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The Rechenbrücke – A project in the introductory phase of studies

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In the transition from secondary to tertiary mathematics education, major difficulties occur for many students. To respond to this situation, the University of Applied Sciences Münster started the Rechenbrücke project with the object to alleviate the transition from school to university for engineering students through various support measures in the area of mathematics. In this article, we present the preliminary course which is part of the support measures of the Rechenbrücke and aims at refreshing basic calculating skills. The initial results of the pilot study presented indicate the potentially positive effect of these measures.

Keywords: Secondary-tertiary transition, preliminary courses, bridging courses.

INTRODUCTION

The transition from school to university brings along many changes which take part over a vast period of time starting at secondary school and ending at some point during the course of studies. Differences between school and university can be found in thought structures and knowledge organisation, argumentation, and mathematical communication, as well as teaching methods and the expectations of the institution (Gueudet, 2008). Bridging or preliminary courses cover one part of that period and as they are currently common measures to alleviate transition from school to university they present an important factor in the transition issue.

In Germany there are at least two types of tertiary education institutes. Although the differences were reduced in the last years, there are still some important distinctions between universities and universities of applied sciences. While the first ones are “normally strongly research-oriented and typically offer a wide range of subjects” (Hochschulrektorenkonferenz,

n.d.) the latter emphasise practical work and application and “usually offer a narrower range of subjects [with focus] on fields of engineering, business, and social sciences” (ibid). Furthermore students at universities of applied sciences are even more heterogeneous with often considerably lower mathematical skills than those at universities as you can start your studies without an A-level school leaving certificate (Abitur) but with an advanced technical certificate (Fachhochschulreife) or even with a finished apprenticeship and some work experience. Therefore many students spend some years between school and university working or in an apprenticeship.

The secondary-tertiary transition is experienced as difficult by many new students who take mathematics courses at tertiary level (De Guzman, Hodgson, Robert, & Villani, 1998). High drop-out rates and low satisfaction with the chosen study course are the results. In universities of applied sciences the drop-out rate of engineering students has been at 31% in the last years (Heublein, 2014, p. 501). While it is difficult to interpret the concrete percentage due to varying definitions of drop-out, the drop out quote of engineers is the second highest (after *Mathematics and Natural Sciences* with 34%) and is notably higher than the average drop-out of 23% (ibid). The difficulties described above also occur for engineering students at University of Applied Sciences Münster, for which reason the Rechenbrücke project has been started in order to alleviate the transition from school to university. The Rechenbrücke is a cooperation project between five of the engineering faculties of University of Applied Sciences Münster and the Institute for Education in Mathematics and Computer Science of the University of Münster [1]. In this project, various mathematics support measures for prospective and first-year engineering students at University of Applied Sciences Münster are developed and evaluated.

THEORETICAL FRAMEWORK

In many countries students entering higher education lack proficiency in basic mathematical concepts and therefore are not able to develop a sound understanding of those key mathematical ideas needed at universities (e.g., ACME, 2011, Biehler et al., 2014). The situation is even worse at universities of applied sciences as there students with many different learning backgrounds enter studies. The Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (Kultusministerkonferenz) adopted educational standards in mathematics in 2003/04. These standards describe subject-based competencies to be acquired by students by certain stages of their school career. The competence K5 “Mit symbolischen, formalen und technischen Elementen der Mathematik umgehen” (KMK, 2012, pp. 8f.) which includes e.g., working with variables, terms, equations, functions etc. is needed by the other competencies as a tool (ibid). Therefore lacking mastery of K5 often results in lacking mastery of the other competencies.

Preliminary courses and other support measures have been created in many countries to alleviate the secondary-tertiary transition. As such courses are often designed by single universities, there are many different approaches. Decisions to be made in designing preliminary courses are discussed in Kürten, Greefrath, Harth, & Pott-Langemeyer (2014): Framework conditions, objectives and contents, and competencies to be taught have to be clarified. Framework conditions vary from e-learning to blended-learning to classroom courses, from some weeks to two semesters, with voluntary or mandatory participation. Course objectives range from compensation of mathematical deficits to repetition of school mathematics to development of skills used at tertiary education. The contents taught vary from specific mathematical contents (from lower secondary to tertiary level) to mathematical ways of thinking to metacognitive competencies (Biehler et al., 2014). Despite this richness in course conceptions, research on these measures is still at its beginnings. Questions like “How can we measure the effects of preliminary courses?” or “What are the effects of preliminary courses?” have yet to be answered (Biehler et al., 2014).

Many support measures share the aim to enhance success rates by reducing student drop-out, but drop-

out quotes can only be directly measured after the students of a cohort have left university. Therefore the effects of support measures have to be measured by other variables which can be measured shortly after realization of the support measure and are predictors for the drop-out quote. Heublein (2014, p. 504) characterises the drop-out as result of a complex inter-relationship between individual and institutional factors. Performance in studies is just one factor in that process but on the other hand it is a factor which can lead to drop-out enforced by university. Therefore, and as it can be measured by exam grades, in this paper, we will focus on effects the preliminary course has on the students’ performance in studies. A similar approach is used at the University of Applied Sciences Aachen where first results show, that students that attended the preliminary course get significant better results in their mathematics exams than students that did not attend (Greefrath, Hoever, Kürten, & Neugebauer, 2015).

INITIAL SITUATION

In individual interviews with the responsible mathematics lecturers of University of Applied Sciences Münster an estimation of the difficulties, students faced at the beginning of their studies, was ascertained. All the academic staff asked stated a lack of proficiency from school mathematics, especially from lower secondary level. Namely they claim that students fail in written exams in mathematics due to missing skills in term conversion (a common mistake is the linearization of all kinds of terms as in $(a + b)^2 = a^2 + b^2$) and fraction arithmetic (e.g. a common mistake is the addition of numerator and denominator: $\frac{a}{b} + \frac{b}{d} = \frac{a+b}{c+d}$). These basic skills from lower secondary level are required for studying engineering at University of Applied Sciences Münster and therefore are not treated explicitly in the lectures. Nevertheless they are needed for solving of various problems in calculus and linear algebra. In her study regarding the British education system, Kitchen (1999) also determined deficits in the prior knowledge required of new students by universities. The answers from the mathematics lecturers point out numerous parallels to the results of De Guzman and colleagues (1998). They describe a lack of interest in mathematics itself, of necessary prior knowledge, of an appropriate thought structure, independence, learning methods and organisational skills. Therefore the situation at German universities of applied sciences is not unique in Europe. Thus answers to the question whether basic calculation skill

training can alleviate transitions problems (especially for students with low mathematical skills) should be of broad interest.

CONCEPTUALISATION OF SUPPORT MEASURES

Within the scope of the project, various measures have been designed which should alleviate the transition to university in the area of mathematics. As the target group contains many students with assumed low mathematical skills, focus was laid on competence K5 to create a basis on which further mathematical understanding could be built as described above. In an initial step, a collective minimum requirements catalogue for mathematics was created. Based on this, a modular preliminary course was developed that encompasses an upstream diagnostic pre-test. Different scientific evaluation measures (e.g., a post-test and evaluation sheet subsequent to the preliminary course) are used to examine the effectiveness and feasibility of these offers.

The minimum requirements catalogue

The minimum requirements catalogue of mathematical prerequisites for students in engineering courses of study is based on the mathematics minimum requirements catalogue which the cooperation team school – university (cosh) in Baden-Württemberg developed as a consensus of schools and universities. As a result, it can provide an expedient basis for the selection of mathematical contents in a preliminary course or a mathematics test at the beginning of studies (Dürschnabel et al., 2013). In the project this catalogue was adapted and defined in coordination with the mathematics lecturers at University of Applied Sciences Münster. To improve the transparency of the requirements, the catalogue has been published for all interested parties on the homepage of the University of Applied Sciences [2].

The mathematics preliminary course at University of Applied Sciences Münster

The concept for the mathematics preliminary course was chosen to account for three aims: As much facets as possible mentioned above should be considered, it should be possible to recapitulate most of the topics posed in the minimum requirements catalogue by visiting the preliminary course and the expectations of the teaching staff in mathematics should be satisfied as far as possible. The result was a modularly structured preliminary course concept created in the first

half of 2013. In the course, contents of school mathematics from the lower and upper secondary levels are addressed in ten modules developed as a consensus of the participating staff of which the following arose from the initial interviews: *Basic calculation methods and fractions; terms; equations with one unknown and functions (part I)*. The minimum requirements catalogue was taken as a basis for the modules that complement the preliminary course: *Percentage calculation, power and square root calculation; inequations with one variable; functions (part II); differential calculus; integral calculus and simultaneous equations, vectors and matrices*. Besides post-processing of school mathematics, preparation for the requirements of the study course is also featured. Two modules address interdisciplinary mathematical and course-relevant aspects such as notation of statements and equations, argumentation, systematic approaches, lecture post-processing, examination preparation, etc. Here preparation refers to metaknowledge, interdisciplinary methodology, and organisational information (Hoffkamp, Schnieder, & Paravicini, 2013). The preliminary course takes place as a classroom course composed of lectures and tutorials, which is supported by E-learning contents. Amongst other things, this includes parts of scripts, exercises and short videos regarding individual subjects. Due to the large number of new students, the course is conducted in two parallel courses divided according to faculty.

Based on an entry test, students can decide which modules of the preliminary course they wish to process. Subsequent to conducting the test, students receive feedback as to which tasks they have solved correctly or wrongly. For every wrongly answered task, they receive the additional urgent recommendation to visit the corresponding module of the preliminary course. In this way, the target group should be sensitised to the support offer. Given that the clientele of University of Applied Sciences Münster comprises of full-time, parallel-to-profession and dual system students, the online materials should simultaneously enable preparation for the study course. Furthermore, students can decide which module they wish to process in the classroom course or online. Modularisation and flexibility should furthermore enable preparation for new students for their study course, adapted to their personal proficiencies.

RESEARCH QUESTIONS AND METHODS

Given the initial situation described above and the project aim to alleviate secondary-tertiary transition for engineering students with heterogeneous and partly low mathematical skills, three research questions were designed.

- 1) What are the difficulties experienced by new engineering students when trying to use school mathematics?
- 2) Can a preliminary course reduce these difficulties and if yes, to which extend?
- 3) To which extend do these difficulties influence the outcomes of written exams in mathematics?

Within the scope of the project, data from mathematics tests and exam results are collected. In addition to these quantitative tests, semi-structured interviews are conducted with students and the students' evaluations regarding the conducted measures are gathered with the aid of a questionnaire in order to ascertain the effects of the measures in a differentiated manner. In the following, we address the stated quantitative research methods and initial results.

In the project a pre- and post-test are used in connection with the preliminary course. The pre-test should not merely act as a self-diagnostic instrument providing the students with feedback regarding their existing deficits, but moreover, in combination with the post-test, should serve as an evaluation of the preliminary course. Based on these objectives, the test has become mandatory for all who wish to take part in the preliminary course, and is set up voluntarily for all others. Two dates were selected for implementation – prior to and shortly after the preliminary course. The test procedure is computer-based and, for the objectivity of test procedure, takes place centrally in PC pools at the university. The tests have been integrated into the learning platform, ILIAS, used throughout the university. The evaluation requires automatically correctable task formats such as single choice and multiple choice tasks and tasks with short answers. Given that fundamental proficiencies are queried in

these tasks, the test procedure was designed as assistance tool-free. The test comprises of 13 items which are associated with the contents of the preliminary course modules (see Table 1). The following items are two of those used in the pre-test 2013 (translation into English).

Task 2: Calculate and write as an irreducible fraction $\frac{a}{b}$.

$$\text{a) } \frac{\frac{1}{3} + \frac{3}{5}}{\frac{7}{5}} = \frac{a}{b} \quad a = \underline{\quad} \quad b = \underline{\quad}$$

Task 10: We are seeking an equation of the line with the following characteristics: intersects the x-axis in $\frac{1}{2}$ and has the slope $-\frac{1}{2}$. The equation should be stated in the form $y = m \cdot x + b$.

$$m = \underline{\quad} \quad b = \underline{\quad}$$

In addition, „Type of school qualification“, „Time since the end of school“, „Average mark in school leaving qualification“, „Final mark in the subject mathematics“, and „Use of calculators in upper secondary level“ were ascertained. After the preliminary course, the students take part in a parallel-designed post-test. This takes place at the beginning of the lecture period. The first implementation of this test took place as a pilot study in winter semester 2013/14. For organisational reasons, the pre-test was carried out by students on home PCs and the post-test as a paper test during Mathematics I lecture at the beginning of the semester. In addition to the information ascertained in the two tests, the students' results in the written mathematics exams are ascertained after the first (Mathematics I) and second (Mathematics II) semester. An example for items used in the exams is shown in Figure 1.

The written exam marks of the students are anonymously assigned to the corresponding data gathered in the tests. A possible correlation between a preliminary course attendance and the results in written exams should be investigated using this data.

RESULTS

689 test persons took part in the pre-test, and of these, 603 completed the test and provided evaluable results. Of initial interest for the Rechenbrücke project was

1. b) Calculate the real and imaginary part of $z = \left(\frac{i+1}{\sqrt{2}}\right)^{14} \cdot i^3((i+1)^2 + i)$.

Figure 1: Item of the Mathematics I exam in mechanical engineering (translation into English)

the question of whether the contents of the preliminary course were expediently selected, i.e. whether room for improvement actually exists for these topics. The solution rates and topics of the individual tasks are depicted in Table 1. Even the task regarding basic calculation methods, with the highest solution rate, could only be solved by less than three quarters of the test people. Task 4 (power and square root calculation) had the lowest solution rate with only 21% correct answers. The solution rates of the items indicate that addressing these contents in the preliminary course is sensible.

Due to the non-objective test procedure in the pilot study, a comparison of the solution rates between pre- and post-test is only conditionally possible. For a small portion of the random sample ($N = 209$), the results from the pre- and post-test could be correlated. In the course of this, significant changes with a small effect size ($|Cohens\ d| > 0.2$) were indeed determined for several tasks (improvement with tasks 1, 4 and 6 and deterioration for task 7), however these results serve as an indicator at the most and will be checked in the upcoming run in the actual investigation. The

Task and Topic		Solution rate
1	Basic arithmetical operations involving brackets in Z	73%
2	Basic arithmetical operations on fractions, cancelling	61%
3	Percentage calculation: markup problem	67%
4	Solving of a fractional equation where numerator and denominator involve powers and square roots	21%
5	Term conversion using binomial formulas	52%
6	Calculation of inverse proportionality using the rule of three	69%
7	Solving of a fractional equation	70%
8	Solving of a quadratic equation	36%
9	Solving of a linear inequality	63%
10	Setting up the equation of a linear function	53%
11	Offsetting of a parabola	31%
12	Solving of a simple logarithm equation	33%
13	Trigonometry: definition of sine, cosine	53%

Table 1: Solution rate for the individual tasks in the pre-test ($N = 603$)

reliability of the tests was determined by means of Cronbach's Alpha. For the pre-test, a value of 0.72 ($N = 603$) resulted. For the post-test, the value lies at 0.73 ($N = 805$). Therefore the internal reliability of the test is acceptable.

Based on the data of the tests and written exams, the correlations between written exam results in Mathematics I (the first lecture on mathematics in engineering studies at University of Applied Sciences Münster) and potential influencing factors have been investigated. The variables investigated were „Average mark of school leaving qualification“, „Final mark in mathematics“, „Number of points in the pre-test“ and „Number of points in the post-test“. Statistically significant correlations ($p < 0.01$) were determined for all variables which lie between 0.37 and 0.45. The differences between the correlation coefficients were tested with Fisher's z-transformation and are not significant.

Furthermore, it was investigated whether the results in the written mathematics exams of students who have or have not visited the preliminary course differ. Looking at the overall random sample ($N = 280$), no significant deviation could be initially determined. However, if the results are divided according to the preliminary course groups, then for group B (Faculties of Chemical Engineering, Mechanical Engineering and Physical Technology, $N = 176$) a significant deviation ($p = 0.037$) is obtained with the Mann-Whitney U-test. In these faculties, the written exam results of the students who have taken part in the preliminary course are significantly better than those of the students who have not taken part in the preliminary course. In the other preliminary course group A (Faculties of Electrical Engineering and Computer Science and Energy – Buildings – Environment, $N = 104$) no significant deviation of distribution could be determined. A comparison of the average mark of school leaving qualifications showed no significant difference between the students either in group A or group B who took part in the preliminary course or not.

DISCUSSION

In winter semester 2013/14, the first measures of the Rechenbrücke project started. In the course of the investigation conducted, initial data was ascertained in pre- and post-tests and evaluated.

The difficulties experienced by new engineering students determined in the pre-test already confirm that the repetition of elementary calculation skills from mathematics lessons is expedient. Corresponding results are also indicated in the tests conducted by University of Applied Sciences Aachen. For each initial test, the students there attained an average solution rate of 40–50%, depending on the prerequisites (Greefrath et al., 2015). The solution rate of the entrance test which has been conducted for more than ten years at the Universities of Applied Sciences in North Rhine-Westphalia lies even below this (Knospe, 2011). A possible reason for this lack in basic skills might be the task of solving arithmetic problems without using a calculator which is unusual for students in North Rhine-Westphalia.

At this point of the project a definite answer to the second research question cannot be given as the results of the pre- and post-tests are not comparable due to the non-standardised procedure. The determined tendencies of a slight improvement for some tasks could however be an indicator for the success of the preliminary course. The cause of the deterioration for the result of task 7 must be further investigated. The introduction of prerequisites which must be observed prior to solving a fraction equation possibly had a negative influence on the previous, direct calculation of the solution. The positive correlation determined between preliminary course participation and performance in the Mathematics I written exam in some faculties can have diverse reasons, such as a higher level of motivation and willingness to learn among students who take part in a preliminary course. The quantitative numbers presented here are underpinned by the answers given in the questionnaire: Students state, that they feel better prepared for mathematics lectures after visiting the preliminary course. The evidence presented above gives reason to state the hypothesis that the preliminary course can reduce the difficulties in school mathematics of new students. Further investigations will test the hypothesis to answer the second research question.

During the search for causes for different effects in both of the preliminary course groups, differences in prior knowledge were sought and measured on the basis of the school leaving qualification marks. However, the research has not yet revealed any significant differences between the different groups. Both preliminary course groups were conducted by the

same lecturer in the same way; however, the subsequent mathematics activities in the various faculties are different in their content and in the way they are conducted. For this reason, the match between the preliminary course concept and the lectures is possibly not given to the same extent in all faculties. In the following execution of the preliminary course, audio recordings or written minutes could improve the monitoring of the course implementation.

Concerning the outcomes of written exams in mathematics in this investigation correlations between all variables and the Mathematics I exam have been found. Correlations between pre-test respective post-test and the Mathematics I exam can be explained by the basic skills which are needed to solve the items (e.g., that in Figure 1) used in the exams. An interesting result is that the final mark in mathematics seems to be no better predictor for exam results than the average mark from school leaving qualification or the points achieved in the post-test.

The modular preliminary course concept with the possibility of an individual compilation of preliminary course topics by the students provides great flexibility. To what extent this flexibility is utilised by the students and which effects this has on performance in the written exams will be investigated in the main study. Furthermore, the Rechenbrücke supports the first semester students for the transition from school to university through further, in part freely selectable measures. The results from the pilot study presented in this article indicate promising findings from the performance of the main study in the coming years.

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2. The catalogue is available for download here: <https://www.fh-muenster.de/rechenbruecke> (downloaded on January 29, 2014).

ENDNOTES

1. The Rechenbrücke has a run time from January 2013 until July 2016 and is financed by the “Bund-Länder-