DEVELOPMENT AND TRIAL OF A BLENDED LEARNING CONCEPT FOR STUDENTS IN ENGINEERING STUDY COURSES

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ABSTRACT

This paper provides an overview of digital learning elements used in academic teaching and summarizes the current state of research concerning the utilization of digital learning elements at German universities. It demonstrates that the blended learning approach compared to other e-learning approaches proved best and is widely administered (cf. Schmid et al., 2017; Wannemacher, 2016). As a result, the blended learning approach has been selected for the present research project.

The main part of the paper describes the experience of developing a blended learning concept from a practical perspective. A flipped classroom concept was developed for “point kinematics,” a part of the module called “technical mechanics” for a bachelor’s mechanical engineering study course with two self-learning (e-learning) phases and two in-class phases.

In addition, a comparative group study examines the effectiveness of the designed blended learning course. Two groups have been compared. One group attended a traditional in-class lecture, and for the other group, the blended learning course was implemented. The results of the analyses show that the group in the blended learning scenario as opposed to the traditional learners had significantly improved from the prior-knowledge test to the final exam.

INTRODUCTION

In view of the increasing number of students, the growing heterogeneity of students, internationalization and the increasing competition at German universities, it can be argued that digitalization could help to address these challenges (cf. Albrecht and Revermann, 2016; Schmid et al., 2017).

Digitalization is a current topic in higher education because of the increasing networking in the last years and the simplified access to the digital world via mobile devices. The pressure to keep pace with developments in other industrialized countries has intensified in Germany. Facing a growing number of students, universities are challenged to ensure the quality of their lectures and to counteract the overstraining of teachers as well as the limited premises. The large number of applicants and the variety of university entrance qualifications lead to growing heterogeneity in student groups. This situation results in individual learning needs which have to be taken into account, depending on the biographical conditions (cf. Jürgens, 2017).

Furthermore, because of the increasing competition in the private higher education sector and the expanding portfolio of foreign universities, it seems necessary for state universities in Germany to take advantage of the opportunities offered by digital media. The development of new teaching concepts with digital media could be a chance to address these challenges.

The key question of this research is whether the support of teaching with e-learning elements and the didactic preparation of the contents within a blended learning scenario leads to a better understanding of the topic and, accordingly, better results for students than teaching without e-learning elements.

STATE OF RESEARCH AND THEORETICAL FRAMEWORK

Digital teaching and learning at German universities

Digital presentation tools followed by digital texts and the common office programmes are widely used by students in university courses (Schmid et al., 2017). In their private lives, students use Wikipedia or wikis and videos. Schmid et al. revealed that a mixture of online and attendance phases and inverted classroom formats for seminar preparation are favored by students.

In his research, Wannemacher (2017) illustrates that lecturers mainly use classical teaching and learning materials, as well as videos, presentation tools or a whiteboard to impart knowledge (cf. ibid., p. 21). He acknowledges social and collaborative learning with digital media as particularly crucial for the didactic design. However, he argues that special didactic concepts for digital learning are still missing. University management discerns opportunities in the use of digital learning media that can help to master certain challenges, such as strengthening individualized learning, coping with the growing number of students and dealing with the heterogeneity of students. The management assumes that digital media can also contribute to the inclusion of students and the monitoring and analysis of learning success (cf. ibid., p. 25). In terms of the challenges and difficulties in the context of digital learning at the university, the lecturers' first priority are legal issues (rights of use; copyright; data protection). These issues represent a major challenge for both teachers and universities, because there are still no comprehensive legal regulations for their use in Germany. The intense effort necessary for designing and producing digital learning material and the question of crediting the work in the teaching budget is the second challenge (Wannemacher, 2017).

Persike and Friedrich have also found that the use of digital media varies greatly between subjects (cf. Persike and Friedrich, 2016, p. 7). Schmid stated that, until now, merely isolated solutions exist at German universities, and only a few have a comprehensive cross-university strategy for the digitalization of teaching (cf. Schmid et al., 2017, p. 28).

Lochner states that the blended learning approach has now established itself. In his opinion, it is undisputed that "a pedagogically–didactically meaningful concept is decisive for the success of a (partially) digitized course" (Lochner et al., 2017, p. 144).

Learning success with digital media

Greller *et al.* have compiled international comparative studies on the performance of students with online and face-to-face teaching (e.g., Piccoli *et al.,* 2001; Skylar *et al.*, 2005; LaMeres and Plumb, 2014). They conclude that the results may vary depending on the context, because it is not clear how the embedding and didactic design of the examined online parts are constructed (Greller *et al.*, 2017). Ledermüller and Fallmann have identified essential factors from educational psychology that have an influence on learning effectiveness: previous knowledge, time invested in the learning process and repetition of effort in solving problems. Self-regulated learning ability shows no significant influence on test performance, which is surprising, because e-learning is usually highly self-directed (cf. Ledermüller and Fallmann, 2017, p. 81). They conclude that the use of digital media in the classroom makes it possible to respond more flexibly to different types of learning.

Moreover, Kulik *et al*. demonstrate in their meta-analysis that computer-based teaching promises higher learning success than traditional teaching with the effect strength of d = .35[1] in favor of computer-assisted teaching (Kulik *et al*., 1986). Nevertheless, the advantage of e-learning shows a minor effect. Kerres displays an effect for adult continuing education when computer-assisted learning is combined with conventional teaching, as opposed to "the use of computers alone." The effect strength of d = .42 has reached a moderate value (cf. ibid.). Kerres points out that learning success is independent of the media system used; whether media-based learning has a favorable or unfavorable effect on learning success depends on moderator variables such as acceptance, self-learning skills and dropout rates (cf. Kerres, 2003, p. 6).

In summary, the results can vary depending on the context and the didactic design of the online elements. Having an influence on learning effectiveness are previous knowledge (Nickolaus and Abele; Ledermüller and Fallmann, 2017); the time invested in the learning process (Kerres, 2011); and certain learning strategies that are considered important for self-directed digital learning (Ledermüller and Fallmann, 2017).

Flipped classroom concept

Blended learning is a combination of classroom learning and learning with digital media. However, there is a disagreement in the literature about the percentage share of face-to-face elements and online elements (cf. Kerres, 2011; Wannemacher, 2016). Wannemacher distinguishes three scenarios for the distribution: 1. *Enrichment*: Already existing face-to-face lectures will be enriched with digital elements, without making any major adjustments to the existing structures. 2. *Integration*: Blended learning approaches in which the in-class and online components complement each other. 3. *Online learning*: These scenarios have little or no in-class phases.

The *inverted classroom* or *flipped classroom* is a didactic model for blended learning courses. The method is administered through self-learning materials - for example, via PDFs, e-lectures or instructional videos and podcasts. In the face-to-face section, the content learned through self-study is reinforced by the teacher and increased through exercises. The flipped classroom teacher is no longer the agent of the lecture contents but supports the students in the self-controlled learning processes. An advantage of the flipped classroom is, on the one hand, the individualization of the learning processes, which offers students the possibility to learn, record and repeat content at their own pace. On the other hand, the clear separation of teaching and the deepening of knowledge, as well as reflection in the online and in-class phases, can be beneficial.

DEVELOPMENT AND TRIAL OF A BLENDED LEARNING CONCEPT

For the research project, a lecture from the basic studies of an engineering course at a university of applied sciences was selected. The lecture on *technical mechanics* is regarded as a core subject of engineering studies (cf., e.g., Behrendt et al., 2015). At the test university, this lecture is a traditional classroom face-to-face lecture with individual and group exercises. The professor provides the students with a script in PDF format, in which the theory of the topic is described in detail and supplemented with sample calculations and examples for a better understanding. Approximately 60 to 70 students participate in this lecture per semester.

[1] Cohen designates an effect of d = 0.2 as small, d = 0.5 as a mean effect and d = 0.8 as a large effect (Cohen, 1988).

Development of the learning scenario

Because the lecturer has little time to discuss exercises during the lecture, given such a large group, or to respond to individual, weaker students, the flipped classroom concept has been chosen. It is intended primarily to help weaker students better understand the content, and to supply the lecturer with more time to explain the solution strategies of the sample calculations in class.

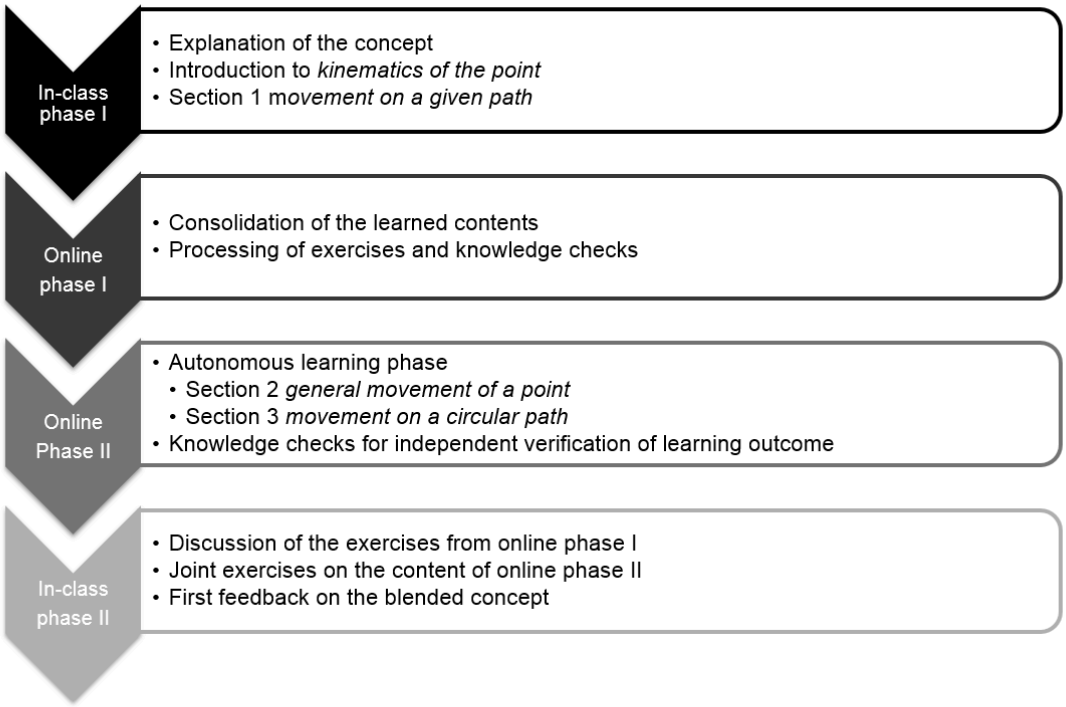

Figure 1: Visualization of the developed concept

Figure 1 visualises the designed learning scenario. After reviewing the existing learning materials of the lecture, three sections were selected for implementation in a blended learning concept: Section 1: *movement on a given path*; Section 2: *general movement of a point*; and Section 3: *movement on a circular path*.

The first in-class phase is about introducing the students to the learning concept and the topic of the lesson. The lecturer gives a face-to-face lesson to the students of Section 1 (as seen in Figure 1). The script was used as a basis for creating the materials for the online phases by using the software Articulate. In the Online Phase 1, the learned contents from the In-class Phase 1 should be intensified by processing exercises and knowledge checks. The aim is to provide learning outcome assessments based on quiz questions for learners, and the provision of assistance for difficult topics. Various exercises and case studies are incorporated to enable explorative learning and problem-oriented learning. The division of the knowledge elements into small subareas should enable the learners to return to the subject matter at any time without any problems. Opportunities for an exchange with the

lecturers (via forums) and fellow students (via chats) are to be provided in the learning setting.

Based on the findings in Chapter 1.2, the design and the concept of the learning environment, as well as the embedding in the lecture, were especially considered for development.

Furthermore, the following methods were implemented in the e-learning sections: *direct instruction* (review, presentation, guided practice, corrections and feedback, and independent practice) in order to deepen the learned contents; and *induction and deduction* (abstract information is presented, and concrete examples promote abstract thinking; learners are encouraged to be active). This method was used to convey theoretical contents (cf. Kerres, 2011). One of the core elements in the creation of the learning content was the division of the content into small, independent learning sections, with individual feedback on their learning progress for the learners, and close guidance of the learners through the course unit. A key insight learned during the development was to bundle the contents into small packages, because of the expected short attention span of the students; one unit lasts a maximum of 45 minutes. In our experience, to fill an e-learning course with content for 45 minutes, at least two to three working days are needed to transform the content of a given structure with Articulate.

An overview or a preview of the learning contents and connections is represented graphically, so that the learner can always follow at which point of the learning unit he or she is. For the face-to-face lectures, as well as the e-learning parts, the lecturer always maintains an advisory position.

To summarize the development phase, much time has to be invested in the entire development and implementation of the content, and multiple hours are required to transform the classic lecture into a flipped classroom lecture. The majority of lecturers are most likely not able to spend this amount of time to transfer their lecture contents into a flipped classroom concept. Therefore, the conclusion can be drawn that an expert is needed for the implementation of the contents and the design of the overall concept.

Experimental study

Study design and sample

The aim of the study is to investigate whether students taught with a didactically embedded blended learning concept achieve better exam results than students who are taught in the traditional way. The data on which the quantitative study is based was collected at Aalen University between December 2016 and July 2017.

Before the lecture started, the prior knowledge of the students was examined, and at the end of the lecture, the acquired knowledge was tested with an exam. The prior-knowledge test consists of 12 test questions or, instead, 18 items from the validated test: "KoM@ING Survey of Physical – Technical Competence at the Beginning of Studies" (cf. Behrendt et al., 2015). In total, up to 21 points can be achieved in the abridged test used for the present study. The test questions were selected by the lecturer. A total of n = 109 students participated in the survey. The sample was a complete survey of engineering students who had to take this course at Aalen University. The first group consists of n = 63 students from full-time courses. All respondents from this group attended the lecture on technical mechanics without a blended learning concept (this group is hereinafter referred to as *Group 1 without tool*). The second group consists of a total of n = 46 students. These students learned the contents with the developed blended learning concept (this group is hereinafter referred to as *Group 2 with tool*). A classic comparison group design is used, consisting of two groups and two measurement points.

Table 1: Sample description

	Group 1 *without tool* *n = 63*	***Group 2*** *with tool* *n = 46*
Gender		
Male	75.4%	58.7%
Female	24.6%	41.3%
University entrance		
Abitur	61.3%	42.2%
Fachhochschulreife	33.9%	40%
Professionally qualified	4.8%	17.8%
Average university entrance qualification grade	M 2.6, SD .60	M 2.8, SD .65
Study form	**n = 62**	**n = 46**
Full-time	100%	58.7%
Part-time	0%	41.3%

Table 1 shows the descriptive findings of the two comparison groups. Group 2 with the tool has an average of 2.8 in the university entrance qualification examination, while Group 1 scores slightly better with an average of 2.6. Furthermore, 36.4% of the total group have passed the university entrance qualification examination (Abitur), 36.4% have completed a Fachhochschulreife and 25.3% are professionally qualified persons. The majority (81.7%) are full-time students.

Results

A comparison of means of the prior-knowledge test demonstrates that Group 2 achieves 7.5, whereas Group 1 achieves 10.4. Group 2 has comparably less previous knowledge than Group 1. The difference between the two groups is highly significant. The group without the tool has a higher level of prior knowledge.

Table 2: Comparison of means in entrance examination

		n	***M***	***SD***	***p***
Prior-knowledge test	Group 1 *(without tool)*	63	10.4	4.4	< .001
	Group 2 *(with tool)*	45	7.5	4.2	

Notation. K–S-test significant (no normal distribution); total score: 21 points

In the comparison of means of the point kinematics exam (Table 3), it can be seen that the mean value of Group 2 is 0.61 higher than in the group without the tool. The Mann–Whitney U test showed no significant difference between the two groups.

Table 3: Comparison of means in the final exam

		n	***M***	***SD***	***p***
Exam point kinematics	Group 1 *(without tool)*	43	2.88	2.42	n.s.
	Group 2 *(with tool)*	36	3.49	3.66	

Notation. K–S-test significant (no normal distribution); total score: 12 points

In the mean value comparison of the point kinematics exam task (Table 3), it can be seen that the mean of Group 2 is 0.61 higher than in the group without the tool. There are no significant differences in the exam results.

In order to evaluate whether the individual learning increase is statistically significant, the difference of the percentage level of achievement is determined. The Mann–Whitney U test shows a high significance with .002. Group 2 has improved by 31% from the prior-knowledge test to the exam results.

SUMMARY

The research illustrates that the students (Group 2) who learned with the blended learning scenario have improved significantly compared to the group with the traditional in-class concept. Although Group 2 demonstrated significantly poorer previous knowledge in the entrance test, the students managed to compensate for this deficit. The central question as to whether the students are able to understand the topic better by having lessons with the developed blended-learning concept can be confirmed by the results.

It is unclear to what extent the blended learning tool itself has led to the improvement of Group 2, because the lecture design of Group 1 provides many self-study exercises. It is most likely that the success of Group 2 could also have to do with the fact that the material has been didactically processed and structured by an expert. Especially for weaker students with less previous knowledge, professors who are giving traditional lectures may introduce topics at too high a level, whereas the preparation of the materials by a didactics expert in combination with the professional expertise could help explain complicated topics in a more understandable manner. This leads to the recommendation that, for a successful digital teaching and learning concept at universities, teachers must be supported with the expertise of experts in didactics and in digitalization of learning content to develop successful concepts. The frequently integrated learning success checks in the blended concept, the small learning units and the appealing design and processing of the teaching content could also have been beneficial for learning success.

Another challenge is that various concepts of blended learning and e-learning are outlined in the literature, and the application and implementation are regarded as important, but there are barely any indications of the details for the implementation and the possibilities in connection with didactic concepts. Here, too, there still seems to be a great need for research. There should be some kind of guidelines for the implementation of digital learning that describes in detail the procedure and the possibilities, from the conception of a didactic concept to which technology is best suited for which setting, and how digital content can be created and what can be achieved with it - and, above all, how these online elements can be interlinked with face-to-face lectures.

In summary, the following conclusions can be drawn from the present work: for the created blended learning concept, success can be recorded on the basis of the statistical results. The problem of overcrowded lectures in basic subjects described above can indeed be counteracted by a well-developed blended learning concept. Students can be flexible about learning, and there is more time in class to concentrate on the transfer of content or for exercises. Especially for heterogeneous student groups, a blended learning format can be helpful to be able to better respond to the different learning speeds and knowledge levels.

All in all, the success of a blended learning concept stands or falls with the preparation of the content and the didactic concept, regardless of which digital media are used. The biggest obstacle to widespread use continues to be the intense effort required to create the online learning materials.

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