Biehler, R., Fischer, P. R., Hochmuth, R., & Wassong, T. (2011). Designing and evaluating blended learning bridging courses in mathematics. In M. Pytlak, T. Rowland, & E. Swoboda (Eds.), Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education. CERME 7 (pp. 1971-1980). University of Rzeszów, Poland. hal-02158191

DESIGNING AND EVALUATING BLENDED LEARNING BRIDGING COURSES IN MATHEMATICS

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Varying mathematical skills, rising dropout rates and growing numbers of first year students confront the universities with major organizational and pedagogical problems. This paper describes an innovative way of teaching and learning that claims to improve this situation by specific bridging courses particularly including self-diagnostic e-assessment and supporting self-regulated learning. In order to give an overview of our whole bridging-course programme we will discuss our material with regard to content-related and pedagogical aspects as well its integration in various course scenarios. Focusing on selected results of an accompanying evaluation study we will finally substantiate the acceptance and success of our courses and highlight some interesting findings regarding our learners.

Keywords: bridging courses, eLearning, blended learning environments.

INTRODUCTION

The transition between school and university studies is a difficult one. The gap between school and university seems to be larger in mathematics than in other subjects (cf. Gueudet, 2008, Bescherer, 2003, de Guzman, 1998, Holton, 2001, Tall, 1991).

In 2003, the project VEMA – "**V**irtuelles **E**ingangstutorium **Ma**thematik (Virtual Entrance Tutorial for Mathematics) (http://www.mathematik.uni-kassel.de/vorkurs) started the development of multimedia resources primarily for supporting the pre-term bridging courses, which are intended to bridge this gap. VEMA was initiated at the University of Kassel and was extended to the Universities of Darmstadt and Paderborn later on. During the years the project extended its concern and redesigned the whole pre-term courses by new course scenarios that better integrate the multimedia learning material into the course. The material as well as the course scenarios have been continuously improved taking into account our yearly experiences and evaluations.

THE INTERACTIVE MATERIAL OF VEMA

The content of the VEMA-material

In order to support students to individually recapitulate certain topics we decided to structure the content into small learning units called "modules". Each module essentially concentrates on one mathematical topic. In its latest version the learning material contains six chapters: "Arithmetic", "Powers", "Functions", "Higher Functions", "Analysis" and "Vectors". On average each chapter has about 10 modules. The clear module-structure supports self-regulated learning and helps teachers in choosing content suitable for the field of study of their students.

Structure of a learning unit

We chose a well-defined and consistent structure for all modules, i.e. each module consists of identical types of *knowledge units*. This structure helps learners in their navigation through the material, which is further supported by the layout of the interactive book: There are two navigation frames. One enables learners to choose the modules to which they like to switch and the other enables selecting the different units of a chosen module by clicking on the corresponding icons.

The structure of a module mainly consists of the units: *overview*, *introduction to the domain*, *info*, *Info/Interpretation/Explanation (IIE)*, *application*, *typical mistakes*, and *exercises*. Before and after learning with a module, learners can perform a *diagnostic test* to assess their knowledge of the domain.

i. The *diagnostic pre-test* contains 4 to 5 exercises and gives the opportunity to the students to test their pre-knowledge concerning the content of the module. After a student has performed all tasks, the system automatically corrects his answers and provides feedback in form of a score for each exercise and for the test as a whole, a model solution, an individual feedback on his mathematical competencies and provides learning advice for further working on the module. With this individual feedback the students are supported in structuring their learning.

ii. Then the modules start with the *overview* unit, which essentially consists of a list of the major topics and learning goals.

iii. The second unit is called *introduction to the domain*. It uses discovery-based, inductive and exemplary approaches to familiarize the learner with the content. We also support the knowledge construction process by interactive exercises: learners have the opportunity to make mistakes, to withdraw them and to recapitulate the task until finding a correct solution. The content is presented to learners on a concrete level, with visualizations and references made to their assumed previous knowledge.

iv. The third *info* unit lists the definitions, theorems and algorithms of the module. These are the central concepts of the module. The *info unit* presents the content on an abstract mathematical level, the pure definitions, theorems and algorithms are presented without examples or exercises.

v. The fourth *IIE* unit (*Info / Interpretation / Explanation)* repeats the central definitions, theorems and algorithms of the *info* unit. A network to other concepts is built. Illustrations, concrete examples and explanations are added. In case of theorems one can find plausible arguments and/or proofs for their correctness. The learners also find interactive exercises, flash-films and animations they can interact with and which help them to developing a deeper understanding of the concepts. Since the learners can look at the concepts from various perspectives the memorisation of knowledge is supported, too.

vi. The fifth unit is called the *application* unit: Here such applications inside and outside mathematics are presented that show the connection of the actual domain to other mathematical and non-mathematical domains. This unit may contain examples e.g. from engineering contexts that are relevant for the engineering students but may be also relevant for other students to see the practical relevance of mathematics. The inner-mathematical applications are used to connect the definitions, theorems and algorithms within mathematics.

vii. The sixth unit is called the *typical-mistakes* unit: In this unit erroneous argumentations or solutions are presented to the learner, who is invited to find the mistakes, to correct them and to explain possible reasons for them. These exercises are provided to train the learners' diagnostic competencies and to depict misconceptions in order to avoid them in the future. The learners can check their answer by comparing to a correct argumentation or solution. For future mathematics teachers this is important for training their diagnostic competence (cf. Wittmann 2007).

viii. The last unit is the *exercises* unit: This unit is important for the learners for checking their understanding of the topic and to give opportunities for practicing the concepts. For each exercise a model solution is available to compare own solutions with. These model solutions can also be used as hints for getting an initial idea or for helping when the solution process gets stuck.

ix. The *diagnostic post-test* has the same structure as the diagnostic pre-test. Its idea is to give the students the opportunity to check their performance after having worked on a module. The diagnostic pre- and post-tests also aim at the elaboration of the students' abilities in self-regulation and self-evaluation, which are major factors for successful learning (Ibabe & Jauregizar, 2010).

TYPES OF BLENDEND LEARNING SCENARIOS

For our bridging courses we combined self-directed and externally-regulated learning types of instructional formats (cf. Niegemann et al., 2008, p.66). Both formats have their justification in the specific case of bridging courses: on one hand learners are new at the university, so they have to acclimatise themselves with the new learning environment. Here attendance phases can help them to familiarize before the terms start. On other hand learners at university level have to be more self-directed in their learning than at school. Here eLearning phases can help to adapt their learning behaviour (cf. Mandl & Kopp, 2006). For our bridging courses we developed two different blended-learning course scenarios: a course scenario with an extensive attendance part (P-course) and a course scenario with an extensive eLearning part (E-course). When registering to the bridging courses each learner can freely choose between these types according to individual preferences.

The P-course

This course scenario is structured and led by the teacher while the learner has fewer opportunities for self-regulated learning. The course lasts 4 weeks; each week consists of three days with attendance at university with three hours of lectures and two hours of practice-session each. The remaining days are free for individual learning and homework. This homework consists of two parts: one part has exercises on the topics that were taught in the lectures and another part has specific tasks for individual working on the modules, aiming at recapitulating or preparing content for the next attendance day. Some of the diagnostic tests are available and recommended to the students.

The E-course

This course covers 4 weeks with 6 days attendance at the university. The remaining time is to be spent for online learning. The first week starts with one or two orientation days, where the learners are introduced to the learning system and course material and get advice how to learn with the material. The first modules are presented by means of lectures. Later in the course there is only one attendance day at the end of every week. The learners have the opportunity to ask questions about the content in the first part of the morning session and can pre-select the topics for the lectures in the second part of the morning. The afternoon is devoted to small group learning with exercises related to the content of the morning lectures. The small group work is supported by a tutor.

The rest of the learning time is free for learning with the online resources. Questions that come up in this process can either be asked and discussed on the next attendance day, posted in the forum of the learning platform or posed to the human online tutor, who is available during all normal working hours, including opportunities for online chatting. Moodle supports the learners in choosing their learning paths: The diagnostic tests with the individual feedback support students in structuring their learning, and a list of recommended modules for every study programme helps to identify the most important topics. Besides, we provide a text that explains the use of the material, the diagnostic tests and the role of the days at the university

THE EVALUATION-STUDY

In context of his PhD-project the second author of this paper extensively investigated the 2008 bridging courses in Kassel. His PhD project aims at designing, evaluating and refining the bridging course scenarios as described above. Major questions of the study were the identification of the reasons for the students' choice of the course variants, the description of the participants concerning personal aspects, the investigation of the course effects on the learners' performance and attitudes, the analysis of the acceptance and the rating of both, courses and learning material, and the investigation of the students' use of the learning material (cf. Fischer 2008).

For data collection, three questionnaires, one at the beginning, one in the middle and one at the end of the course, and two assessment tests were used. The questionnaires were anonymous online-forms requiring a personal key that enables us tracing the students' answers while keeping the students anonymous to us. Part of the items were adapted from different studies (Prenzel et al., 2002, Baumert et al., 2008, Bescherer, 2003) and items from the general course evaluation questionnaire of Kassel University. Thus we composed a new instrument for an investigation of blended learning scenarios for mathematical bridging courses. An electronic pre- and post-test was administered under exam conditions in a computer room for measuring students' mathematical proficiency levels. While the pre-test included exercises from school-mathematics, the post-test focussed on the bridging courses' content. In the following we can discuss only a few selected results of the study.

The courses from the learners' perspective

For investigating the acceptance of our bridging courses in general as well as the two course scenarios in specific, the students had to answer to three questions: 1. *"In general I was satisfied with the bridging course"*, 2. *"The participation in the bridging courses is absolutely recommendable"* and 3. *"I would decide for the E-/P-course of the bridging course again".* A Likert type scale with four answering categories was used here: (1) "is not true", (2) "is rather not true", (3) "is rather true" and (4) "is true".

Question	**P-course**			**E-course**		
	M	SD	N	M	SD	N
1: *"In general…"*	3.57	0.62	254	3.64	0.53	96
2: *"The participation in…"*	3.69	0.62	254	3.69	0.56	96
3: *"I would decide for …"*	3.67	0.68	254	3.48	0.79	96

Table 1: Results for questions concerning the acceptance of the courses.

Table 1 reveals very high scores for the courses in general and similar results for the two course types. Hence we can state that the learners were very satisfied with the bridging course type they had chosen. This proves the success of our course design decisions from this point of view.

Results from pre- and post-test assessments

The pre-test showed very similar results for both course types, but for the post-test, the results in the E-course are even better than in the P-course (see Table 2).

An analysis of variance for the results of the post-test considering the course variant as dependent variable and the results of the pre-test as covariant showed that the difference in the results of the course variants is highly statistically significant.

Test	Results for P-course			Results for E-course		
	M	SD	N	M	SD	N
Pre-test 2008 Maximum: **19 points**	8.52	3.14	226	8.52	3.64	146
Post-test 2008 Maximum: **20 points**	9.21	3.13	131	10.93	4.02	72

Table 2: Assessment results.

Since we only hoped to achieve at least comparable results for both course types in order to disprove the argument that the E-course may be a popular scenario for some students but it will not improve the students' performance as much as by traditional scenarios, we were happy to have such positive results.

Students' reasons for choosing a course variant

The students had to indicate which factor of a given list was relevant for their decision for a course variant and how important the respective factor was (Likert type scale). For each factor we calculated the mean in order to identify reasons with a high impact and reasons with a low impact.

For the **E-course** we found that the mean scores for extrinsic factors such as job-related restrictions, living situation, being on vacation or other external reasons had low values between 1.24 and 2.4. In contrast, the questions for intrinsic reasons revealed high mean scores from 2.73 to 3.52. Therefore we can interpret them as main factors for the decision: this includes reasons concerning the opportunity for a more self-regulated learning within the E-course, the possibility of individual timing as well as a personal interest in eLearning as a learning method. It is not surprising that the reduced numbers of days with compulsory attendance was a further important reason for the students' choice (M = 2.7).

The results for the **P-course** showed again that extrinsic reasons like the availability of a computer, the internet or an internet-flat rate had very low mean scores from 1.06 to 1.32. Aversions to learning with the computer (M = 2.13) or bad experiences in eLearning (M = 1.33) were also reasons with a low impact. Instead the opportunities of personal contact with other students (M = 3.4) and with the teacher (M = 3.64) as well as the opportunity of experiencing typical lectures were reasons with high mean scores (between 3.4 and 3.64) and can therefore be interpreted as main factors. We also asked for doubts in one's ability of self-regulated learning (M = 2.6) and doubts concerning the method eLearning itself (M = 2.61) but these results show that these are not strong factors for or against the choice of the course variant.

At the beginning of the study we assumed that especially those students would decide for the E-course who either have an affinity to working with the computer or who already have made (positive) experiences in learning with the PC. That's why we asked for these aspects in both course-scenarios and surprisingly found no substantial differences between the answers of the P- and E-course participants:

Question	**Results for P-course**			**Results for E-course**		
	M	SD	N	M	SD	N
"I have already experiences in eLearning"	1.97	0.4	376	1.95	0.33	209
"I like to learn with the PC"	3.23	0.74	376	3.4	0.7	209
"In the last year in school I have already learnt with a PC"	3.32	1.58	376	3.39	1.55	209

Table 3: Results for questions on learning with computer. Answering categories for the third question: (1) almost every day, (2) 2-5 times a week, (3) about once a week, (4) 1-2 times per month, (5) less often, (6) never.

Usage of the learning material within the E-course

Within the E-course the students were asked questions concerning their use of the diagnostic tests and of the modules. The participants had to indicate how often they had used the diagnostic tests. The results can be found in Table 4:

Test	**(1)** practically all	**(2)** most of them	**(3)** some of them	**(4)** barely none	**M**	**SD**	**N**
Pre-tests	28.5%	33.8%	22.5%	15.2%	2.25	1.03	151
Post-tests	19.9%	30.5%	23.8%	25.8%	2.56	1.08	151

Table 4: Use of the diagnostic tests.

The results show a slightly higher average usage of the diagnostic pre-tests, which is also supported by the user data that were collected in moodle: The number of pre-test-users is always higher than the respective number for the post-tests. The variability in the test usage is fairly high.

We also asked the participants to indicate how helpful the diagnostic tests were for them. Those students who didn't use the pre-tests (10.6% of the interviewees) or the post-tests (19.9%) could indicate it separately and were filtered out. The following table shows very positive results for both test types.

Tests	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**M**	**SD**	**N**
Pre-tests	30.4%	42.2%	19.3%	6.7%	0.7%	0.7%	2.07	0.97	135
Post-tests	21.5%	48.8%	23.1%	4.1%	2.5%	0%	2.17	0.9	121

Table 5: Acceptance of the diagnostic test by those you used them. Answering categories: (1) "helpful" … (6)" not helpful at all".

Since the students had the opportunity to use a CD offline instead of learning online with moodle, we asked them "*Did you learn online within the learning platform or offline with the CD*?" For this we used a scale with options from (1) "only online" over (3) "nearly equal" up to (5) "only offline". The quite high spread of SD ≈ 1.4 however revealed quite varying student opinions, so we decided to have a more detailed look at the results.

Hence we analyzed the results differentiating four different groups in view of the fields of study: E1 (electrical engineering & computer science), E2 (construction engineering & mechanical engineering), E3 (bachelor of mathematics or science & mathematics teachers for grammar schools) and E4 (teachers for primary and lower secondary schools):

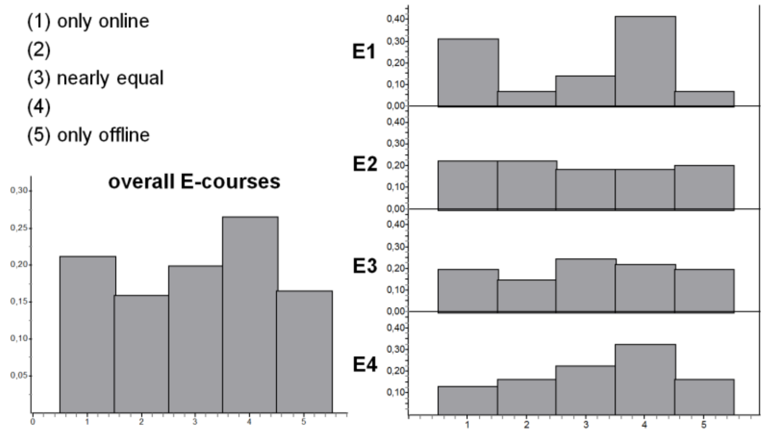

Figure 1: "Did you learn online within the learning platform or offline with the CD?"

It is noticeable that the groups E2 and E3 answered very similarly, while group E4 tends to learn offline. For group E1 we can identify two subgroups: One that is only learning online and another one that is learning almost only offline. Further data analyses showed that this split into subgroups can neither be explained by gender nor by the field of study (construction engineering & mechanical engineering).

Obviously there seem to be typical learning approaches that depend on the field of study, while others are independent of it. This assumption is further emphasized by an analysis of the students' use of the modules. We asked the students to indicate for each module unit within the first three chapters how intensively they have typically used them. We calculated the percentage of all users that indicated an intensive usage and visualized the results for the groups E1-E4 in figure 2. The y-axis of this diagram displays the percentage of "intensive users" of the respective module unit that can be found on the x-axis. For comparing the profiles of the different groups, we sorted the units on the x-axis with respect to the results of group E3 (Bachelor of mathematics and science, mathematics teacher for grammar schools) in decreasing order.

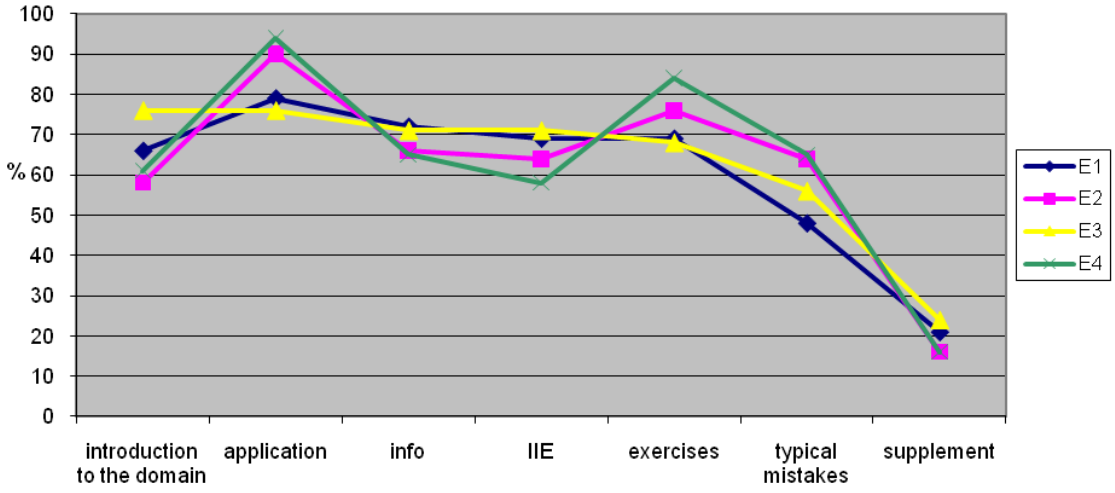

Figure 2: Percentage of intensive users for the units of a module.

We see that the learning profiles of the groups E1 and E3 are very similar as well as the profiles of the groups E2 and E4. This result was not expected since the fields of study of the groups would rather imply a different pairing. This suggests that it is not only sensitive to evaluate the courses with regard to the variants and the fields of study but also to classify different types of learners and to explore them.

PERSPECTIVES

The second author of this paper is currently working on different aspects of the evaluation study in the context of his PhD project. We have collected data on learners attributes e.g. personality, motivation, attitude towards mathematics and abilities in self-estimation and self-regulation. A classification of different types of learners and of typical learning strategies will be related to the learning behavior in the course and the effects of the courses on students' mathematical knowledge and attitudes. The data on students' rating of different elements of the courses and the learning material will be used for identifying aspects for improvement of the course design. We also revise our diagnostic tests, develop new content and design a new course structure in moodle for a better integration of interactive material. We expect that the instruments that we have developed will also be useful for the evaluation of blended learning bridging courses in general.

NOTES

This paper is partly elaborated in Biehler, R., Fischer, P. R., Hochmuth, R., & Wassong, Th. (in press). Self-regulated learning and self assessment in online mathematics bridging courses. In A.A. Juan, M.A. Huertas, S. Trenholm, & C. Steegmann (Eds.), Teaching Mathematics Online – Emergent Technologies and Methodologies. Hershey, PA: IGI Global.

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