AC 2012-5187: AN INTRODUCTORY MATHEMATICS COMPUTER COURSE AS A SUPPLEMENT TO A MATHEMATICAL BRIDGE COURSE

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An Introductory Mathematics Computer Course as a Supplement to a Mathematical Bridge Course

Abstract

At the beginning of their studies the majority of freshmen are overcharged in the transition from high school to academic education. The biggest continual problems appear in mathematics for engineering students or natural scientists. This is based on the high degree of abstraction and on the fact that the mathematical education takes place at the beginning of their studies. Thus, deficiencies become apparent at an early stage. In order to facilitate freshmen's transition from high school to the university the Department of Mathematics of Technische Universität Berlin offers a four-week introductory course to mathematics before the beginning of each semester. The course is addressed particularly to freshmen of engineering, natural sciences and mathematics. Additionally, a so-called mathematics computer course is offered with capacity for a part of the participants of the introductory mathematics course. In this two-week course the participants learn how to handle the Linux operating system, how to employ a computer algebra system (Maple) and they obtain an introduction to the scientific text processing system LaTeX. We investigated if the mathematics bridge course and the mathematics computer course lead to a better academic performance by the students in their later courses.

Introduction

Mathematical comprehension and proficiency are some of the most important utensils of engineers and natural scientists. Based on the high degree of abstraction of mathematics for most freshmen in engineering and natural sciences the biggest problems in transition from high school to university appear in their mathematics courses. Moreover, as opposed to high school, success at the university requires self-organized learning to manage the unusually high density of the syllabus: For example, topics like curve sketching are dealt with for several months at school, but at the university this is only a side note.

At large universities the extreme demands in mathematics are felt especially serious because the individual student easily gets lost. Therefore, students are recommended to discuss problems in teams and to work in teams to prevent this. This may be unfamiliar to students of colleges in the United States with special honor codes. Furthermore, because working in teams is typical for their future professional life, students need to have already been trained to work in teams at the university. Therefore, at German universities it is not unusual to hand in assignments by teams of two or three students.

Many universities are offering "bridge courses" or preparatory courses to bridge the gap between high school and university. At least at German universities, as far as the authors know, these are additional voluntary courses and they are intended as a repetition of the mathematics that (should) have been learned at high school[1, 2, 3]. Some courses are designed to give the freshmen the opportunity to discover their strength and weakness[4]. Additionally, there are courses where students have the opportunity to take the mathematics of the first semester before they enroll at the university[5].

Mathematics Bridge Course

In order to facilitate the transition from high school to university the Department of Mathematics of our university offers a four-week bridge course before each semester. In this course mathematics on the level of an advanced high school course is repeated. The course consists of a daily two-hour lecture and a two-hour exercise. Before the summer semester regularly 200-300 and before the winter semester 800-1000 freshmen participate in this course (see figure 1). Because of financial reasons recitations classes in small groups cannot be offered and assignments are offered but cannot be graded.

The course repeats the last five years of high school mathematics within four weeks. It starts with elementary topics like numbers and arithmetical operations and end with complex numbers rarely dealt with at high school. The main topics of the course are as follows:

- Numbers and arithmetic operations
- Fractions
- Powers
- Binomial theorem
- Elementary algebra
- Linear functions and linear maps
- Quadratic functions and quadratic equations
- Roots and radical equations
- Exponential functions
- Logarithm
- Euclidean plane geometry
- Trigonometric functions and trigonometric equations
- Elementary combinatorics
- Mathematical symbols, formulae and texts
- Elementary logic and mathematical proofs
- Functions and differentiability
- Maxima and minima
- Integral calculus
- Euclidean solid geometry
- Vector calculus
- Systems of linear equations
- Matrices
- Complex numbers

Only approximately 1/3 of the freshmen students in engineering, natural sciences and mathematics studies participate in the mathematics bridge course. Some reasons are a lack of time, especially for students coming from abroad or moving to Berlin, military service/alternative civilian service or internships that have to be completed before the enrollment. Therefore, the Department of Mathematics also offers an online bridge course[6]. This course was developed at the Royal Institute of Technology (KTH, Stockholm) and it is offered to all freshmen at Swedish universities. This course was translated to German (and English) and it

is offered at four large institutes of technology, among them three members of the TU9 German Institutes of Technology e.V., an incorporated society of the nine largest universities focusing on engineering and technology[7]. The online bridge course – as well as the face-to-face bridge course – starts before the official enrollment at the university. Therefore, users only have to register at the website, but there is no proof of future enrollment required.

Figure 1. Lecture Hall during the Mathematics Bridge Course.

Figure 2. Students working in the Unix Pool.

The Mathematics Computer Course

In addition to the mathematics bridge course, we offer a so-called mathematics computer course. This is a two-week course, offered to all freshmen, in particular students in engineering, natural sciences and mathematics. This is also a voluntary course which is attended by approximately 1/6 of all freshmen in these fields. Most of them (79%, see figure 3) at least also attend the mathematics bridge course.

Two participants each work together on one computer in the largest computer pool of the university, the Unix Pool (see figure 2). The mathematics bridge course (lecture and exercise) is held from 9 a.m. until 1 p.m. During this four-week course the participants of the mathematics computer course are working from 1 p.m. until 6 p.m. in the computer pool. For most of the students this is the first time they are working more than 8 hours a day, but this is a good opportunity to familiarize with academic life.

The mathematics computer course has been offered since 2005 with up to 200 participants before the summer semester and 400 participants before the winter semester. Most of the participants of the mathematics computer course attend several preparatory mathematics courses (see figure 3). 35% of the participants are female, 65% are male. This is an interesting fact because most of them are engineering, natural sciences and mathematics majors and there are only approximately 27% female students in these fields. It has been supposed that many male students cannot attend the preparatory courses because of the military service/alternative civil service. Since summer 2011 in Germany the military or alternative civil service is not obligatory any more, but the

female/male ratio of the participants has not changed. The reasons are not obvious and have to be investigated in the future.

In the two-week mathematics computer course the participants learn how to handle the Linux operating system[8], they learn the employment of the computer algebra system Maple[9, 10, 11] and they obtain an introduction to the scientific text processing system LATEX[12, 13, 14, 15]. Mathematics as a universal tool for users is the connecting component. In the course, exercises of the introductory mathematics course are addressed. A problem from the engineer's everyday life is to be solved as final assignment to which all knowledge obtained from the course has to be used.

The main reasons for the freshmen to participate in the mathematics computer course are as follows (winter semester 2011/12, multiple answers permitted):

- I want to repeat more mathematics. (50%)
- I want to learn new topics useful for university. (38%)
- My high school diploma dates back some time. (37%)
- I doubt my mathematical skills. (16%)
- This course is known to be helpful. (14%)

On the other hand, many students estimate their knowledge of the topics of the mathematic bridge course very high (see figure 4). Therefore, we assume that participants of the preparatory mathematics courses are eager to learn and repeat as much as they can before the regular courses start.

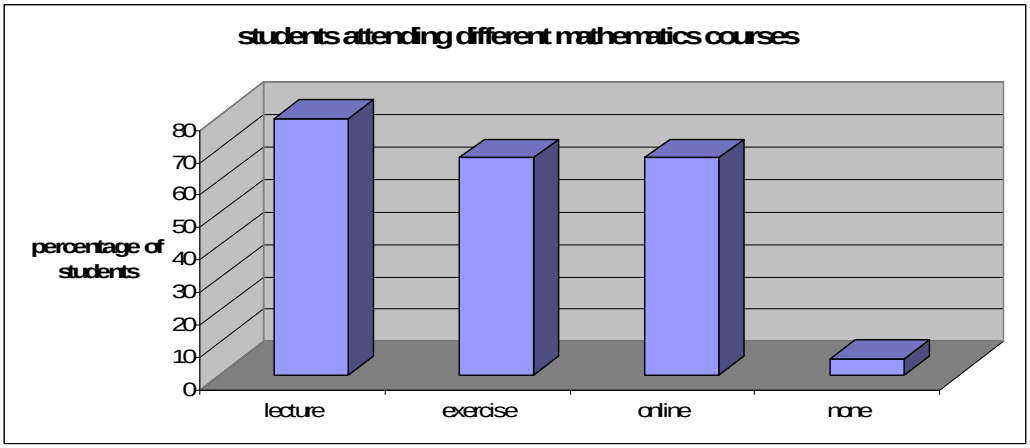

Figure 3. Percentage of students attending different mathematics preparatroy courses (winter semester 2011/12, multiple answers permitted).

In several mathematics courses the students are working in the computer pool of the Department of Mathematics which uses the Linux operating system. Therefore, we integrated a short introduction into Linux into the mathematics computer course. Additionally, many students are getting interested in the free operating system Linux during the course.

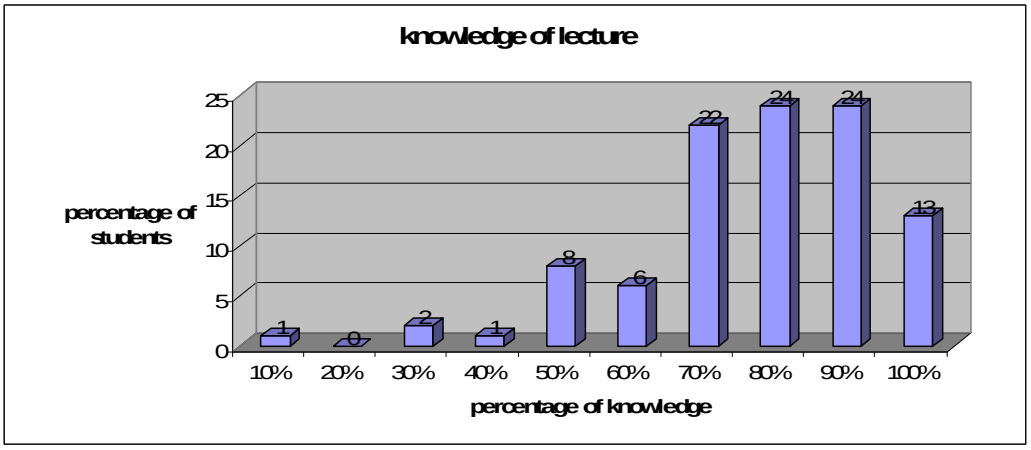

Figure 4. Knowledge of the topics of the mathematical bridge course (winter semester 2011/12, esitmated by students).

In the course we are using a computer algebra system (Maple) instead of standard numerical software (e.g. MATLAB[16]) even if the students will learn to solve engineering problems with numerical software packages in their future academic/professional career. However, at this early stage of their academic education we are emphasizing the mathematical comprehension which can be supported in an ideal way by a computer algebra system instead of numerical software. We decided to use the commercial computer algebra system Maple instead of open source software like Maxima[17]. Maple has a very convenient graphical interface (see figure 5) and offers the possibility to create interactive worksheets. This gives the possibility to concentrate on mathematics instead of programming. The graphical interface and the advanced work sheet mode of Maple is the reason why we decided not to use MATLAB which also does symbolic mathematics to some extent. Last but not least, we prefer Maple instead of the other leading commercial computer algebra system Mathematica[18] for reasons of price policy. Even though we use commercial software, we recommend to the students installing open source software like Maxima on their own computer.

For mathematicians, natural scientists and engineers LaTeX is the most used scientific text processing system, especially for technical documents, Bachelor, Master or PhD theses full of mathematical formula. Therefore, we integrated into the course a short introduction to LaTeX. Generally, this is the first time students come into contact with a non-visual oriented text processing system. For most participants the power of LaTeX is amazing and they are eager to learn more about the system.

The mathematics computer course benefits from the freshmen's interest in the computer employment and connects it with the imparting and above all independent exercise of mathematics. Pupils are used to (playful) handling of the computer indeed and also use it as a source of information and for communication. However, the employment as a tool for research and teaching is unfamiliar. Therefore, an emphasis of the course lies in conveying the employment of the computer as a tool for research.

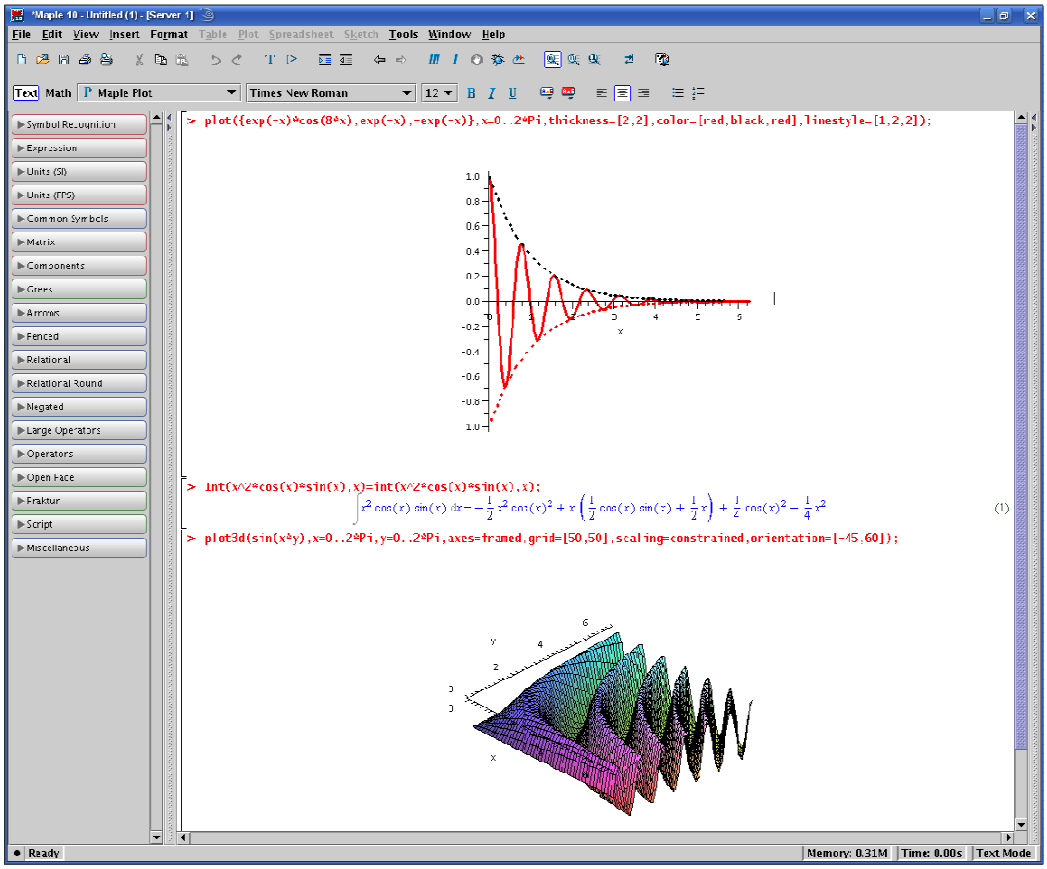

Figure 5. Screenshot of graphical interface of Maple

Evaluation

The mathematical bridge course and the mathematics computer course are both popular courses that are attended by several hundred freshmen each year. The mathematical bridge course is offered as an opportunity to repeat high school mathematics and to bridge the gap between the freshmen's mathematical skills and the high school mathematics needed at the university. Additionally, the mathematical computer course introduces the computer as a tool for learning and research in mathematics. Students are encouraged to think more on mathematical modeling of problems and to use software for routine calculations.

Even though both are voluntary courses and the participants are investing a lot of time it is an interesting question if there is evidence that both courses help to improve the students´ performance in later academic courses. This is a difficult question for several reasons: As mentioned above, the courses are held before the students are enrolled. Therefore, there is no access restriction to the lectures/exercises of the face-to-face bridge course and the online bridge course. There are also no assignments handed in that could be used to get data of participants of the face-to-face bridge course. The data of the online bridge course can be used to analyze how the participants perform during this course. But for data privacy protection reasons it is very

difficult to identify freshmen attending the online bridge course with students in later university courses.

Fortunately, since winter semester 2010/11 in the mathematical computer course we are using the moodle[19] course management system of our university to distribute course material like Maple work sheets. The mathematical computer course starts after the face-to-face bridge course. At the beginning most of the students – or at least one member of two students who are working as a team – already have their access data to use the campus network including moodle. Therefore, we have been able to compare the performance of students who attended the mathematical computer course (MCC) with students who did not take this course.

We selected three mathematics courses and an engineering course that are attended by most engineering students. The students have to take final written exams that are graded on a scale from 1.0 (excellent) to 4.0 (sufficient) and 5.0 (failed). The increments are 0.3 and 0.7 (1.0 and 1.3, excellent; 1.7, 2.0 and 2.3, very good, and so on). The following table shows the average grades of the students who attended the mathematics computer course (identified as mentioned above) and the average grades of all other students in these courses.

Table 1. Average grades of MCC students and other students for selected courses

Course	Average grades of students in MCC	Average grades of other students
Linear Algebra	2.53	2.92
Calculus I	2.71	3.14
Calculus II	2.55	2.95
Mechanics I/Statics	2.82	3.02

The results show that students participating in the mathematical computer course get significantly better grades in these mathematics courses (0.39 to 0.43) and in Mechanics I/Statics (0.20). As most of the students in the mathematical computer course also attend the mathematics bridge course this gives a hint that there is a correlation between these bridge courses and the performance in later academic courses. We could only identify approximately half of the students in the mathematical computer course because the students worked together in teams of two students and they therefore only used one computer account to access the course material. Thus, statistically there should be a bigger difference of the average grades between these two groups if all participants would be taken into account.

One should be careful to interpret these results. One should at least take into account that freshmen who are spending four weeks to pass voluntary mathematics courses might be more motivated than other students. These results have to be thoroughly analyzed to investigate if at least a part of these results is based on students´ motivation.

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Bibliography

1 W. Scharlau, Schulwissen Mathematik: Ein Überblick, 1995, Vieweg, Braunschweig.
2 W. Schirotzek, S. Scholz, Starthilfe Mathematik, 5th ed., 2005, B.G. Teubner.
3 E. Cramer, E., J. Neslehova, Vorkurs Mathematik, 2nd ed., 2005, Springer, Berlin, Heidelberg, New York.
4 D. D. Budny, Mathematics Bridge Program, Frontiers in Education, Vol, No 1, 1995, 2a4.11-2a4.15.
5 S. Jeschke, A. Kato, O. Pfeiffer, E. Zorn, Pre-Freshmen Students Gearing up with Early Bird, Proceedings of the 2009 ASEE Annual Conference, ASEE
6 http://www3.math.tu-berlin.de/OMB/
7 https://www.tu9.de/
8 http://en.wikipedia.org/wiki/Linux
9 A. Heck: Introduction to Maple, 3rd ed., 2003, Springer, New York.
10 Maple User Manual, Maplesoft, a division of Maple Waterloo Inc., 2011, www.maplesoft.com.
11 L. Bernardin, P. Chin, P. DeMarco, K. O. Geddes, D. E. G. Hare, K. M. Heal, G. Labahn, J. P. May, J. McCarron, M. B. Monagan, D. Ohashi, S. M. Vorkoetter, Maple Programming Guide, Maplesoft, a division of Maple Waterloo Inc., 2011, www.maplesoft.com.
12 D. E. Knuth, Computers & Typesetting, Volume A: The TeXbook, 1986, Addison-Wesley.
13 D. E. Knuth, Computers & Typesetting, Volume B: TeX: The program, 1986, Addison-Wesley.
14 L. Lamport, LaTeX: A Document Preparation System, 2nd ed., 1994, Addison-Wesley.
15 F. Mittelbach, M. Goossens, Der LaTeX -Begleiter, 2nd ed. 2005, Pearson Studium
16 MATLAB, http://www.mathworks.com/products/matlab/
17 Maxima, a Computer Algebra System http://maxima.sourceforge.net/
18 Mathematica, http://www.wolfram.com/mathematica/reference as listed in your bibliography.
19 moodle, http://moodle.org