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Yes, It's Possible – Online Mathematics for First-Semester Students

Abstract

Many first-semester students at technical universities of applied sciences have severe gaps in fundamental mathematics. These gaps lead to high drop out rates of students of mathematics and other important technical degree programmes, such as engineering mechanics, physics or electrical engineering. Heilbronn University has established a sustainable practice and assessment process to assist first-semester students in acquiring the basic mathematics knowledge required for their university studies. This process is based on an online mathematical learning and assessment tool. This paper shows the achievements of this approach after more than 2 years and 5 terms of experience. The authors are convinced that these methods can be successfully transferred to other universities.

Keywords

Personalized fundamental mathematics education, Adaptive online learning system, eLearning, eAssessment, Engineering mathematics, elementary students

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1 Introduction

Typical for the student profile in the technical courses of study at Heilbronn University (HHN), which has more than 8,200 students, is the ties that many first-semester students have to the region, whether through their place of residence or their parents' place of residence. As at many universities for applied sciences, at Heilbronn, approximately 60% of the first-semester students have a so-called *mittlerer Bildungsabschluss* (intermediate level education standard), often in combination with second-chance education programmes. The variation in the students' preparation means that there is little continuity in their basic mathematical knowledge. Despite their great motivation, it is precisely these students for whom their interrupted educations make getting started more difficult, as described by Hetze 2011. Initially, this affects mathematics education in the first semesters of study. However, it is also critical for the important course of study-related basic courses such as technical mechanics, physics, and electrical engineering.

Therefore, the goal was to improve the individual state of knowledge of the basic principles of mathematics using a new, course-accompanying media-based learning system. The aim was to take advantage of the openness of many first-semester students to using computers and the Internet with pictures, animations, and videos and to use this method for mathematics. Additional required attendance in the evenings or on Saturdays as well as the associated costs keeps many students from attending bridge or advanced training courses. The goal of the HHN pilot team is to reduce this additional work using a Web-based approach and to transform it into a valuable and individually-controlled time for practising basic mathematical principles.

The goals mentioned above led to an introductory project and subsequent regular operation. This article reports about the experience gained and the successes achieved over the course of five semesters.

2 Selection process and initial experiences

The requirements catalogue, selection process and evaluation of alternative media-based mathematical learning systems is described in detail in Daberkow et al. 2013 with the experiences in the first test semester. At the beginning of the introductory project in 2011, there were only a few online mathematical learning systems available that met the requirements of the HHN. The so-called subject-specific mathematics in the first lectures for electrical engineering, construction technology or technical mechanics requires basic calculation techniques, for example in the solution of fraction equations, root equations and terms, so that the mathematical learning system must have high functionality, especially in the basic principles (see Figure 1).

a $$\frac{1}{R_{ges}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Gesamtwiderstand R_{ges} bei einer Parallelschaltung dreier Widerstände R_1, R_2 und R_3

b $$d \geq \sqrt[3]{\frac{16 \cdot M_T}{\pi \cdot \tau_{Zul}}}$$

Mindestdurchmesser d einer kreiszylindrischen Welle mit der ertragbaren Torsionsspannung τ_{zul} unter Belastung durch ein Torsionsmoment M_T

Fig. 1 Examples of basic subject-specific mathematical requirements in the first semester of technical courses of study from Grote and Feldhusen 2011

Another requirement is the ability to integrate the learning system into the integrated learning, information, and work cooperative system ILIAS [Integrierte Lern-, Informations- und Arbeitskooperations-System] (Kunkel 2011). The ILIAS installation at HHN structures the modules of courses of study clearly for students in courses, groups, and exercises. Other requirements for the mathematical learning system were the possibility of examinations with the administration of examination participants as well as high functionality for the visualization of mathematical content (functions, geometry, value tables) which is important for engineer training .

The evaluation then led to a cooperation with bettermarks GmbH (bettermarks 2008), which has developed an award-winning online learning system for the individual advancement and performance improvement in mathematics up to the *Abitur*. A scientific-didactic examination of this online learning system, also in comparison to other mathematics learning systems, is available in Stein 2012. The online learning system offers more than 40 interactive input possibilities per formula, via colour markings, with graphs and geometry construction to functions and tree diagrams. User guidance is supported by so-called micro and macro adaptivity and an implemented learning network. Building on this, individual knowledge gaps can be identified and are reported to the user. A task pool with more than 100,000 tasks with great variety in their depth and breadth as well as a teacher centre for the administrative control of exercises and tests support professional use at a university (Speroni 2014).

As an example of the media-based mathematical support in the system, Figure 2 depicts the interactive construction of a linear function using 2 points from the topic area of functions.

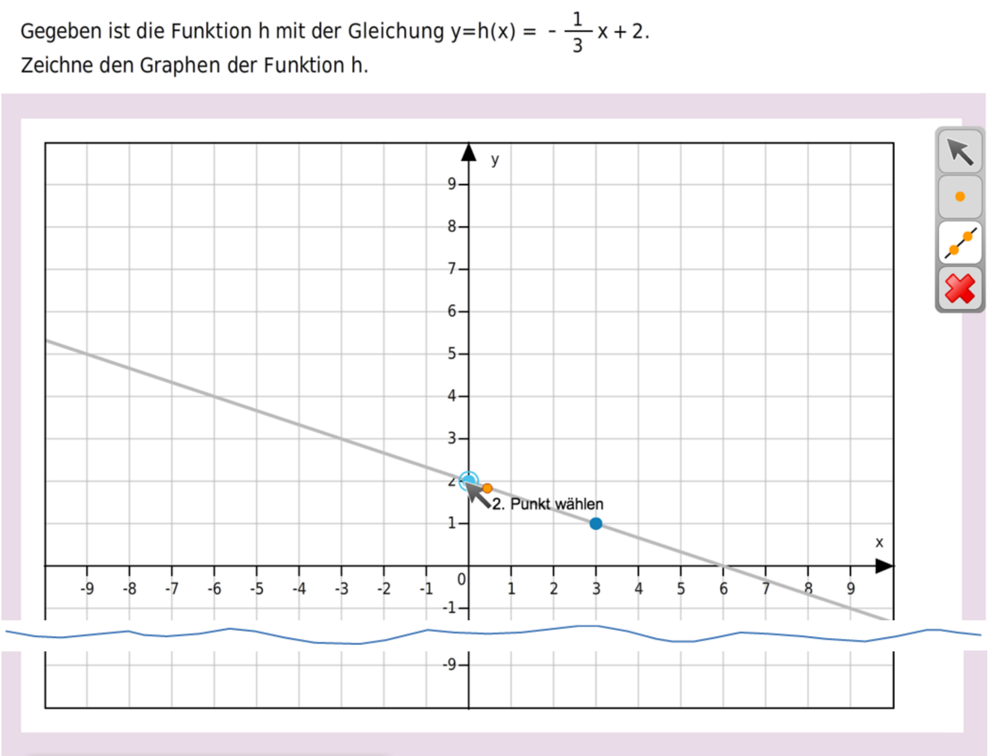

Fig. 2 Sample task with interactive construction of a linear function in the mathematics learning system

This example demonstrates the micro adaptivity of the online learning system. Micro adaptivity means that the student can initially display an aid for the construction of the straight lines. If the incline of the straight lines is constructed correctly but the axis intersection is wrong, the system detects this and the student receives a hint for second attempt.

Considered initially was that at the project start, the learning system only had content up to the 9th grade at the *Gymnasium* and in its approach, it was clearly designed as a learning system for school use. The integration of ILIAS and the mathematical learning system is then done via packages of a standard interface (SCORM 2013).

At the project start in the winter semester 2011/12 with 60 students from the "Robotics and Automation Technology" and "Electronics and Information Technology" courses of study, the mathematics experts of the HHN pilot team selected the tasks with the desired degree of difficulty from the learning system pool of approximately 100,000 tasks. In an on-site component, the students had to attend an introductory event and they could take a voluntary entrance examination. If they solved 60% of the tasks correctly, then they passed the test; otherwise they could take another voluntary completion test at the end of the semester. The entry and completion examinations were administered under supervision in the university's computer laboratory. On these agreed-upon dates, the system supplier guaranteed fault-free operation of the learning system.

It quickly became clear that the intuitive operation of the learning system required only a little support effort for the students and the support team. The long-standing suspicion of the teachers that many students are lacking basic mathematical knowledge was then confirmed after the entry test: 70% of the participants do not pass and should repeat the completion test. The close project supervision then demonstrated that a voluntary repetition of basic mathematical principles on the *Mittelstufe* level was only accepted by a few students. Similarly, the school-like approach of the learning system was rejected (for example, the selection of a school type, a school grade level, the required depiction of results as a mixed number as well as the use of the informal "you" with the user).

After discussions on the pilot team and with the system provider, initially a decision was considered to cancel the project and then measures were taken to make a last attempt at introduction in a later project phase.

3 Modifications to the learning system and in the introductory process

As the greatest focus of criticism, the school references in the learning system were removed. Similarly, it was possible to change the use of the informal "you" on the first level of the learning system. In the newly-modified system, in the upper left area of the learning system portal, the reference to the university is always present (see Figure 3).

Fig. 3 Mathematics learning system with school (lower left) and university approaches (top right)

In addition, for the selected target course of study "Automotive Systems Engineering", there was close cooperation with the examination committee and the university office responsible for teaching and quality assurance in its responsibility for guidelines and the basic mathematics examination was made mandatory for students. Without passing the basic mathematics examination, no approval for particular first semester examinations is given. In this course of study, only 37% of the students passed the entry test on the first try. The system, the selected tasks, and the implemented examination, exercise, and individualised support processes were well-received in the summer semester 2012 and motivated the introduction team to continue the project in the following semester with an expanded group of participants.

4 Modifications to the learning system and in the introductory process

Meanwhile, for regular operation, content up to *Gymnasium* grade 10 was available in the learning system; in 65 minutes per test, 4 tasks from 5 topic fields "fractions", "functions", "terms", "equations" and "trigonometry" must be solved.

For each course of study of the courses of study now involved (6 with a total of 260 students in winter semester 2012/2013, 3 with a total of 80 students in summer semester 2013 and 9 with more than 400 students in the winter semester 2013/2014), a responsible professor from the appropriate examination committee assists with the integration of learning system activities into the schedule and the curriculum. The learning system is available for students starting in the second week of classes. In the fifth week of classes, the first test is conducted; three weeks before the start of the examination period, there is a second chance to pass the test. The automatic and immediate correction of examinations by the learning system is an unbeatable advantage for teachers and students.

In regular operation, it has been confirmed that only approximately 40% of the students pass the entry test on the first try. The schedule-oriented learning behaviour of the approximately 60 students who repeated the test in summer semester 2013 shows (Figure 4).

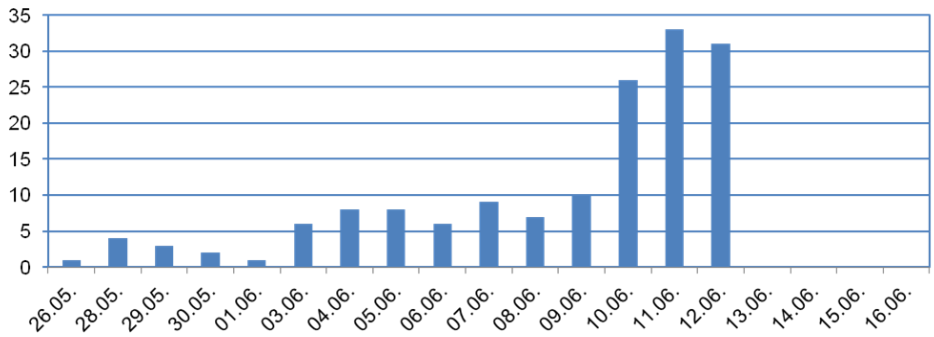

Fig. 4 Learning activity (number of users per day) before the second mandatory completion test in the summer semester week 11 on 6/13/2013

The use of the learning system is accompanied continuously by surveys based on the "Technology Acceptance Model 2" of Venkatest et al. 2003. Despite the extra work, in the accompanying student survey, the mathematical learning system and the support processes were evaluated largely positively. In the winter semester 2012/2013, 74% of the 185 people surveyed agreed completely or mostly that practising mathematics with the learning system is a good idea. Those surveyed in the summer semester 2012 to summer 2014 give the learning system grades of 2.7, 2.3, 2.2, 2.7 and 2.5. For the students' personal impression, see, among others Junge Wissenschaft 2013.

5 Summary and conclusion

A new media-based training system for basic mathematical principles was established successfully at the University of Heilbronn with a professional online learning system. The goal of closing gaps in students' basic mathematical knowledge due to the transition from school to university was achieved. At the latest after the second mandatory repetition, more than 95% of the first-semester students passed the test, thus showing that they had filled the gaps in their basic mathematical knowledge. General aspects and encouraging factors in the opinion of the authors are:

- The attractiveness and content as well as the didactic design, stability and integration possibilities of the learning system
- An individualization of personal learning content, of the place of learning and of the learning times thanks to the learning system
- The economical automatic correction and repeated usability of exercises and tests and
- The readiness of the learning system provider to integrate the university's requirements from learning and examination operation cooperatively into future versions of the learning system.

Bridge and advanced training courses in mathematics are also offered as on-site courses. These courses were attended only by a portion of the students, exactly like the media-based basic mathematical principles course that is not mandatory, . The authors' thesis is that precisely those students are frequently not reached who mistakenly assess their basic knowledge as sufficient.

eLearning and eAssessment are interdisciplinary in terms of subject and organization (Klimsa 2011). The authors therefore believe that additional important factors for the successful use are:

- The constructive cooperation of computer and media centres, examination office, the offices for teaching and quality management with the people doing the teaching
- The accompanying demand for basic mathematical knowledge also for basic technical subjects, as well as
- The students' obligation to take the basic mathematical principles test directly or indirectly via the SPO.

If one of the above-mentioned university offices is not integrated into the introduction process or if for reasons of competence or capacity it cannot assist or is even opposed, then a successful implementation is very difficult and practically impossible.

6 Forecast and open questions

The basic mathematical principles training with the online learning system is currently being continued in regular operation in the summer semester 2014. The scope and level of the exercises and test up to the *Gymnasium* 10th grade level is regarded as sufficient for the basic mathematical training of calculation techniques. The online learning system can also be used even when students are still in school or before the start of the first semester. The announced expansion of the system to include the *Abitur* material will then expand the use of the learning system for mathematics education with the material for the first semester.

According to the experience gained over five semesters, it has become clear that approximately 60% of the students in technical fields have insufficient knowledge of basic mathematical principles. Apparently, schools can frequently no longer teach these principles or breaks in students' individual educational paths do not permit this.

The authors are convinced that with the methods described here, which can be transferred to other universities, it is possible to ease the transition from school to university. Their belief is that the successful elimination of gaps in basic mathematical principles of MINT students in their first semester can only be achieved with a mandatory process, that is, the combination of eLearning and eAssessment.

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