



**HAL**  
open science

## Design and evaluation of digital innovations for an attendance-based bridging course in mathematics

Yael Fleischmann, Tobias Mai, Biehler Rolf

### ► To cite this version:

Yael Fleischmann, Tobias Mai, Biehler Rolf. Design and evaluation of digital innovations for an attendance-based bridging course in mathematics. INDRUM 2020, Université de Carthage, Université de Montpellier, Sep 2020, Cyberspace (virtually from Bizerte), Tunisia. hal-03113840

**HAL Id: hal-03113840**

**<https://hal.science/hal-03113840>**

Submitted on 18 Jan 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Design and evaluation of digital innovations for an attendance-based bridging course in mathematics

Yael Fleischmann<sup>1</sup>, Tobias Mai<sup>2</sup>, and Rolf Biehler<sup>2</sup>

<sup>1</sup>Norwegian University of Science and Technology, Norway, [yael.fleischmann@ntnu.no](mailto:yael.fleischmann@ntnu.no); <sup>2</sup>Paderborn University, Germany

*We describe how we extended a bridging course for mathematics at the University of Paderborn, including the lectures and phases of self-regulated learning outside the lectures, with multimedia learning materials. At the example of one lecture day of the course, we illustrate how digital learning materials were integrated into the course concept. In order to evaluate our interventions, we developed a methodological study design with a tight connection to the teaching innovation, supporting high response rates from the students at each conducted survey. We provide data on the students' valuation of different types of digital learning materials. Our results suggest that students appreciate in particular the integration of interactive exercises, but also of more passive didactical elements, in a traditional attendance-based learning environment.*

*Keywords: Transition to and across university mathematics, digital and other resources in university mathematics education, teaching and learning of mathematics for engineers, bridging course, evaluation design.*

## INTRODUCTION

During the last two decades at the university of Paderborn, several approaches to support the transition from school to university mathematics for our (prospective) students have been developed. For several years, free pre-university bridging courses of four weeks length have been offered to prospective students, who could choose between a traditional, attendance-based and a mainly e-learning-based course concept. Since 2014, we also developed an online course called studiVEMINT. The studiVEMINT material is designed as an independent online course in mathematics that can be used by any person who wishes to prepare themselves for university mathematics (see Biehler, Fleischmann, Gold, & Mai, 2016; Colberg, Mai, Wilms, & Biehler, 2017; Biehler, Fleischmann, & Gold, 2018 for further description of the contents, design and didactical concept of the course; see [go.upb.de/studivemint](http://go.upb.de/studivemint) for the project homepage). In particular, the material is *not* originally designed to be used in the context of an attendance-based bridging course for mathematics at university, but for individual work outside a supervised course.

After finishing the development of this course material in 2016, we came up with the question how the studiVEMINT course material could be used to enrich the didactical concept of our attendance-based preparation courses. The starting point for the study presented in this paper was our desire to create a scenario of blended learning, where our well-tried bridging course concept should be combined with the advantages of additional, digital learning materials. The condition for this integration was that the

existing course should not be fundamentally changed or shortened with respect to mathematical contents, but the materials were supposed to be integrated seamlessly into the existent learning environment. The idea was to integrate digital elements into the lecturers talk, a passive use from the students' point of view, as well as into self-reliant learning phases of the students inside the classroom (active use during self-instructing phases that were interspersed into the lecturer's talk) and outside the classroom.

## **THEORETICAL BACKGROUND**

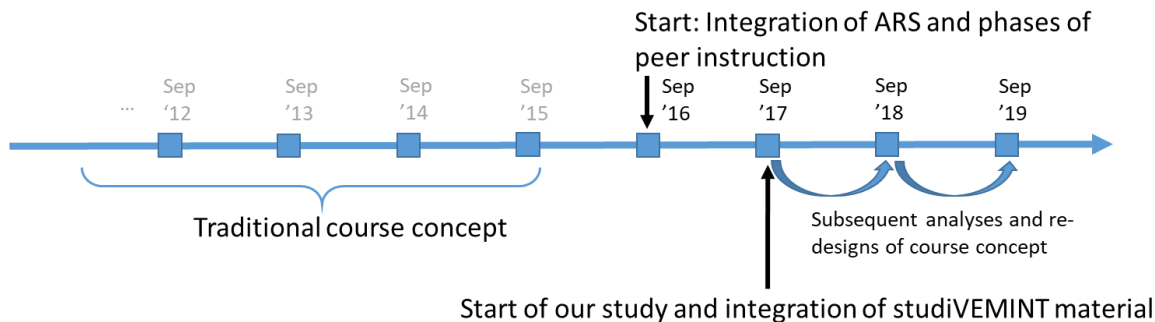
We follow an approach of design research in this study (Bakker & van Eerde, 2015; Nührenbörger, Rösken-Winter, Link, Prediger, & Steinweg, 2019). The integration and evaluation of digital learning materials was first implemented in the course in 2017. Based on the results of the accompanying study, we recreated several interventions for the next implementation in 2018 and repeated this procedure in 2019 (Figure 1). The focus of the subsequent studies was changed moderately in each year, with respect to the particular needs that were identified in the previous analyses. In this paper, we go into details about the implementation and scientific results concerning the study in 2017 and discuss some local results that led us to the changes we implemented in the 2018 and 2019 course designs.

There are many different definitions of blended learning in the literature. Bernard, Borokhovski, Abrami, Schmid and Tamim (2014, p. 91) note the following to this matter: "The issue of blended learning is a complicated one; there has been considerable discussion even of the meaning of the term itself". We consider our interventions within the lectures as a case of blended learning as they are a mix of e-learning and a face to face situation. Despite the problem of its definition, blended learning is of general concern for higher education (Keengwe and Agamba, 2015) and is even subject to meta-studies (Bernard et al., 2014). The case of mathematics in higher education narrows the field in term of its contents a little bit. Systematic evaluations of blended learning approaches usually yield a result that implies its benefits, e.g. as in the work of Lin, Tseng, & Chiang (2017), who conducted a study in a seventh grade math course, Dai and Huang (2015), who systematically compared e-learning, blended learning and traditional instruction, and Kinnari-Korpela (2015), who evaluated the use of short video lectures for engineering students. This glimpse at ongoing research hints at the broad use of blended learning in terms of methods, contents and audience.

As blended learning already includes digital technologies, the use of these for evaluation purposes seems natural. Audience response systems (ARS) can support feedback from learners and provide a means to collect data for research purposes. Ebner, Haintz, Pichler, and Schön (2014) suggest a distinction between front-channel (direct feedback during lectures) and back-channel (asynchronous feedback during and out of the lecture) of those systems. They also distinguish these further into qualitative and quantitative forms of feedback. The subject of this article is an evaluation based on a research method for teaching scenarios in mathematics with blended learning that

utilizes the front channel and is, in contrast to many other rather specialized methodological designs, transferable to other teaching contexts in a blended learning setting.

## CONTEXT AND RESEARCH INTEREST



**Figure 1: Timeline of the development of the course and our accompanying studies**

The course in which we conducted our study was a 4-week-long mathematics bridging course at the University of Paderborn. The target audience are freshmen majoring in mechanical engineering, electrical engineering, industrial engineering, computer engineering and chemistry. The course concept, which was tested multiple times in several preceding years, relies primarily on face-to-face teaching consisting of three hour lectures followed by two hours of tutor group meetings on Monday, Wednesday and Friday of each week. In the tutor groups of up to 25 participants, the students work together on mathematical exercises and under the supervision of a tutor. Furthermore, the students are required to repeat and deepen their understanding of the mathematical contents on the so-called “self-learning days” on each Tuesday and Thursday. The course takes place annually in September in preparation for the following winter term. Participation is voluntary and neither graded nor specifically rewarded in any way regarding the subsequent studies of the students.

In September 2017, between 100 and 150 students regularly attended the course. The interventions which we integrated into the course concept focused on the lecture and the self-learning days. Traditionally, the lecture had a classical concept of knowledge transfer. In 2016, the lecturer had already included some innovative didactical elements in form of short phases during the lecture. These phases included exercises which the students had to solve and discuss with their peers, leading to phases of peer instruction with feedback by a digital audience-response system into the lectures. This didactical innovation was not part of our intervention, but was continued in 2017 during our study. The lecturer reported his positive experiences with this element and was interested in extending the use of digital elements and interaction during the lectures.

One goal of our interventions was to find ways in which the digital learning materials that we had designed for the studiVEMINT online course could also be used as a supplement in general in the context of a “classical” attendance-based bridging course and in particular with this course. The material includes 13 learning units covering

mathematical school contents, starting with basic knowledge such as fractional arithmetics up to contents of the final school years such as integral calculus or vector geometry. The course has the particular claim to explain the contents in a way that meets the requirements of correctness at university's standard and rigour, and to present it in a way that closes the gap between school and university mathematics concerning notations and precision of argumentation. The chapters of the course have a consistent structure consisting of several units, starting with an introduction, followed by text units (supplemented by figures and interactive applets) containing explanations and some proofs of the mathematical contents, up to extensive collections of exercises for each contents unit. In most cases, the user can also insert an answer to these exercises into an input box and check the answer for correctness. For all exercises, detailed solutions are presented on demand. Some chapters contain units with additional applications and further complements to the mathematical contents, depending on the subject of the chapter. In the explanation as well as in the exercise part, interactive applets and videos are included in the material to illustrate mathematical contents dynamically.

## **INTERVENTION DESIGN**

The integration of digital learning materials in our intervention had two focuses: Firstly, we wished to enrich the lecture by the inclusion of dynamic illustration, (additional) phases of self-reliant work by the students and other variations of teaching methods into the lecturer's talk. Secondly, we modified the self-learning days by providing the students with digital learning materials that support their independent repetition of the mathematical contents. Because of limitation of space, the procedure and analytical results concerning this second part of our study cannot be considered in detail in this paper. We give an overview about the results and consequences for the following cycles of the study in the conclusion at the end of the paper. Since the tutor group meetings were already well supported by tutors and no need of additional materials to stimulate students' learning in these phases was reported from the previous years, this part of the course was not changed in terms of our intervention.

We developed detailed timetables for the inclusion of digital elements into the lecture together with the lecturer. In particular, our interventions included the use of videos and dynamic applets to illustrate mathematical contents, and we integrated phases into the three hours lectures in which the students were asked to work with parts of the online materials independently. A concrete example for the process of such a lecture is given in Table 1. All lectures were planned in order to provide a balanced mixture of traditional and innovative teaching methods, and to alternate between active and passive phases of the audience.

As mentioned in the description of the context, the ARS had already been used for periods of peer instruction in the previous year. The lecturer first posed an exercise to the students at the blackboard, then collected their answers using an ARS and presented them to the audience. Thereafter, he let the students explain their solutions to each

other, followed by a new feedback using the ARS. We distinguish between these exercises (analogue, answer via ARS) and the ones that we integrated in 2017 (digital, answer self-checked via studiVEMINT-course) in terms of our study.

Phase	Activity	Active part	Objective of activity
9:00 – 9:10 Lecture start	Lecturer communicates some organisational matters	lecturer	Course organisation
9:10–9:20 Start mathematics	Students read text in online-material (studiVEMINT)	students	Warm-up phase, revision of the definition of an angle
9:20–10:15	Blackboard talk	lecturer	Knowledge transfer
10:15–10:45	Break	-	Recovery time
10:45–10:55	Students work on exercises in online-course material (with input and control function for solutions)	students	Repetition and application of knowledge, practising of computation methods
10:55–11:00	Students answer ARS-questions concerning exercises in previous phase	students	The lecturer gets feedback concerning the students' current knowledge and can react to possible problems and questions that occurred
11:00–11:55	Blackboard talk, including -presentation of a video -presentation of an applet	lecturer	Knowledge transfer, visualisation of mathematical contents
11:55–12:00, end of lecture	Feedback questions concerning digital elements of the lecture, answered by the students via ARS	students	Scientific evaluation of interventions

**Table 1: Schedule of lecture 4 (trigonometry)**

## RESEARCH QUESTIONS OF THE EVALUATION STUDY

The focus was on the integration of digital learning elements into a classical, attendance-based learning environment in a way that teachers and students accept and students appreciate as a valuable part of their learning process. In order to elaborate a suitable concept for acceptance and appreciation and its measure, the following research questions were in focus of the design of our evaluation study:

Which elements and ways of integration of the digital learning materials included in our online course can be beneficial for the students in an attendance-based learning environment? In particular:

- 1) Do students appreciate and enjoy the integration of digital learning elements into classical lectures, and do they consider these methods as helpful for their learning process?
- 2) Do students perceive differences between different medial formats of integrated digital elements such as videos, interactive applets, digital exercises with automatically checked solution entry field or mathematical texts, concerning their acceptance and personal resonance?

## DESIGN AND METHOD OF EVALUATION

To approach our research questions in a differentiated way, we needed to design a proper evaluation method that allowed us a detailed scientific analysis of the implementation and provided us with a detailed feedback about our interventions into the course concept. The results produced by many traditional evaluation methods used in attendance-based learning environments do not allow immediate feedback or a fine

differentiation between different teaching methods or digital elements used in the same session. In our case, we were interested in concrete and detailed feedback exactly concerning the acceptance and appreciation of the different types of intervention and different digital media formats.

Since the lecturer already reported positive experiences with the use of an ARS during the previous conduction of the course, we came up with the idea to use this channel also to collect feedback concerning our interventions. This ARS became a central part of the design of our study. The students became used to working with it during the lecture and it had proven to be widely accepted by the students in previous year. Hence, we decided to ask the students for feedback concerning the digital elements of the lectures with this system as well. Since it is easily accessible, students could give feedback using their smartphone within a very short period of time. In most lectures, the lecturer asked the students to answer a collection of 4-7 of our research-motivated feedback questions using the ARS after using the last digital element of the day.

We asked the students in particular if they considered the use of the specific digital elements during the lecture of that day helpful for their personal learning processes and whether they enjoyed working (actively or passively) with these digital elements. For the scientific analysis of the collected data, we grouped them into three categories:

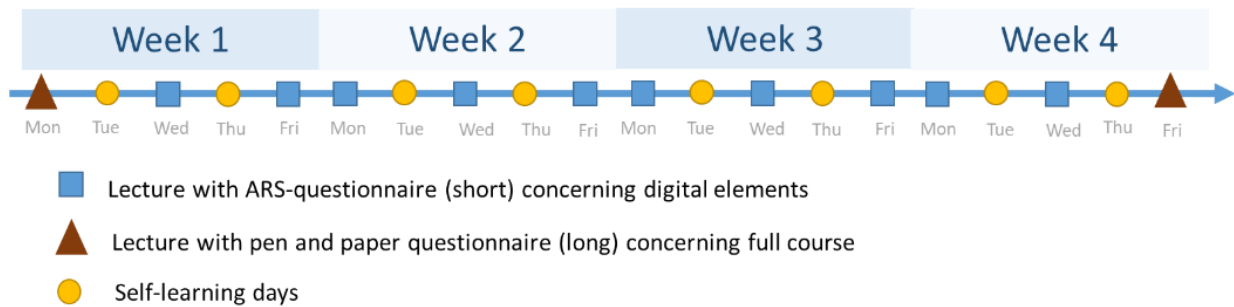
- Applets and videos: This category contains all videos and applets that the lecturer either presented during his talk or, in some cases, he instructed the students to work with themselves before he continued with the lecture (therefore, it was mostly not possible to distinguish between active and passive use of these elements in our questionnaires).
- Exercises: Part of the lecture were intervals when the students were asked to work on specific mathematical exercises that are part of the online course, solve them alone or together with their neighbor and check their answers for correctness.
- Texts and figures: These elements were used by the lecturer to integrate a methodic variation into the lecture. The students were asked to work through a section of the explanation part of the online course on their own. This altered the primary teaching method for a limited amount of time (usually 10-20 minutes) and was created with the intention to activate the students during the lecture, allowing them to work on a certain topic at their respective individual learning speed.

Regarding these three categories of digital elements used in the lectures, each time when such an element was used, we asked the students for feedback concerning two aspects:

- Whether the use of the element supported their learning process: “The use of (...) in the lecture was supportive for my understanding”, with possible answers: “fully agreed”, “rather agreed”, “rather not agreed”, “fully not agreed”, “I did not participate”.
- Whether they enjoyed working with this element: “I enjoyed the use of element (...)” with possible answers: “fully agreed”, “rather agreed”, “rather not agreed”, “fully not agreed”, “I did not participate”.

The second type of questions concerning enjoyment were included since we considered the aspect of motivation of the students to be crucial for their success in a course that is, as in our case, completely voluntary and not rewarded in terms of any credits.

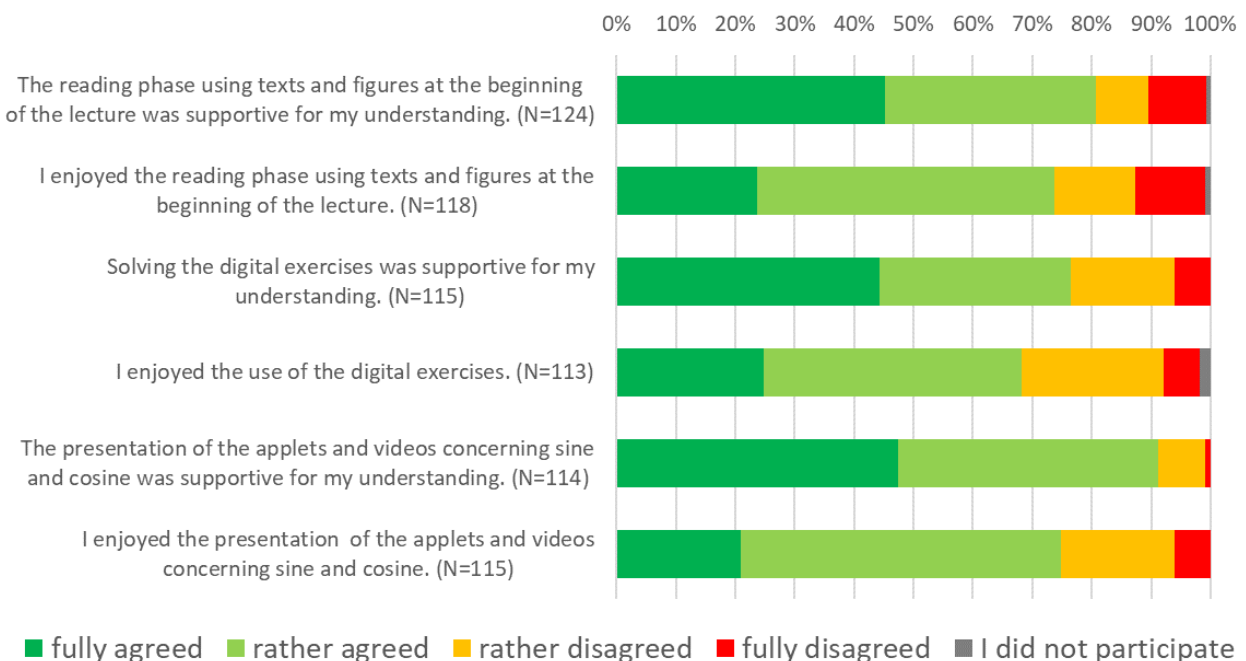
In addition to these digital data collections, there was a pen and paper questionnaire on the first and last day of the bridging course, which we used, inter alia, to obtain data concerning the students' overall impression of the interventions. An overall schedule of the course and the data collections is given in Figure 2. All data collected by the ARS and the pen and paper questionnaires was analysed quantitatively.



**Figure 2: Schedule of the four weeks course concept and scientific evaluation**

## RESULTS AND LOCAL DISCUSSION

Due to limitations of space, we can report here just a small excerpt of the results that we obtained in our study. We concentrate on the feedback concerning the different types of digital elements during the lecture, which are described in detail in the previous section, the summary of all ARS questionnaires and a general feedback concerning the digital learning material.



**Figure 3: Results from ARS-questionnaire in lecture 4 (trigonometry)**

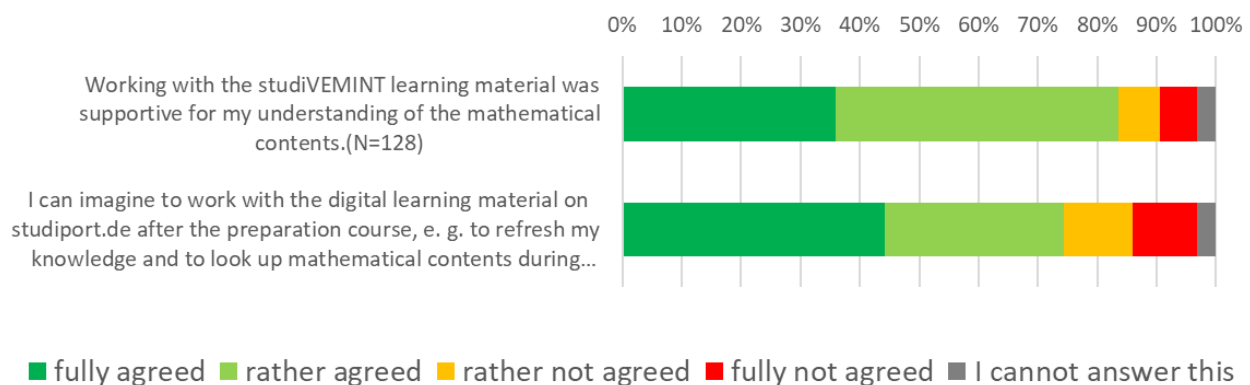


Figure 3 shows students' feedback about the lecture described in Table 1, using the ARS during the same lecture session. We note that overall, students appreciated the integration of digital elements into the lecture, and all elements get comparably similar positive feedback. It is noticeable that the aspect of "support of understanding" is in all cases rated higher than the aspect of "enjoyment". It is also remarkable that in particular the presentation of dynamic applets and videos as a part of the lecturers' talk (so in this case, a completely *passive* element) gets very positive feedback concerning its effect on students' understanding.

category	criteria	
	"The use of (...) in the lecture was supportive for my understanding.", answers: "fully agreed" or "rather agreed"	"I enjoyed the use of element (...).", answers: "fully agreed" or "rather agreed"
applets and videos (N=677)	80%	70%
exercises (N=812)	78%	78%
texts and figures (N=359)	73%	60%

**Table 2: Summary of results of all ARS-questionnaires**

Over the four weeks of the course, we collected 677 feedbacks, each concerning both aspects (support of learning process, enjoyment) about applets and videos, 812 feedbacks about exercises and 359 feedbacks about texts and figures. A summary of the results is presented in Table 2. Note that this may include several answers from the same student to several singular questions concerning different elements of the same type. The results from the pen and paper questionnaire in the last lecture, in which we collected the answers of 129 students, support the impression that the students appreciated the use of digital elements in the lecture overall. The aspect of support for their understanding was again overall higher valued by the students (74.4% (concerning applets and videos) to 81.4% (exercises) "fully agreed" or "rather agreed") than the aspect of enjoying the use of the elements (where from 68.2% (applets and videos) to 72.7% (exercises) reported "fully agreed" or "rather agreed"). In this questionnaire, we also asked the students whether they considered the digital elements to be a welcomed enrichment of the lectures. About 82% (rather) agreed to this for



**Figure 4: General questions concerning the digital studiVEMINT learning material (pen and paper questionnaire on the last day)**

each of the three types of elements. Overall, it can be stated that the use of the digital *exercises* was rated best in all categories in the pen and paper questionnaires. An interesting finding is that students seem to be aware of and able to distinguish between the property of an element of being fun and of being supportive for their learning processes. The overall feedback for our interventions at the end of the course, concerning the support for the learning process by the digital learning material and the chances for future use was quite positive, too (see Figure 4). These data together with constantly high response rates suggest that the double use of a well-accepted system (the ARS) in content- as well as in research-related context is a promising approach.

## CONCLUSIONS

Our results, in particular concerning the first research question, support the findings of Bernard et al. (2014) concerning the general benefits of blended learning in higher education for the specific case of mathematical teaching and learning. Ebner et al. (2014) formulate the requirement of scientific evaluation of front-channel feedback systems used in tertiary education; with our study we can present an example of a well-accepted implementation providing relevant feedback. Where Lin et al. (2017) could show positive effects of blended learning on the learning outcome and the attitude of high school students in mathematics, our results on both research questions suggest that these findings also hold for tertiary education.

In the sense of our design research setting, the results of the study were used to further develop the bridging course design in the following cycles, accompanied by scientific evaluation. Many of the innovations designed for the interventions of this study were maintained in the next iterations. We considered this as our first milestone on the way to the development of a design for a blended learning scenario, based on an already existing traditional course concept. In order to increase students' benefit from the digital learning materials in the subsequent cycles of the study, we decided to concentrate on the self-learning days of the course. Students were asked, but sometimes struggled, to work on tasks on their own, using the studiVEMINT course material. Based on the positive results concerning the digital exercises, we designed and refined tasks for the self-learning days. We also decided to put a focus on the aspect of motivation in the following conceptions of our study. There, we concentrate on interventions to increase the motivation of students on the self-learning days and collect more detailed data about their engagement on these.

## LITERATURE

Bakker, A., & van Eerde, D. (2015). An Introduction to Design-Based Research with an Example From Statistics Education. In A. Bikner-Ahsbals, C. Knipping, & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education: Examples of Methodology and Methods* (pp. 429–466). Dordrecht: Springer Netherlands. [http://doi.org/10.1007/978-94-017-9181-6\\_16](http://doi.org/10.1007/978-94-017-9181-6_16)

Bernard, R. M., Borokhovski, E., Abrami, P. C., Schmid, R. F., & Tamim, R. M.

- (2014). A meta-analysis of blended learning and technology use in higher education: from the general to the applied. *Journal of Computing in Higher Education*, 26, 87–122.
- Biehler, R., Fleischmann, Y., & Gold, A. (2018). Konzepte für die Gestaltung von Online-Vorkursen für Mathematik und für ihre Integration in Blended-Learning-Szenarien. *Beiträge Zum Mathematikunterricht 2018*. (pp. 277–280). Münster: WTM-Verlag
- Biehler, R., Fleischmann, Y., Gold, A., & Mai, T. (2016). Mathematik online lernen mit studiVEMINT. In C. C. Christoph Leuchter, Frank Wistuba & C. Segerer (Eds.), *Begleitband zur Konferenz Erfolgreich Studieren mit E-Learning*. Aachen 2017. Retrieved from [studiport.de/lehre-undberatung/%0Ainfomaterialien](http://studiport.de/lehre-undberatung/%0Ainfomaterialien)
- Colberg, C., Mai, T., Wilms, D., & Biehler, R. (2017). Studifinder : Developing e-learning materials for the transition from secondary school to university. In R. Göller, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Didactics of Mathematics in Higher Education as a Scientific Discipline – Conference Proceedings*. (pp. 466–470). Kassel: Universität Kassel: Khdm-report 17-05.
- Dai, C., & Huang, D. (2015). Causal complexities to evaluate the effectiveness of remedial instruction. *Journal of Business Research*, 68(4), 894–899.
- Ebner, M., Haintz, C., Pichler, K., & Schön, S. (2014). Technologiegestützte Echtzeit-Interaktion in Massenvorlesungen im Hörsaal. Entwicklung und Erprobung eines digitalen Backchannels während der Vorlesung. In K. Rummler (Ed.), *Lernräume gestalten - Bildungskontexte vielfältig denken*. (pp. 567–578). Münster: Waxmann.
- Keengwe, J., & Agamba, J. J. (2015). *Models for Improving and Optimizing Online and Blended Learning in Higher Education*. Hershey PA: IGI Global.
- Kinnari-Korpela, H. (2015). Using Short Video Lectures to Enhance Mathematics Learning – Experiences on Differential and Integral Calculus Course for Engineering Students. *Informatics in Education*, 14(1), 67–81.
- Lin, Y., Tseng, C.-L., & Chiang, P.-J. (2017). The Effect of Blended Learning in Mathematics Course. *EURASIA Journal of Mathematics Science and Technology Education*, 8223(415), 741–770.
- Nührenbörger, M., Rösken-Winter, B., Link, M., Prediger, S., & Steinweg, A. S. (2019). Design Science and Design Research: The Significance of a Subject-Specific Research Approach. In H. N. Jahnke & L. Hefendehl-Hebeker (Eds.), *Traditions in German-Speaking Mathematics Education Research* (pp. 61–89). Cham: Springer International Publishing. [http://doi.org/10.1007/978-3-030-11069-7\\_3](http://doi.org/10.1007/978-3-030-11069-7_3)