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. In this paper the authors describe an innovative way of teaching and learning that claims to improve this situation by specific bridging courses including particular 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 concerning content-related and didactical aspects as well as methodical and organisational aspects of supported 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.

INTRODUCTION

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

The project VEMA – "**V**irtuelles **E**ingangstutorium **Ma**thematik (Virtual Entrance Tutorial for Mathematics) (http://www.mathematik.uni-kassel.de/vorkurs) started in 2003 the development of multimedia resources primarily for supporting the pre-term bridging courses, which try 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 course scenarios have been continuously improved taking into account our yearly evaluations.

THE INTERACTIVE MATERIAL OF VEMA

The content of the VEMA-material

In order to enable students to individually repeat 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". Each chapter has about 10 modules on average. The clear module-structure supports self-regulated learning as well as it enables the teacher to choose content suitable for the field of study of the 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 supports the learner in his navigation through the material, which is further supported by the layout of the interactive book: The chapter navigation frame on the left side enables the learner to choose the modules to which he likes to switch while the module navigation frame on top of the page 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, the learner can perform a diagnostic test to detect his deficits.

i. The *diagnostic pretest* gives the students the opportunity to test their pre-knowledge concerning the content of the module. The diagnostic test contains 4 to 5 exercises concerning the content of the module. After the student performed all tasks, the system automatically corrects his answers and provides feedback in form of a sore for each exercise and the test as a whole, a model solution, an individual feedback on the mathematical competencies and learning advices for the work with 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 of a module.
iii. The second unit is called *introduction to the domain*. It uses discovering, inductive and exemplary approaches to familiarize the learner with the content. We also support the knowledge construction process by interactive exercises: the learner has the opportunity to make mistakes, to withdraw them and to repeat the task until he found a right solution. The content is presented on a concrete level for the learners, with visualizations and references to their previous knowledge. The introduction starts from knowledge that is prerequisite and develops from this basis the new domain.
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 but networks them among each other and illustrates them with concrete examples and explanations. In case of theorems one can find plausible arguments and/or proofs for their correctness. The learner also finds interactive exercises, flash-films and animations he can interact with and which helps him to develop a deeper

understanding of the concepts. Since the learner can see the concepts from various perspectives the memorisation of knowledge is enabled, too.

vi. The fifth unit is called the *application* unit: Here some applications inside and outside mathematics are shown and discussed. These concrete examples 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 important 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 diagnostic competencies of the learners and to depict misconceptions in order to avoid them in the future. The learners can check their answer using a corrected model solution. For future mathematics teachers this unit is of particular importance in order to train their diagnostic competence (cf. Wittmann 2007).

viii. The last unit is the *exercises* unit: This unit is important for the learner to check their understanding of the topic and to give opportunities for practicing the concepts. For each exercise a model solution is available, which the learner can use to compare it with his own solution. These model solutions can also be used as hints to get an initial idea to the solution or to help the learner when the solution process gets stuck.

ix. The *diagnostic posttest* has the same structure as the diagnostic pretest. Its idea is to give the students the opportunity to check their performance after learning in view of the intended knowledge of this module. The diagnostic pre- and post-tests also aim at the development of the students' abilities in self-regulation and self-evaluation, which are major factors for the success of individual learning (Ibabe & Jauregizar, 2010).

TYPES OF BLENDEND LEARNING SCENARIOS

For our bridging courses we combined self-directed and external-regulated learning types of instructional formats (cf. Niegemann et al., 2008, p.66). Both formats have their justification in the specific case of bridging course: 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). To offer both aspects to each learner and also to consider his individual needs we developed two different blended-learning course scenarios for our bridging courses: a course scenario with an extensive attendance part (P-course) and a course scenario with an extensive eLearning part (E-course).

The P-course

This course scenario is mainly structured and led by the teacher. The course includes 4 weeks; each week consists of three days with attendance at university with three hours of lectures and two hours of practice-session.

The remaining days are free for individual learning and homework. This homework consists of two parts: one part with exercises on the topics that were taught in the lectures and another part with specific tasks to work individually with the modules in order to revise or to prepare content for the next presence day. This course variant is extensively steered by the teacher, while the learner has fewer opportunities for individual learning. The teacher also decides which diagnostic tests are available.

The E-course

This course includes 4 weeks with overall 6 presence days 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 confronted with the learning system, get some hints of how to learn with the material and the first modules are discussed in terms of lectures. These first two days introduce the course to the learners, its learning opportunities and to the university in general. Afterwards there is only one attendance day at the end of every week. Here the learners have the opportunity to ask questions about the content in the first part of the morning and to select the topics that are lectured in the second part of the morning. In the afternoon there is a small group working opportunity with exercises related to the content of the morning lectures. The small group work is guided by a tutor, who supports the learners in solving the exercises and in revising the content, if necessary.

The rest of the learning time is free for learning with the online resources. Open questions that appear in this process can be asked and discussed in the next attendance day. Beside the orientation days, moodle supports the learners in their learning paths: The diagnostic tests with the individual feedback support the structuring of 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. Moreover the learning system enables synchronous (chat) and asynchronous (forum and mail) communication opportunities. The students can either communicate among each other or ask questions to an online tutor who is available through moodle.

THE EVALUATION-STUDY

In context of his PhD-project the second author of this paper extensively investigated the bridging courses 2008 in Kassel. His PhD project aims at designing, evaluating and refining the bridging course scenarios as described above. The 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 the collection of the data 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 using a personal key that enables tracing the students' answers. The questionnaires' items were adapted from different studies (Prenzel et al., 2002, Baumert et al., 2008, Bescherer, 2003 and items from the course evaluation of the University of Kassel) and enriched by specifically developed items. This aimed at the development of a new instrument for a differentiated investigation of blended learning scenarios in context of mathematical bridging courses. In order to measure the students' mathematical proficiency level an electronic pre- and post-test was written under testing conditions in a computer room. While the pre-test included exercises from school-mathematics, the post-test was specifically designed focusing on the bridging courses' content. In the following we will discuss only a few selected results of the study.

The courses from the perspective of the learners

In order to investigate the acceptance of our bridging courses in general as well as the two course scenarios in specific, the students had to rate 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 fairly comparable results of the two courses. Hence we can state that the learners were very satisfied with the bridging courses in general and their chosen scenario in specific, which approves the success of our course design decisions from the view of the participants. Similar results on the students' acceptance can also be found in Sikora & Caroll (2002), but what is the effect of the courses concerning the students' proficiency?

Results from pre- and post-test assessment

The pre-test to the bridging courses showed very similar results for the participants of both course types, but for the post-test, the results for the E-course are even better than the results of the P-course as can be seen in table 2.

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.

We additionally analyzed the variance for the results of the post-test considering the course variant as dependent variable and the results of the pre-test as covariant. This proved that the difference in the results of the course variants is highly significant.

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

Furthermore we found one interesting detail: The statistical spread of the E-course's test results is higher than the spread within the P-course. We found this for both, pre- and post-test. Within the E-course's results the spread did not decrease from pre- to post-test but instead even slightly increased.

Students' reasons for their choice of the course variant

Within the study the students had to indicate for several predetermined reasons how relevant they were for their decision on the course variant. For this we again used the same Likert type scale as mentioned above. For each of these questions' results we calculated a mean score 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, the living situation, being on vacation or other external reasons had low values between 1.24 and 2.4. In contrast to this, 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 of a more self-regulated learning within the E-course, the possibility of individual timing as well as a personal interest in eLearning as teaching 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-flatrate had very low mean scores from 1.06 to 1.32. An aversion 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 opportunity of personal contact to students (M = 3.4) and to 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 the results show that these are neither strong factors for or against the choice of the course variant.

At the beginning of the study we assumed that especially those students decide for the E-course that either have an affinity to working with the computer or that 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 to describe their use of the diagnostic tests and of the modules. For this 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 proved 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. Obviously the tests were used diversely which asks for the students' acceptance of the tests.

Therefore we asked the participants to indicate how helpful the diagnostic tests were for them. Those students who didn't use the tests could indicate it separately and were filtered out. The following results show 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. 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 rather online within the learning platform or rather 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 resulted mean of M ≈ 3.01 showed that the students of the E-courses learn rather offline. The quite high spread of SD ≈ 1.4 however revealed a quite indifferent students opinion, 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 sciences), E2 (construction engineering & mechanical engineering), E3 (bachelor of mathematics and science & teachers for grammar schools) and E4 (teachers for primary and secondary schools):

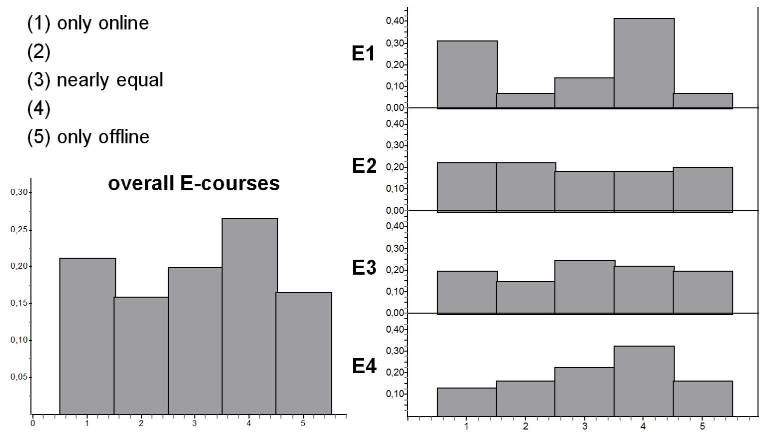

Figure 1. "Did you learn rather online within the learning platform or rather offline with the CD?"

It is noticeable that the groups E2 and E3 answered very indifferently, while group E4 is rather learning 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 explorations showed that these subgroups can neither be specified as electrical engineers vs. computer scientists, nor with regard to their gender.

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

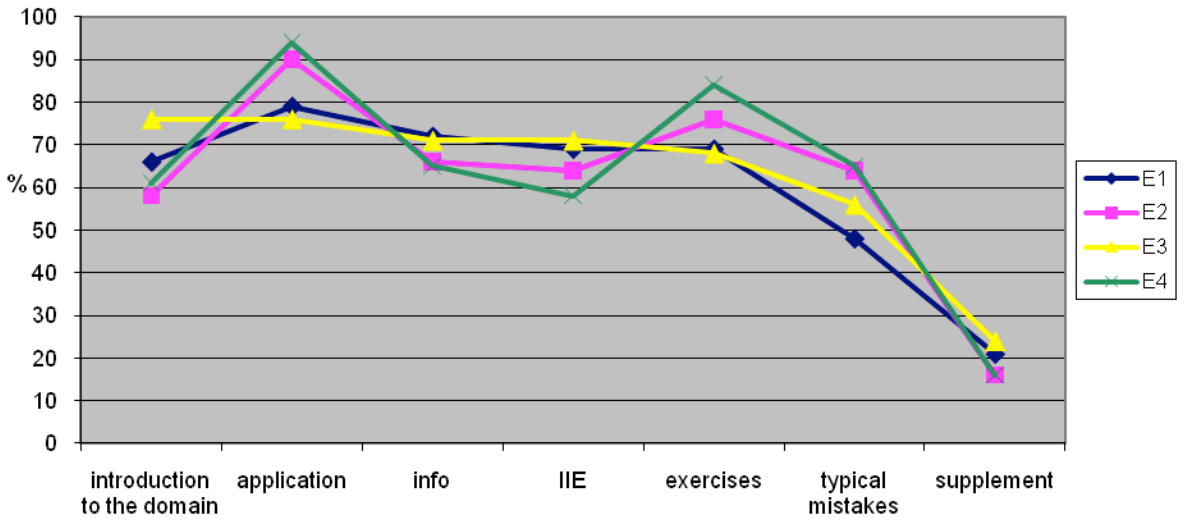

Figure 2. Percentage of intensive users for the units of a module.

We can observe 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 another pairing. This showed 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 context of his PhD. Amongst others he is analyzing the learners concerning their intrinsic attributes e.g. personality, motivation, attitude towards mathematics or abilities in self-estimation and self-regulation. This aims at a classification of different types of learners and of typical learning strategies. Moreover he investigates the effects of the courses on some of the students' abilities and attitudes. Furthermore he is analyzing the students' rating on different elements of the courses and the learning material. This will not only be used for identifying aspects for improvement but also for developing a conception for the evaluation of blended learning bridging courses including specific measuring instruments.

In the context of VEMA the annual evaluation of the bridging courses is used to develop new course elements. Besides we actually revise our diagnostic tests, develop new content and design a new course structure in moodle for a more structured integration of our interactive material.

REFERENCES

Baumert, J. et al. (2008). *Professionswissen von Lehrkräften, kognitiv aktivierender Mathematikunterricht und die Entwicklung von mathematischer Kompetenz (COACTIV): Dokumentation der Erhebungsinstrumente* (Materialien aus der Bildungsforschung, Nr. 83). Berlin: MPI.

Bescherer, C. (2003). *Selbsteinschätzung der mathematischen Studierfähigkeit von Studienanfängerinnen und –anfängern* (Doctoral dissertation). Retrieved September 15th, 2010, from http://opus.bsz-bw.de/phlb/volltexte/2004/1626/

De Guzmann, M., Hodgson, B.R., Robert, A., & Villani, V. (1998). Difficulties in the passage from secondary to tertiary education. In *Proceedings of the International Congress of Mathematicians, Volume III*. (pp. 747 - 762).

Fischer, P.R. (2007). E-Learning als effizienteres Mittel für den Brückenschlag zwischen Schule und Universität*?* In: *Beiträge zum Mathematikunterricht 2007*. Münster: WTM-Verlag.

Gueuedet, G. (2008). Investigating secondary-tertiary transition. *Educational Studies in Mathematics*, *67* (3), 237-254.

Holton, D. (Ed.). (2001). *The Teaching and Learning of Mathematics at University Level. An ICMI Study.* Dordrecht: Kluwer.

Ibabe, I. & Jauregizar, J. (2010). Online self-assessment with feedback and metacognitive knowledge. *Higher education, 59* (2), 243-258.

Mandl, H. & Kopp, B. (2006). *Blended Learning: Forschungsfragen und Perspektiven. (Forschungsbericht Nr. 182)* München: Ludwig-Maximilians-Universität.

Niegemann, H.M., Domagk, S., Hessel, S., Hein, A., Hupfer, M., & Zobel, A. (2008). *Kompendium multimediales Lernen*. Heidelberg: Springer.

Prenzel, M., Senkbeil, M., Ehmke, T. & Bleschke, M. (Hrsg.). (2002). *Konzeption, Evaluationsinstrumente und Unterrichtsmaterialien des SEMIK-Projekts "Didaktisch optimierter Einsatz Neuer Medien im naturwissenschaftlichen Unterricht"*. (IPN-Materialien) Kiel: IPN.

Sikora, A. & Carroll, C. (2002). *A Profile of Participation in Distance Education: 1999-2000.* Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Tall, D. (1991): *Advanced Mathematical Thinking*. Dordrecht: Kluwer.

Wittmann, G. (2007). Von Fehleranalysen zur Fehlerkorrektur. In *Beiträge zum Mathematikunterricht 2007*. Münster: WTM-Verlag.