Knowledge Controlled Mathematical Coaching
Strategies and Results of a Personalized Blended Learning Approach

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Abstract: The mathematical competence of first year students is an important success factor at least for technical studies. As a significant percentage of students do not have sufficient mathematical skills, universities often utilise blended learning courses to increase these skills prior to the start of studies. Due to the diversity of students and their educational backgrounds, individual strategies are needed to achieve the necessary competence for successfully managing their studies. This paper describes our approach at the University of Applied Sciences Ruhr West, where we are using personalized blended learning concepts based on the measurement of individual mathematical competences at the beginning of a coaching process. This is used to gain a better matching between the individual learner level and the adapted learning concepts. We combine individual presence learning groups and a personalized e-learning environment. This environment is adapted based on mathematical skills of each student. It uses individual learning advices, short-term optical feedback and up to date e-learning material in a Moodle-based LMS (learning management system). The coaching concept is approved by the results of summative and formative evaluations.

1 INTRODUCTION

In recent years, university professors in technical studies report decreasing mathematical skills and an increasing diversity of their educational classes.

Since 2002 the mathematical skills at the Universities of Applied Science in North Rhine Westphalia have been tested. The mathematical competence has been evaluated in a standardized mathematical test carried out on the first day of their university education since then.

Ten basic mathematical subjects (e.g. solving equations, quadratics, powers and logarithms, linear equation) have to be solved.

The average value of solved questions is shown in column three of Table 1 (Knospe, 2012).

The already disappointing results of 2002 are continuously getting poorer.

The approach described here utilizes an individual adapted mathematical coaching for each student in order to improve and equalise the qualifications of all students before the beginning of their university education.

Table 1: Results of math-examination before the start of studies.

Year	Number of participants	Number of points (all participants)
2002	2936	3.99
2003	3240	3.86
2004	2741	3.52
2005	1626	3.65
2006	2151	3.66
2007	2593	3.51
2008	2941	3.54
2009	2565	3.86
2010	2493	3.28
2011	3508	3.27

A maximum of 10 points are possible

This paper starts with a section about related work and continues with a description of the architectural approach and detailed information about the implementation, shows results of the evaluation of the system described and concludes with an outlook on planned future work.

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2 RELATED WORK

In a blended scenario, our approach combines an online learning course and presence courses that are adjusted to the results of a mathematical test. (Schäfer et al., 2012).

The online course is developed due to the approach of the ARCS-Modell of motivational design by John Keller (Keller, 2010). It uses different elements to gain and keep the attention of the students and to increase the satisfaction, as these are main factors of learner motivation.

We use several concepts of personalized feedback to keep motivation and support the learning outcome. This is similar to concepts of Saul and Wuttke (Saul and Wuttke, 2011). Regarding the results of Jarvis and de Freitas (Jarvis and de Freitas, 2009) on the effects of in-game feedback to the learning transfer improvement, we are using similar feedback mechanisms. In a first pilot study we enriched our interface with a humanoid avatar to improve learning effects as evaluated by Ayad (Ayad, 2010). The learning design considers aspects of diversity as shown by Bhattacharya and Hartnett (Bhattacharya and Hartnett, 2008). To improve the quality of the coaching concept it is embedded in a quality improving process based on a modification of the PDCA cycle (Deming, 1986).

3 ARCHITECTURAL APPROACH

The central idea of our approach is to improve the matching between the individual knowledge of each student and our online and offline teaching strategies. Therefore, each student does a mathematical test with 48 items out of fifteen topics as shown in Table 2.

Table 2: Topics of the mathematical test.

Topic	number of items
Fractions	3 items
Arithmetic with powers and radicals	3 items
Logarithm laws	2 items
Transforming equations	3 items
Solve quadratics	1 item
Build inverse functions	3 items
Elementary power and logarithm values	6 items
Pythagorean theorem	1 items
Definition of trigonometric functions at the triangle	4 items
Drawing of functions	9 items
Symmetrie of functions	2 items
Unit conversions	2 items
Elementary derivatives	5 items
Elementary integrals	3 items

The results are stored in a database and used to adapt the online and presence courses. Further information is presented in (Schäfer et al., 2012).

In order to design the presence courses three clusters of different ability levels are built. Students with low abilities have courses with a duration of three weeks starting in small groups with less than ten participants. Medium-level student courses will take two weeks while high-level student courses will last only one week. An overview is presented in Table 3.

Table 3: Presence learning group arrangement.

Group number	Student ability level	Maximum of students in one group	Duration of lessons
1	low level	10	3 weeks with 6 hours a day
2	medium level	20	2 weeks with 6 hours a day
3	high level	35	1 weeks with 6 hours a day

New students have to complete the courses weekly to prevent a separation in different learning groups corresponding to the ability levels. Students with low-level abilities are starting in small groups of 10 participants. After one week students with medium abilities join these groups up to a maximum of 25 participants. They are starting again with the same mathematical subjects, but quicker.

One week later, students with high-level abilities complete the courses up to 35 participants and the whole course starts again with the same subjects but even quicker.

The advantage of this is that the students with lower abilities had the possibility of repeating the same subjects several times. The learning velocity of students with higher abilities is adequately taken into account. We prevent a separation of students due to their different skills in the beginning because all students should recognise an equalized state of knowledge of the other participants in their course.

The online-learning course starts prior to the presence courses and it can be attended additionally. The course is adapted for every student. The results of the mathematical test are taken into account for a dynamic generation of personal feedback and for giving learning advice. The feedback is given with textual and graphic analysis, symbolic and textual learning advice. Due to the motivational design by John Keller, screencasts are used to get attention and simple mathematical tests with optical feedback are used to keep attention, to show the learning enhancement and to support confidence and satisfaction. Like in serious games the personal aim is to get as much positive optical feedback as possible.

The adapted blended learning design as shown above is summative and formative evaluated. Due to this the learning outcome proven and structured feedback is available to optimise the whole coaching process.

4 IMPLEMENTATION

The mathematical coaching was developed in the year 2010 and it was used with 335 students in the year 2011. After a formative evaluation with the result of an overall good feedback but a less good acceptance of the online learning course (Schäfer et al., 2012), the motivational elements were enhanced. In the year 2012, more than 600 students took part.

The mathematical test of each student was done as paper and pencil test. Here, an anonymous number and the email-address were collected to be able to send necessary information about the organisation of the presence and online courses. The results were stored in an SQL-database being part of the learning management system (LMS). Moodle (Moodle Development Team, 2012) was used as LMS.

Twenty teachers in three locations have done the presence courses after a professor of the university instructed them. Clustering students through competence and study path did the matching. A homogenies cluster with a teacher of the same background/similar degree was built.

An individual mail with the account data to the LMS, the time and place of the best matching mathematical courses was generated and distributed. The online mathematical course combines an all-embracing amount of learning material with a pedagogical and motivational concept to improve the usage of this material and the learning outcome. The LMS-design is based on the university corporate design and enhanced with many graphical and interactive elements. The front page is shown in Figure 1.

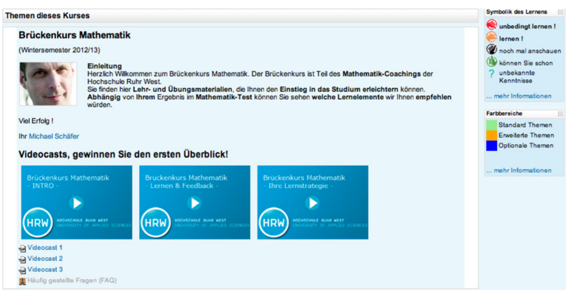

Figure 1: Front page of the mathematical online course.

It gains attention by personally addressing the student and by using motivating screencasts (Figure 2), which reflects the important of mathematical knowledge and guides the students through the next steps.

Figure 2: Screen casts as motivational elements.

They are invited to look at their personal test score as starting point for their own self-regulated learning concept.

As shown in Figure 3 the students can see their own score, the average score of all students and the expected score the university teachers have. For simplicity reasons, the scores are clustered by topics equal to Table 2.

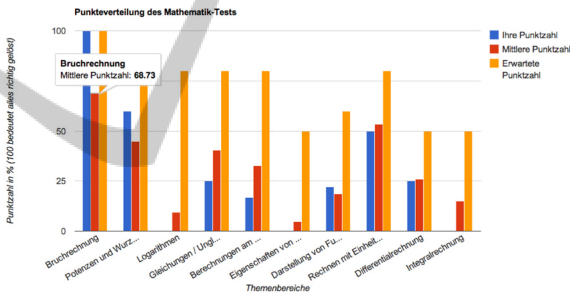

Figure 3: Personal math test result (Blue (first column) – own score of the student (depending on Moodle user), Red (second column) – average score of all students, Orange (third column) – expected score by teachers).

Having had a look at this first feedback, the students are invited to watch the second screencast about learning and feedback (Figure 2). Here they are informed about the feedback symbolism like for example the thumbs to reflect the results of the mathematical test in the current subject. Like the good knowledge of the student with the green thumb up at the top of Figure 4. After reading these explanations the students are guided to pass the first learning element and to do the first mathematical self-test.

A graphical rating scale gives them feedback on their success and the students can prove this by doing a second similar test.

An example is shown in Figure 4.

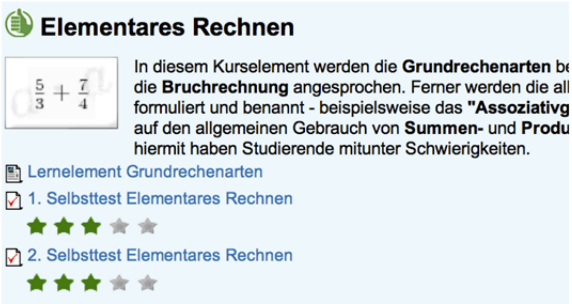

Figure 4: Feedback elements in the online course.

To enhance the engagement and the average length of course-usage an avatar is embedded. This virtual coach, implemented as 3D humanoid character, is used to give feedback and learning advice. Different implementations were evaluated. On the one hand, a lean design of the automotive sector as shown in Figure 5 with text-to-speech translation, which could easily be used for dynamic interactions (CharAt, Version 1.0) was tested. On the other hand, pre-recorded but realistic 3D animated humanoids with synchronized audio from voice-over artists were tried.

Figure 5: Alex as virtual coach in the online course.

This was topped off with short mathematical tests at the end of each week in the presence course and a mathematical test at the end of the coaching process, which is equivalent to the mathematical test done before the coaching was started.

5 EVALUATION AND RESULTS

Three different data sources are used for evaluation. Firstly, it was the log-data of the LMS to prove the usage of the online mathematical course.

Secondly, the summative evaluation of learning outcome based on the mathematical tests before and after the coaching was used.

Thirdly, the formative evaluation one month after the end of the coaching to evaluate the whole system was taken into account.

5.1 Log Data

An anonymous ID and an email address were collected with the mathematical test done in the beginning. Due to data privacy policies it was not allowed to use the data from matriculation. With this data, 613 individual mails with the accounts to the online course were generated. 32 mails came back with failure notices. About 50 mails were suspended to the spam-folders of the recipients by one email-provider. We suppose that a significant part was not read, because of the communication shifts from email to other channels like social media platforms.

In the online course 493 students watched their personal result as shown in Figure 3. The first videocast was watched by 191 students (1200 page views), the first learning element (elementary calculation) was used by 286 students, the second from 282 (powers and radicals) students, the fifth (function) was only used by 149 students. The usage of selftests have the same tendency from 155 students using the first selftest to 24 students using the eleventh selftest.

5.2 Summative Evaluation

In the beginning n=613 of all new students took part in the voluntary mathematical test. This is only a part of all new students (N=893), because the matriculation was possible until the first day of studies. The information about the mathematical coaching and the account to the online course were sent to the students one month prior to the start of studies and the presence course started three weeks before the studies began.

5.2.1 Results before Coaching

Out of 48 items an average value of AVG=13.70 items were correctly solved with a standard deviation of SD=8.82.

5.2.2 Results after Coaching

After our coaching the students could pass another mathematical test with 48 equivalent items (n=132). The results are based on a paired-samples t-test.

The average value of correctly solved items was AVG=28.48 with a standard deviation of SD=7.31. Depending on the kind of eligibility of university admission, the following differences between the different groups are to be found:

a) General eligibility with advanced mathematic course
n=41, AVG=31.90, SD=8.71

b) General eligibility with basic mathematic course n=37, AVG=28.51, SD=8.07
c) Subject-linked eligibility n=50, AVG=26.20, SD=8.69

5.3 Formative Evaluation

A formative assessment is done one month after the studies start to evaluate the usability, acceptance and performance of the coaching-system. The survey consists of 27 items with 12 different dimensions. The first evaluation in 2011 was only done with a small part of the participating students (N=49). First of all we were not sure, if a mathematical test, before the studies are starting, will be accepted. With an average value of AVG=5.42, a standard deviation of SD=.93 and a median of SM=6 the students seem to accept the test as reasonable. Visiting the presence learning courses was profitable for the students with an average value of AVG=5.84, a standard deviation of SD=1.25 and a median of SM=6. In a 5-level-Likert scale (Likert, 1932) the students estimate the influence of the small group-sizes with an average of AVG=1.7 and a standard deviation of SD=1.37 (1: very positive, 2: positive...).

For the question, if using the e-learning platform was profitable to them, the students estimated with an average of AVG=3.74, a standard deviation of SD=1.39 and a median of SM=4. So only a slightly positive result was measurable. Whereas the visiting of the presence-learning course in combination with using the e-learning platform was profitable for the students with an average of AVG=4.93, a standard deviation of SD=1.47 and a median of SM=5.

The overall feedback for fitting the demands of each student, self-observed learning effects and helpfulness for the first year courses was positive. We used these results to improve our online-system as shown before.

6 CONCLUSIONS AND FURTHER WORK

The knowledge controlled mathematic coaching concept was successfully implemented. The summative evaluation shows a significant increase of the mathematical competences of new students prior to the beginning of their studies.

We plan to use our results to further enhance the concept to improve the mathematical competence of the students and the technical implementation. The adaption of e-learning material, the personalized feedback and the arrangement of learning groups depending on the students' competence have positive effects on the improvement of current math skills of first year students. The enhancement through avatars seems to be promising.

In conclusion, this paper presented the implementation of a learner centred adaptable blended learning concept. The mathematical coaching significantly improves learning effects. These effects are controlled by summative and formative evaluations. Some efforts of future work are still necessary in order to enhance this concept and optimise its implementation.

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