sciences. A study by Hanushek and Wößsman (2007) shows that the quality of education has a strong positive influence on economic growth. In their research, students' skills were measured using 13 international tests that included mathematics, science, and reading.

Despite the fact that the value of mathematics in society and economics is understood, unfortunately in recent decades students' mathematics skills have deteriorated in western countries. The report "Mathematics for the European Engineer" (2002) by SEFI (The European Society for Engineering Education) states that this phenomenon prevails in Europe.

The results of the PISA surveys were very flattering to mathematics education in Finnish comprehensive schools. In the survey Finnish 15-year-olds were successful in solving real-life problems, which means that the survey mainly measured students' procedural fluency and adaptive reasoning in mathematics. However, conceptual understanding and strategic competence, which are very important features in university mathematics, were not satisfactorily developed in upper-secondary school mathematics (Joutsenlahti 2008).

As mathematical competency is a prerequisite for studying technical sciences, weak mathematical competence slows down studies. For example, 57% of MSc. students starting their studies in Finland at Tampere University of Technology (TUT) in 2005 had completed all mandatory first year mathematics courses by May 2009 – in four and a half years. Students who had progressed fastest in their studies had typically completed 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 (Pajarre, Lukkari, Lahtinen, 2010).

According to the above-mentioned SEFI report, universities in the western world have observed a decline in mathematical proficiency among new university students and have taken action to remedy the situation. The most common measures are (1) reducing syllabus content – replacing some of the harder material with more revisions of lower level work; (2) developing additional units of study; (3) establishing mathematics support centres; (4) doing nothing.

Math-Bridge was a joint project of nine European universities from seven countries started in May 2009. The aim of the project was to build up a bridge between school mathematics and university mathematics by building up an e-learning platform for online courses of mathematics including learning material in seven languages: German, English, Finnish, French, Dutch, Spanish and Hungarian. This learning material can be used in two different ways of learning: in self-directed learning of individuals and as a "bridging course" that can be found at most European universities (Math-Bridge, 2009, 2011).

Tampere University of Technology has set up an extensive set of measures to support and help freshmen with their mathematics skills. These include Basic Skills Test, Mathematics Remedial Instruction, and Mathematics Clinic (Pohjolainen et.al, 2010).

Basic Skills Test

Since 2002 every TUT freshman has participated the Basic Skills Test (BST) to identify the students lacking mathematical skills. BST is a computer-aided test with 16 upper-secondary school mathematics problems to be solved within 45 minutes. The test uses STACK system (System for Teaching and Assessment using a Computer Algebra Kernel) (Sangwin, 2010) making it possible to generate slightly different problems for each student. Moreover, STACK automatically assesses students' inputs and gives immediate feedback. Thus, students get their test results right after completing the test.

Mathematics Remedial Instruction with Math-Bridge

Those who do not pass the BST must participate in the Mathematics Remedial Instruction (MRI) and pass it in the following four weeks. In Fall 2011, MRI was carried out with e-learning system Math-Bridge. In this and following sections the pedagogical remedial scenario of Mathematics Remedial Instruction with Math-Bridge

e-learning system is described together with results of the pilot run of MRI with Math-Bridge

Mathematics Remedial Instruction is a computer-aided brush-up program that includes 71 upper-secondary school level mathematics problems to be solved. The remedial instruction is based on a pure e-learning scenario where a student independently solves given problems within 4 weeks. MRI is realised using a STACK system (Sangwin (2010), which generalises randomly parameterised problems, checks the correctness of students' answers and saves the results in a database.

In MRI the STACK system is integrated to Math-Bridge so that all 71 STACK exercises used in TUT Mathematics Remedial Instruction are executed in the Math-Bridge system. Moreover, a specially designed content from school mathematics is available in Math-Bridge for a student to support his/her studies.

The system built up during the project, is also called Math-Bridge. The users of the Math-Bridge system can be grouped as follows: administrators, authors, tutors and learners/students. They all have a different role in using the Math-Bridge system. The Math-Bridge system serves many pre-defined courses, the option to build own courses from thousands of mathematical learning objects or to use the adaptive course generation tool. The learning objects include theorems, proofs and definitions as well as instructional examples and interactive exercises. The Math-Bridge system pays attention to a student's individual needs by making it easy to find mathematical learning objects necessary for him/her to study. Because of the multilingual learning material, mathematical knowledge in other languages is increased, while knowledge of languages is increased on average (Math-Bridge, 2011).

The Mathematics Remedial Instruction was brought into the Math-Bridge system. There was a special book for MRI, which consisted of theory material, examples and interactive STACK exercises. Hence students were offered self-learning material and not only the exercises, which students had to solve to pass the MRI. Furthermore, students could also make use of many the other learning material served in several languages.

Students who failed to pass BST were directed to participate in Mathematics Remedial Instruction, and other students were also permitted to participate. Thus, instead of 172 students that were directed to MRI, there were 226 students participating in MRI altogether. Subsequently, 182 students accomplished MRI successfully.

Mathematics Remedial Instruction was started on September 19th 2011 with an opening lecture that consisted of information about MRI study procedures and a demonstration of the Math-Bridge e-learning system. On September 20th 2011 a rerun of the opening lecture was arranged so that as many students as possible could get the required information and see the demonstration.

MRI is based on a distance-learning scenario. There are only a few face-to-face teaching sessions: the opening and closing lectures and two-hour tutorials arranged twice a week

during the four weeks of MRI. The tutorials were set up for the students as opportunities to ask for help in difficult or problematic parts of MRI. It was not mandatory to participate in the tutorials and this might be the reason why students did not participate in them at all. There was only one student that actually came in a tutorial session during the whole MRI.

All the mandatory tasks of MRI were done in the e-learning system Math-Bridge that included study materials and interactive STACK exercises of MRI. Moreover, after successfully solving the interactive exercises students were directed to rerun the Basic Skills Test to see if their results have been improved. Thus, for those students that finished MRI, there were BST results for before and after the course, as well as pre- and post-test results, to give the student information about his/her progress and possible knowledge gain.

Data and learning results

The learning gain obtained from the MRI with Math-Bridge was studied. It was examined whether MRI with Math-Bridge was helping students to learn topics of mathematics that are pre-requisites in university level mathematics courses and also tested in Basic Skills Test at TUT.

The data used in the analysis consisted of the BST scores before and after MRI. BST scores of all the students were added to data so that possible improvement in BST scores of the students who finished MRI could also be compared to them. Data was analysed by using MathWorks Matlab.

The statistics of Basic Skills Test before and after MRI with Math-Bridge are in the Table 1. There were 148 students that took both BSTs in fall 2011. Thus, there were 34 students that successfully passed MRI, but had not participated in BST at the beginning of their studies. To make sure that the populations are the same in the comparison of BSTs, the results of these 34 students are omitted from the results of BST after MRI.

TABLE 1. Basic Skills Test results before and after Mathematics Remedial Instruction with Math-Bridge. Basic Skills Test consists of 16 school mathematics problems. Each problem is assessed with grade 0 if the student could not answer correctly and with grade 1 if the student answered correctly.

Statistics	**Before MRI**	**After MRI**
n	148	148
Average	4,86	11,49
Standard Deviation	1,74	3,01
Min	0	1
Max	9	16
Median	5	12
Average Difference	6,63	
Standard Deviation of Difference	2,86	

It can be seen in the results given in TABLE 1 that both average and median scores of BST were remarkably better in the second round. Since the BST scores of the students who were required to participate in MRI were not normally distributed, non-parametric tests were needed in analysis. Difference in medians was confirmed significant using one-way sign-test (p-value $2.72*10^{-31}$). A boxplot of students' BST scores (Figure 1) supports this.

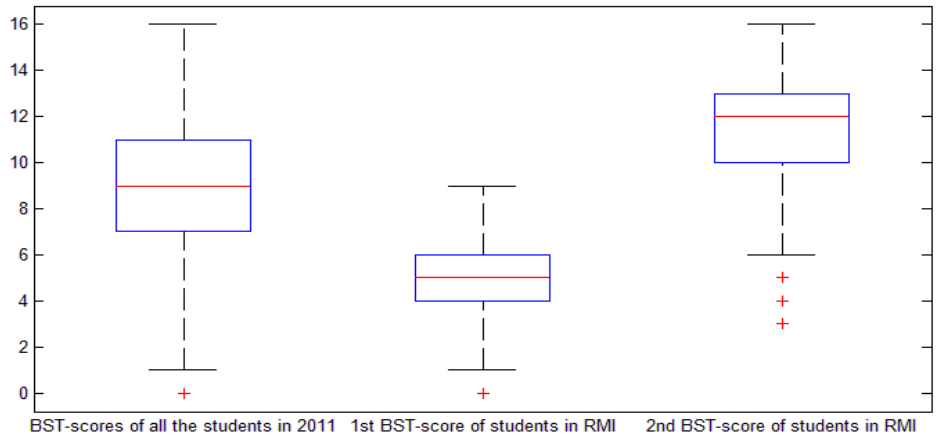

Figure 1. Boxplot of BST-scores.

Figure 1 also shows that the scores of BST taken after MRI seem to be higher than the BST scores of all the students. Median of all the BST scores was compared to the median of the scores of BST taken after MRI using Wilcoxon rank sum test and it was found to be significant (p-value $1.23*10^{-16}$).

So not only did students achieve better on the second BST than on the first but their scores were clearly better with regard to the median even when compared to all the BST scores. The reason for this improvement could be explained with the 71 interactive STACK exercises executed by each student in MRI. These exercises are rehearsing exactly the topics of mathematics that are tested in BST and they are executed in the same way to that the BST problems. Furthermore, after MRI, each student took the Basic Skills Test on his/her own but had access to other materials, such as those offered in Math-Bridge; however, students were told not to use supporting materials during BST after MRI and that test was for them to test their knowledge. Moreover, there was no pressure of passing the BST like it was in the first BST.

Conclusions

Every year students with inadequate mathematical skills begin their studies at TUT. Supportive actions are needed so that these students can complete mandatory mathematics courses and get the tools they need not only to complete their engineering studies but also for other challenges they face after graduation.

Mathematics Remedial Instruction and the Math-Bridge e-learning system are examples of supportive actions carried out at TUT.

It can be said that the overall outcomes of Mathematics Remedial Instruction with Math-Bridge system seem very promising. Although it must be remembered that conditions under which students took the second BST were somewhat different of conditions of the first BST, students' achievement on second BST implies that MRI improved students' basic skills in mathematics.

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