

AC 2008-2703: EARLY BIRD - TEACH MATHEMATICS BEFORE PROBLEMS ARISE

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After receiving her M.Sc. in Physics at the Berlin University of Technology in 1997, graduating with distinction, Sabina Jeschke worked as an assistant teacher at the department for mathematics and natural sciences and earned her doctorate in 2004. Holding a scholarship from the German National Academic Foundation, she spent several months of research at the NASA in Moffet Field, CA. In 2000 and 2001, S. Jeschke worked as an instructor at the GaTech (Georgia Institute of Technology, Atlanta). Since 2005, Sabina Jeschke has been associate professor for "New Media in Mathematics and Natural Sciences" and director of the MuLF Center (Multimedia Center for "New Media in Education and Research") at Berlin University of Technology (TU Berlin). Starting in 2001, her Berlin group has been a driving force behind the development of multimedia technologies at the university, implementing multimedia educational elements in the education of undergraduate students, in particular for engineering students. In May 2007, Sabina Jeschke has taken over a full professorship for "Information Technology Services" at the University of Stuttgart and is also acting as scientific and executive director (CEO) of the "Center of Information Technologies" of the University of Stuttgart. Additionally, she holds a co-professorship at the TU Berlin, in particular targeted towards the co-ordination of the design of new curricula in technology-oriented studies and the coordination of several eLearning and eResearch projects.

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Akiko Kato studied physics, computer science and human medicine, and received both her Diploma in 1999 and her Ph.D. in 2004 in physics from the Berlin Institute of Technology. She wrote her dissertation in the field of statistical physics and quantum-thermodynamics. She has been doing research and teaching mathematics and physics at the same university since 1997, from 1997-1999 as a student assistant, from 1999-2004 as a research assistant and since 2006 as a postdoctoral researcher and assistant lecturer. Her recent field of research is focused on new didactic and educational methods in teaching mathematics and engineering sciences.

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Olivier Pfeiffer received his M.Sc. in Mathematics at the Berlin University of Technology in 2002. His thesis in numerical mathematics investigated "Error Control using Adaptive Methods for Elliptic Control Problems in Matlab". He has been working in several eLearning projects at the TU Berlin, beginning as a student assistant in the Mumie project - a platform using new pedagogical concepts to support teaching of mathematics for mathematicians, engineers and natural scientists - at the TU Berlin in 2001, as a research assistant at SFB609 in Dresden from 2002-2004, and is now part of the Team of the MuLF (Center for Multimedia in Education and Research) at the TU Berlin. In the past three years, Olivier Pfeiffer focused on the organization and coordination of the involved teams and contributed to several other eLTR related projects. He is also involved in the planning and application of future eLTR projects at the Berlin University of Technology and the local coordinator at the TU Berlin of the EMECW3 project. His research interest focuses on the development of interactive mathematical objects especially supporting the visualization of complex mathematics and physics related problems.

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Erhard Zorn studies Physics and Mathematics at the Berlin Institute of Technology. After receiving his diploma in Physics from the Berlin Institute of Technology he worked as a teaching assistant at the School of Mathematics and Natural Sciences. He spent the academic year 2000/01 at the Georgia Institute of Technology, Atlanta. Starting in 2001 he worked as a project manager and lecturer at the Berlin Institute of Technology where he is concerned with the mathematical

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EARLY BIRD – Teach mathematics before problems arise

Abstract

Mathematical knowledge and abilities are among engineers' most important tools and are often needed in introductory classes before the relevant topics can be offered in the mathematics classes. The compromise most often used by doing a digression in the non-mathematical classes is neither very satisfying for students and teachers nor is it especially successful.

We introduce the “Early Bird” project allowing beginners to use the often unused period between “Abitur” (German high-school graduation) and beginning of studies in the winter term for attending the mathematics modules of the first semester (Linear Algebra and Calculus I) before the official beginning of studies. With this project, students have the in-depth mathematical knowledge at their disposal considerably earlier. Students of engineering can reduce the duration of their education in mathematics by one semester by preponing the mathematics classes of higher semesters as well.

1. Motivation

Mathematics is one of the most important foundations for engineering. From the first semesters on a sound knowledge in mathematics is necessary for being successful in the basic subjects of engineering (e.g. mechanics, physics, thermodynamics etc.). Problems in topics using mathematics will occur whenever mathematical knowledge is needed that a thorough mathematical education can provide not until later. Because of the existing curricula it is not possible to realize a preparatory part of studies that is only devoted to the mathematical education. This also interferes with the legitimate wish of engineering students to identify with the actual engineering topics early and by that not to reduce the motivation in those fields of study that leave little space for the “actual” topic because of many service courses from other fields (not only mathematics). In practice the solution most often used is to do digressions that most of the time can only provide calculation rules that make a schematic treatment of special problems possible. This well-intentioned procedure is usually frustrating for students because they do (can) not understand the reasons for their calculation rules. Whereas every teacher in the mathematics service knows the situation, where students understand those recipe-like introduced concepts belatedly and ask the question why the actual facts have not been explained to them earlier.

2. The “Early Bird”-course

For at least some of the students that begin their studies with the winter term (about one third of the students begin their studies with the summer term) the time between Abitur and the start of the winter term offers a solution for this dilemma. Engineering students will attend (with rare exceptions) the modules Linear Algebra and Calculus I in their first semester. These modules can be offered in a concentrated version before the beginning of the winter term in the semester break before the actual enrollment. Because most of the mathematics service classes are offered every semester (except for one module for electrical engineers is offered in the summer term

only) it is possible for most of the engineering students to take the math classes of the second semester in their first and by this finish their mathematical education one semester in advance.

This course called “Early Bird” has been offered the first time before the beginning of the winter term 2006/2007. The total number of lessons is the same as that of both modules Linear Algebra and Calculus I together during a regular semester. This means that the course is not shortened but is only held within a shorter period of time. During that time the prospective students are only occupied with learning mathematics without the usual “distractions” by other university classes.

The regular modules “Calculus I” and “Linear Algebra” consist of two resp. one lecture/s of 90 minutes and one discussion session of 90 minutes per week. In the lectures the more theoretical subjects are presented. In the discussion sessions those subjects are deepened and practiced with the help of examples and problems for which the regular lectures normally leave no room. In the discussion sessions the students can actively take part (e.g. by doing calculations in front of the others at the blackboard) this is neither possible nor would it make sense in lectures with several hundreds of students. In most of the programs of study the students have to hand in written homework once per class and week. For reasons of capacity homework can only accepted and graded for groups of three students. Each module will be completed by an exam. To be admitted to these exams 50% of all points in the homework have to be reached. All of the teachers and tutors offer weekly office hours, also offering homework support.

In the following the setup of the “Early Bird” is described. For the entire course 9 weeks are necessary (compared to 16 weeks during the semester). During this time there will be one lecture of 90 minutes every weekday before noon. In the afternoon every student is attending a 60 minute discussion session. The number of students per discussion session is limited to 16 – with the teacher-student-ratio is much better than during the regular courses during the semester, the number of students in those discussion sections is 35 – 40.¹ Until the evening seminar rooms are at the disposal of the students so that they can do homework collaboratively in groups. Instead of the weekly office hours some tutors are present at anytime as contact persons. The lecturer and the assistant are offering regular office hours additionally.

At the end of every lecture a problem set that is short compared to the regular courses is handed out. This will be the subject of the evening discussion sections and is to be handed in two days later before the lecture. Students will work on this problem set in groups of two. The time between the morning lecture and the discussion session in the evening is long enough to allow a first glance at the problem set. The number of problems in each set is such that the total number of problems at the end of the course is the same as in both of the regular classes together.

The “Early Bird” course is completed by an exam for Calculus I and Linear Algebra each. “Early Bird” participants attend the same exams that are offered before the beginning of the winter term for students of the corresponding regular modules in the summer term.² By that a direct comparison between “Early Bird”-participants and Non-“Early Bird”-participants is possible. Some results are presented in section 7.

¹ Despite the fact that all lecturers agree on 20 students being the maximum number allowing effective lessons, for reasons of capacity the number of participants in the discussion sessions during the semester is 35–40.

² Early Bird-participants also have to qualify for the exam by reaching 50% of all achievable homework points.

Obviously in big classes with several hundreds of students per lecture having a direct contact between the lecturer and every student is impossible. Nevertheless also in discussion sections with 35–40 people this is an issue. Because homework has to be handed in groups of three students, it is impossible to see which students actually have done the homework.

Different from the regular modules during the semester, due to the better ratio of students and teachers it is easier to assure that the participants deal with the problems independently. In addition to the low number of 16 students in the discussion sessions and to the obligatory (for all courses of study) problem sets, the continuous and active participation in the discussion section is a prerequisite for the exam. To ensure that both students of each homework group are working on the topics continuously, both have to present results of solved problems in the discussion session regularly.

The test-exam in the second half of the course as a preparation for the regular final exam resulted from the participants' wish. For the participants this is the first exam at the university at all. During this exam students have the possibility to experience the situation, to get an insight into the usual progress and setup of an academic exam and last but not least to check their knowledge gained up to that point.

3. Comparison “Early Bird” vs. Regular Modules

Of all 45 lectures of this course, 30 are scheduled for Calculus I and 15 for Linear Algebra. These are the usual numbers for these topics during the semester. In Calculus I, differential- and integral calculus of one real variable is treated, Linear Algebra deals with vector spaces and linear structures up to the basics of the theory of linear differential equations. Because both modules are merged within the “Early Bird” course a strict separation of both topics is no longer necessary. This rather gives the opportunity to teach those in parallel (e.g. separated by weekdays). By that it is possible to cross-reference between the topics and to explain freshly introduced mathematical termini under different aspects in both fields. For example the concept of a linear map can be explained with the example of differentiation and integration at hands. This helps the student to develop a deeper understanding of mathematics and its connections.

The involved teachers perceived a very pleasant spirit during the course and the motivation of the students remained very high during the entire course. One reason for this could be that the participants spent their holiday time for studying voluntarily and so were more ambitious anyway, but the good ratio of teacher and students in the discussion sessions also contributed for sure.

We do not want to let unmentioned that the course was very strenuous for the teachers as well as for the students. The workload was very high so that it was necessary to respond with sensitivity to the prospective students' worries (“Can I do all these problems?”, “Will I finish this course successfully?” etc.). A barbecue session after the testing-exam contributed to the sense of community and made the common goal to pass the course clear.

Between freshmen students and teachers as well as among students a good climate developed, which rarely happens in such big classes. In comparison with students of the regular modules, the “Early Bird” participants performed outstandingly. Details for that can be found in section 7.

4. Organizational aspects

All participants applied at the TU Berlin but do not know if they will be admitted at the beginning of the Early Bird course. The choice of participants is done such that by all experiences the chance is very high that they will be admitted. The risk that some of the applicants will (can) not be accepted has to be taken by both sides. Nevertheless, the offer seems to be so appealing to the participants that they are willing to take this risk. On the other hand we believe that we can convince the applicants to start at the TU Berlin even if they are accepted at other universities as well. As a side-effect participants can see for themselves if the intended course of study suits them. A loss by dropouts is taken because it is better for the students too to see as early as possible if their intended study suits them or not. That is why we take the risk that it is possible for participants not to enroll at the TU Berlin after the course.

The usual number of participants of the “Early Bird” course was 350–400. This is about the usual number of students in one of the regular lectures during the semester. This means that no additional lecturer is required for offering the course. By that a concentrated course like can be held anytime without the requirement of additional staff. Only one of the regular parallel lectures and the associated discussion sessions need to be preponed and shifted into the semester break.

For the required better ratio of teachers and students special funds of the university have been requested because the high workload of the students was to be balanced out by an excellent support. In the future the department of mathematics has considered a better endowment with tutors anyway so that by then the course could be offered without further costs.

The “Early Bird” course has yet another positive side-effect: By redesigning a lot of study programs, among other things the switching to the (for the German academic education) new Bachelor/Master-system but also by the growing number of beginning students in the engineering sciences the number of participants in the modules “Calculus I” and “Linear Algebra” has grown so fast, that just in the winter-term up to 2.500 students have to attend these classes. There students attend separate “parallel” lectures that are scheduled not to conflict with the schedules of their further schedule [1]. The contents of all lectures are the same and up to three are taking place at the same time. For that the biggest auditoria of the TU Berlin are needed. “Early Bird” helps to reduce the numbers of students in the regular modules to “only” 2.100–2.200. For these up to five “parallel” lectures take place. Without “Early Bird” up to six parallel lectures would be necessary. By the number of needed seminar rooms, also the associated discussion sessions would be more difficult to organize were it not for “Early Bird”.

5. Socio-psychological aspects

For prospective students “Early Bird” offers an ideal opportunity to get to know life at the university in advance. The German academic system leaves a lot of freedom to the students in arranging their course of studies. Realization of their study goals of course requires a certain

degree of determination and self discipline. Many beginning students feel overwhelmed by the change from well-ordered school system to academic life. The situation is worsened at a huge university like the TU Berlin particularly by enormous freshmen lectures like “Calculus I” or “Linear Algebra” with more than 2.000 participants. The missing orientation and the distance of the teaching staff in a completely new environment with a plethora of studying opportunities and leisure time activities does not rarely lead to delays in the course of study or even dropouts. “Early Bird” participants can test campus life and their own work habits before the actual beginning of their studies on a voluntary basis. In such an intense course it is easier for them to get to know fellow students (from other fields as well) and to form study groups. By the better endowment with staff they will always find a competent contact person whenever difficulties occur. By all that “Early Bird” not only serves the purpose to teach mathematics in time but it also serve as a valuable orientational help for future students.

6. Criticism and Discussion

A few colleagues criticize the “Early Bird” course. Lecturers that teach the “regular” courses during the semester fear that only the less talented - or at least less interested - students will be attending their lectures and by that the standards in the mathematics-service modules that already are characterized as quite low will decline further. They feel confirmed by the better performance of the “Early Bird” participants.

The fluctuations in the exam results of the last years are too big to examine a decline of standards in dependence of missing “Early Bird” participants. Our opinion is rather that the success of “Early Bird” participants can be tracked back to an excellent ratio of teachers and students, a focused study of the mathematical topics and last but not least to the positive almost family-like environment.

We are convinced that in big classes like the mathematics modules of the first semesters for engineers a big improvement can be achieved by strongly improving the ratio of teachers and students like in “Early Bird”. Effects like the concentration of topics are not possible in the regular classes during the semester and might not be suitable for all students because a concentrated course also means a high workload for teachers and for students.

7. First Results

The “Early Bird” course was carried out very successfully for the first time before the beginning of the winter term 2006/07. The participants attended this 9 weeks course and afterwards took the same exams as students that attended the modules in the summer term and took their exams before the beginning of the winter term. This allows a direct comparison between “Early Bird” participants and “normal” students. The “Early Bird” students performed outstandingly well in both exams Calculus I and Linear Algebra. In Calculus I approx. 78% passed (compared to 54% of the Non-“Early Bird”-students), in Linear Algebra 89% of the “Early Birds” passed (compared to 73%). By that the passing rate was higher by a factor of 1.44 in Calculus I and a factor of 1.22 in Linear Algebra (see Figs. 1 and 2). The “Early Bird” course has been offered again at the beginning of the winter term 2007/08. Here the results of both exams were not as

good (they were done by a different lecturer than the year before). Nevertheless the success of the concept could be confirmed because with 1.45 resp. 1.16 about the same factors resulted.

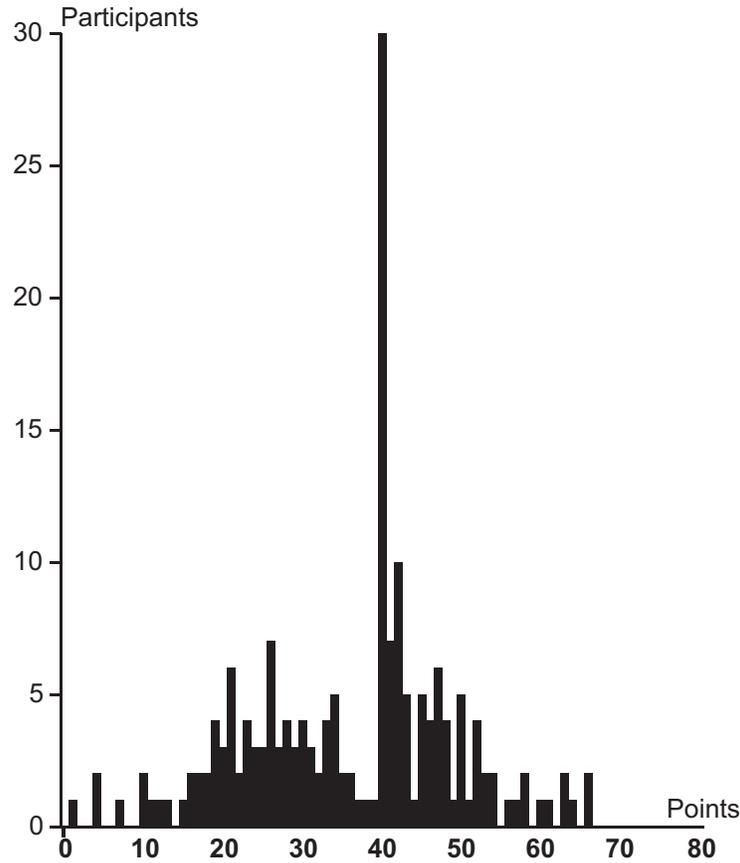


Figure 1. Calculus I exam (09.10.2006), 40 Points necessary to pass, Non-Early Bird-participants, 182 participants, 99 passed (54.4%)

Despite of being held in the summer term there were no difficulties to get teaching staff for the course. All teachers were freed from their teaching obligations in the subsequent winter term by teaching this class. In this way scientific assistants can use their free time during the semester for research. Tutors can use the free time for their studies, internships or study abroad terms, while staying employed at the university and getting paid as well. All of the lecturers/tutors enjoyed the family like spirit and the focused work with the students a lot. This was the reason for them to show considerably more commitment and dedication. In addition to the normal tasks and duties teaching staff voluntarily offered additional services like additional office hours, recapitulating-lessons for selected chapters or a studying trip during the week between the end of the course and the exams. Surely the high motivation on both sides, students and teachers is contributing to the success.

It would be interesting to investigate whether the participation in the “Early Bird” course affects the students’ success in the long run. We will do this after the next semester, when there will be enough results from later semesters.

Already now it is possible to see that this course is very popular. Before the first run a lot of effort had to be undertaken to inform about this opportunity. Viral marketing did a better part of this work in the second run: the Early Bird course before winter term 2007/08 has been recommended to most of the participants by friends and relatives. Because the endowment with staff is not unlimited only about 2/3 of the applicants could be admitted to the course. Especially students already enrolled that wanted to use this course as a revision course had to be rejected.

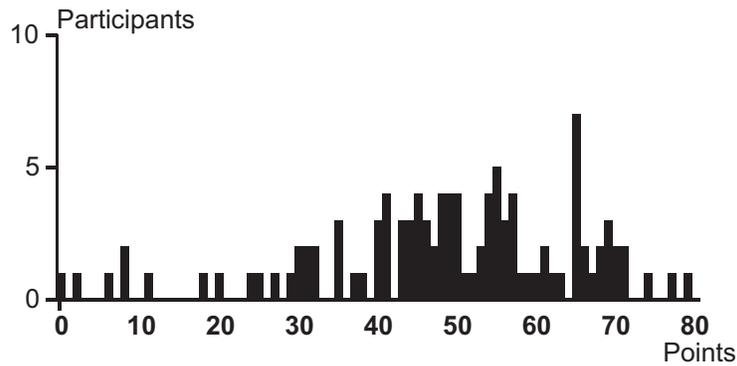


Figure 2. Calculus I exam (09.10.2006), 40 necessary to pass, Early Bird-participants, 106 participants, 83 passed (78.3%)

8. Conclusion

Altogether “Early Bird” was received very positively by freshmen students as well as lecturers/tutors. Freshmen appreciated the intensive support in very small discussion sessions; study groups formed collaborating more intensively than within the “regular” lectures. Teachers and tutors say that the atmosphere with very dedicated students in small groups is more pleasant than in the other courses. Nevertheless we should keep in mind that the course is very strenuous for all participants. For nine weeks lecturers and students are exclusively doing mathematics. Yet over 95% of the students said that they would recommend this class to others. In the end the excellent performance of “Early Bird” participants speaks for itself, where already the same performance as that of the regular students would have to be seen as a success because the students have the mathematics at their disposal when it is actually needed in other classes in the first semester.

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