Best of Germany: Interactive Online Modules as a Digital Support for Students in the Introductory Phase of Civil Engineering Studies

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Abstract: The collaborative research project FUNDAMENT has the objective of increasing the individual learning success of civil engineering students by using digital university teaching. One part of the project is the development and evaluation of interactive online modules (IOM) in the introductory phase for the engineering mechanics lectures. The IOM consist of learning videos and online exercises. This article explores the effectiveness of these IOM using a classic longitudinal experimental and control group design. Paper and pencil knowledge tests were applied at the beginning (MP 1) and the end (MP 2) of the first semester. The use of the IOM was operationalized by recording the clicks on corresponding links. In a sample of n = 34 students an increase of the mean person ability (dichotomous Rasch model) from $B_{MP1} = .05$ to $B_{MP2} = .73$ could be determined.

Introduction

German universities have to deal with the problem of high numbers of university dropouts for many years. Particularly affected are the engineering disciplines, in which 35 % of the students (relatively to the number of first-year students 2012/2013) finish their studies without a degree (Heublein & Schmelzer, 2018). In the field of civil engineering even 42 % do not achieve their degree (ibid.). In other European countries and in the United States it is a common problem as well (De Laet et al., 2017; Pinxten et al., 2017; Ohland et al, 2008).

Dropping out of university is understood as a complex and multidimensional dropout process that can be divided into several phases, which are influenced by different factors (Heublein et al., 2017). In engineering performance problems can be considered the main reason for dropping out of university (ibid.). Especially, these occur in basic subjects such as engineering mathematics or engineering mechanics (EM), which in turn are resulting in failed exams (Heublein, Hutzsch, Schreiber, Sommer & Besuch, 2009). A decrease of special and mathematical knowledge among first year-students can be considered as a possible cause for the mentioned performance problems (Henn & Polaczek, 2007; Heublein & In der Smitten, 2013). Addressing such knowledge gaps is extremely difficult during the introductory phase (Willige, Woisch, Grützmacher & Naumann, 2014). The importance of the introductory phase becomes even clearer, as students without study success in the first semester describe the largest share of the disenrollment (Henn & Polaczek, 2007).

To avoid these problems, Heublein & In der Smitten (2013) have developed a reference model for quality assurance at faculties of engineering sciences. Therefore, it may be helpful for preventive support measures to be anchored at different times in the course of the studies. The different points in time are the preliminary phase (self-assessment and prep courses) and the introductory phase (additional learning offers). Many universities already offer these support measures, but mostly only subject-unspecific topics are dealt with, e.g. engineering application contexts - such as those of EM - remain untreated.

The University of Duisburg-Essen and the Technical University of Kaiserslautern joined forces in 2017 to start the collaborative research project FUNDAMENT (Improvement of individual learning success by the use of digital media in civil engineering). In the context of which a digital support concept was developed, based on the previously presented reference model. The objective is to support the individual learning processes of students in civil engineering studies by the use of digital university teaching. For this purpose, support measures for the preliminary phase (online self-assessment and online prep course) as well as for the introductory phase (interactive online modules – IOM) were developed.

This paper focuses on the introductory phase. Research in this phase of the studies have shown that it is difficult for first-year students to understand the key core concepts of the EM (Prusty & Russell, 2011). Students having problems to link the lecture contents with the corresponding key core concepts, can be a possible reason for this difficulty. To create this link by additional illustrations of the theoretical content has not been successful in physics (Crouch, Fagen, Callan & Mazur, 2004), relating to the EM there is no research available yet.

So-called interactive online modules (IOM), which were already developed in the Anglo-Saxon area, could remedy this situation. Evaluations of these IOM have methodological deficits and do not consider the individual learning processes (i.a. Prusty, Ho & Ho, 2009; Prusty & Russell, 2011).

Therefore, the research regarding IOM in EM will be continued by FUNDAMENT. The developed IOM consists of learning videos and online exercises created for the introductory phase of civil engineering studies, especially for the EM 1 and EM 2 lectures in the first two semesters. The learning videos were designed in two different ways: experimental videos (to illustrate the core concepts, but also to clarify and deepen the conceptual understanding) and animated slideshows (as teaching and learning support for e.g. calculation exercises). For the EM 1 lecture four videos and 77 exercises, for the EM 2 lecture seven videos and 60 exercises were developed.

The online exercises were implemented by the use of the server-based system JACK (Striewe, Zurmaar & Goedicke, 2015), which enables parametric computer-aided testing with automated feedback generation. The IOM are provided in the internal moodle [1] environments at both universities.

[1] https://moodle.org; accessed July 7th, 2019.

Methodological Approach

Several research questions will be answered in the collaborative research project FUNDAMENT. The focus of this paper is on answering the research questions whether the IOM contribute to an increase of the individual learning success of students in the field of EM in the first semester of the civil engineering studies. Also, it will be answered if students accept and use the IOM at all.

These research questions will be answered longitudinal in a classic experimental and control group design (Fig. 1) by paper and pencil tests that are applied at two measuring points (MP): beginning of the first semester (MP 1) and end of the first semester (MP 2). The control group consists of students who attend the EM 1 lecture in the conventional concept. In contrast, students who use IOM in the context of the EM 1 lecture will be assigned to the experimental group. The data collection of the main study took place in the winter semester 2018/2019. To examine the effectiveness of the IOM in the second semester, a paper and pencil test will also be applied at the end of the second semester (MP 3 – summer semester 2019), but this is not subject of this contribution.

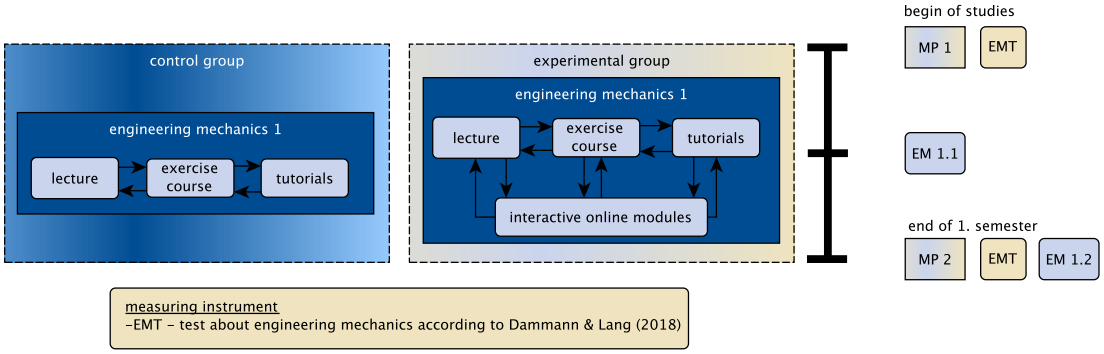

Figure 1. Longitudinal research design of FUNDAMENT – focussing on the first semester

The effectiveness of the IOM is determined by the results of the applied knowledge tests, the exam grades and the achieved credit points. The developed test instrument is based on the item pool of the engineering mechanics test (EMT) by Dammann & Lang (2018) - technical knowledge, subject-specific modeling ability and mathematical knowledge. It is used in a paper and pencil test in a multiple-choice-single-select test design (multi-matrix). The EM 1 exam was split in two parts which were written in the middle (EM 1.1) and the end of the first semester (EM 1.2). The operationalization of the IOM usage is done by recording the clicks in the EM 1 moodle course on corresponding links that forward to the learning videos or JACK exercises [2].

Demographic variables like gender, final school exam grade, last school grades (math, physics, chemistry, computer science and technology), native language and other educational background information are collected.

Conclusions such as the generalizability of the results regarding the effectiveness of the IOM are allowed due to the structure of the study as a collaborative research project.

Results

The first results regarding the usage of the IOM originate from one of the universities of the collaborative research project, the University of Duisburg-Essen. The examined cohort are the first-year students of the civil engineering studies in the winter semester 2018/2019. In order to be able to track the number of clicks on particular parts of the IOM (videos and JACK), it was necessary to obtain a consent from the students. Due to the EU data protection directive, this consent form is required for the recording and storage of the relevant data.

This initial situation has led to a total of 201 students agreeing to this consent form in the EM 1 moodle course. Thus, the data regarding clicks on videos and JACK are available for a cohort of n = 201. The cohort was split into four user groups based on the respective use of the IOM, it was differentiated whether the videos and / or JACK were used: 1. *videos and JACK*, 2. (only) *videos*, 3. (only) *JACK*, 4. *none* (of both). The splitting of the cohort into the

[2] JACK exercises are hereafter abbreviated as JACK.

corresponding groups can be found in Tab. 1. Here are the two groups *videos and JACK* or *JACK* of a same magnitude, the group without any use is less than half the size, while the group *videos* with just one user virtually does not exist.

IOM user groups	n	%
videos and JACK	85	42.3
videos	1	.5
JACK	80	39.8
none	35	17.4
total	201	100.0

Table 1. Classification into IOM user groups

If you add up the clicks separately, an individual student has made on a relevant link in the moodle environment (videos and / or JACK) and subdivide them into the aforementioned groups, you can see that the user group *videos and JACK* generated more clicks on JACK than the group *JACK*. In the following scatter diagram (Fig. 2), the respective click numbers are plotted for each individual student, the following color coding was used for the groups: green – *Videos and JACK*; red – *JACK*, yellow – *videos*, blue – *none*.

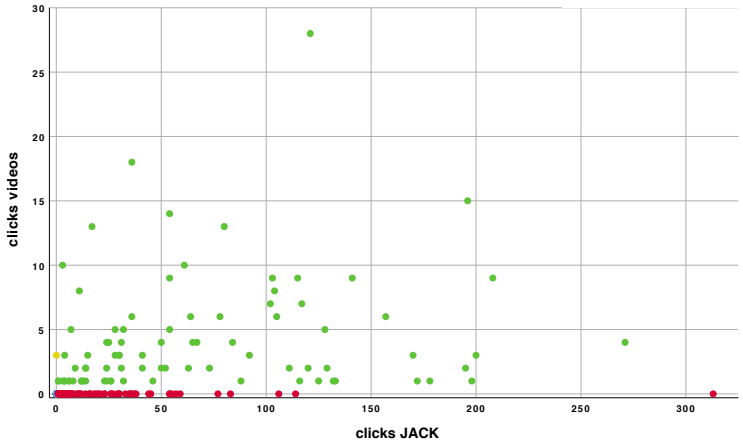

Figure 2. Number of IOM clicks (videos and JACK) divided into IOM user groups

The descriptive statistics concerning number of clicks in the classification of the IOM user groups are shown in Tab. 2. There are clearly differences in the use of JACK. The IOM user group *videos and JACK* has accessed JACK an average of 69.02 times, at 77 available exercises, these are almost 90%. While the *JACK* group has just accessed JACK 23.09 times, less than a third of the exercises. The videos were accessed 4.36 times on average by the user group *videos and JACK*, with four videos available. A comparison with the group *videos* is not listed due to the small number of students (n = 1).

IOM group	clicks	n	M	SD	min	max
total	videos	166	2.25	3.90	0	28
	JACK	166	46.47	57.16	0	313
JACK and videos	videos	85	4.36	4.53	1	28
	JACK	85	69.02	61.71	1	271
JACK	JACK	80	23.09	40.57	1	313

Table 2. Descriptive statistics regarding IOM clicks (videos and JACK) divided into IOM user groups

Personal data is not available for all students. Only 83 students answered the questionnaire for the collection of demographic data. A selection of the results can be found in Tab. 3. In addition to the age, the final school exam grade (Abitur - best: 1.0), the final grades of the subjects mathematics, physics, chemistry, computer science and technology (characteristic 1 - 15 points – best: 15) are listed. It turns out that the students of the examined cohort are

on average 21.34 years old and start their studies with a final school exam grade of 2.56. The bar chart in Fig. 3 shows the exact age distribution of the monitored cohort. While looking at the gender distribution, a distribution of 60.2 % men to 39.8 % women can be found. This already represents a fairly high women's quota for an engineering study program, usually ranging between 12 and 19 % (acatech, 2017). A characteristic of the location (in the Ruhr region) is the distribution of the native language, according to which just half (50.6 %) of the students state German as their native language.

	n	M	SD	min	max
age	83	21.34	2.82	19	35
final school exam grade	80	2.56	.65	1.0	3.7
grade math	72	9.50	2.47	5	15
grade physics	35	9.86	2.75	4	15
grade chemistry	31	9.58	2.78	6	15
grade computer science	12	11.08	3.48	6	15
grade technology	4	8.75	2.50	5	10

Table 3. Descriptive statistics regarding age, final school exam grade and final school grades

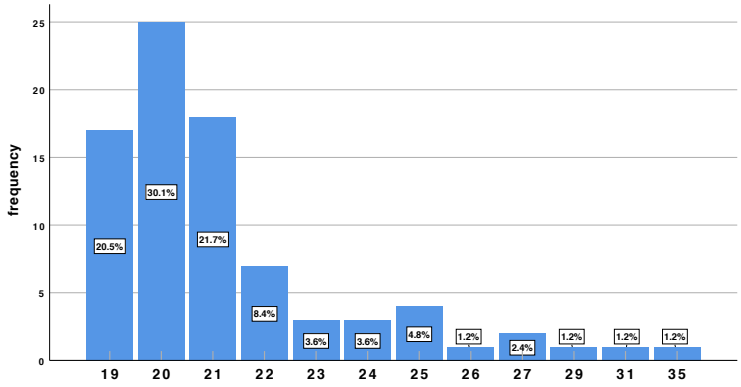

Figure 3. Age distribution

A closer look at the final school exam grade is shown in Fig. 4. In the diagram, the known IOM user groups were taken into account and the classification was made accordingly. The students of the user groups *Jack* respectively *videos and JACK* have better final school exam grades than those of the group without usage of the IOM at all.

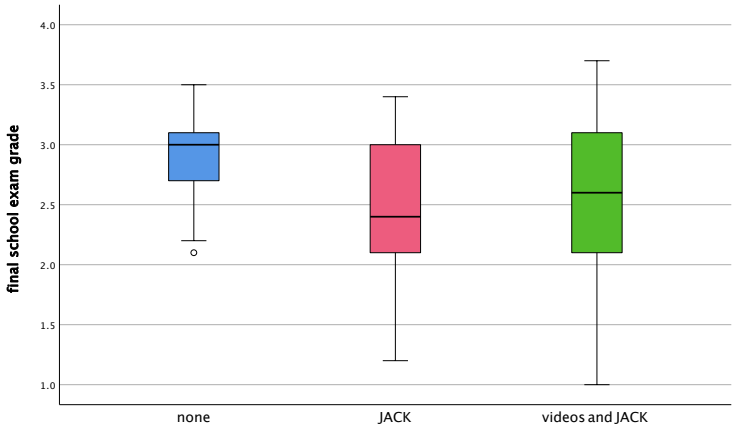

Figure 4. Final school exam grade divided into IOM user groups

In the following consideration, the final school exam grades were assigned to the following groups: A = 1.0 - 1.4, B = 1.5 - 2.4, C = 2.5 - 3.4, D = 3.5 - 4.0. In Fig. 5 you can identify the mean clicks on the videos or JACK. It can be seen that students with lower grades are aware of their need of coaching and respectively use the IOM. Even the particularly good students use the offers more frequently than the students within group B or C. There is no significant correlation between the clicks and the final school exam grade.

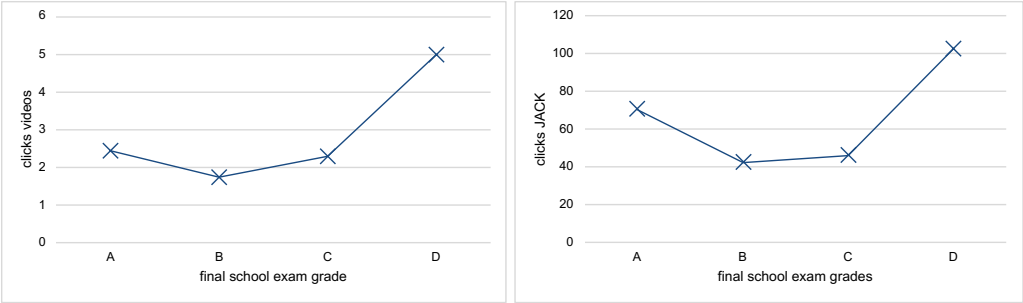

Figure 5. Mean clicks on IOM (videos and JACK) regarding the final school exam grade

The Ruhr region is known not only for a high percentage of non-native speakers, but also families with a low educational background. Therefore, the previously used representation is also applied for the presentation of the family educational background (Fig. 6). The family education background is divided according to the following classification: low = one parent has a vocational (non-academic) degree, average = both parents have a vocational (non-academic) degree, enhanced = one parent has an academic degree, high = both parents have an academic degree. As shown in Fig. 6, a higher family educational background means a more frequent usage of the IOM. But again, there is no significant correlation between the clicks and the family education background.

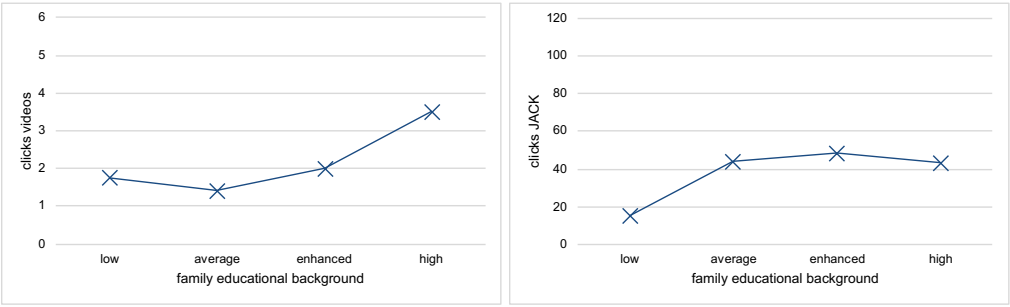

Figure 6. Mean clicks on IOM (videos and JACK) regarding the family educational background

In order to check the effectiveness of the usage of the IOM, the achieved person ability in the applied knowledge tests at the beginning (MP 1) and at the end of the first semester (MP 2) are used. The person ability was calculated according to the dichotomous Rasch model. Different test books with 68 (MP 1) respectively 59 (MP 2) items were used, which were anchored by 28 items. The tests showed satisfactory reliabilities and separations for the entire cohort (person reliability = .86, person separation = 2.45, item reliability .94, item separation = 3.93). To motivate the students to take part in the paper and pencil tests, a compensation of 20 EUR per student was paid, in addition, bonus points for the second partial exam (EM 1.2) were awarded for the participation at MP 2.

In Fig. 7 the error bars of the mean person ability at MP 1 are plotted. Generally, strong distinct error bars indicate a low number of members within the group. Focusing on the final school exam grade, it can be observed that it is a good indicator of the person ability at the beginning of the studies: better final school exam grades are leading to a better person ability. The family educational background also provides an insight into the person ability. As the educational background increases, a gain of the person ability can be observed.

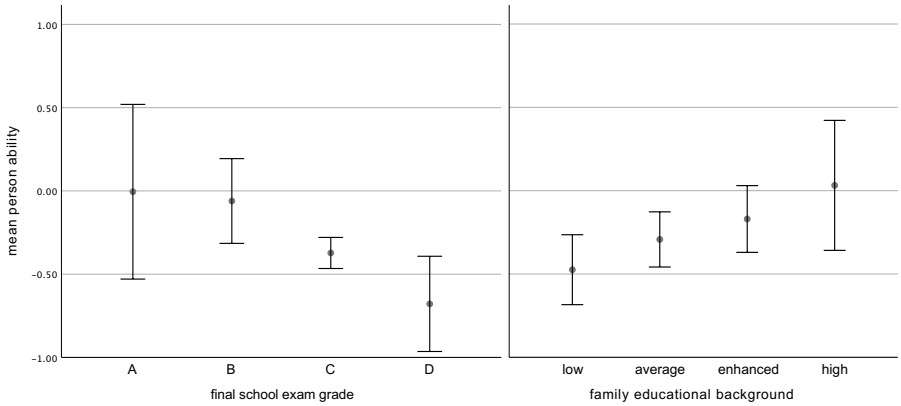

Figure 7. Error bars of the mean person ability of the final school grade and the family educational background

Tab. 4 shows the Pearson correlations between the IOM clicks and the achieved grades in the partial exams. There is a medium correlation between the achieved grade in the part exam EM 1.1 and the respectively clicks on JACK (including only the contents relevant for the first part exam). By contrast, the correlation between the JACK clicks (including only the contents relevant for the second part exam) and the achieved grade in the second part exam (EM 1.2) is not significant. A strong correlation can be found between the individual grades achieved in the partial exams.

		clicks video 1.1	clicks JACK 1.1	clicks JACK 1.2	grade EM 1.1
clicks	JACK 1.1	.430**			
	JACK 1.2	.142**	.335**		
grade	EM 1.1	-.024	-.336**		
	EM 1.2			-.166	-.735**

** < .01

Table 4. Correlation (Pearson) between IOM clicks and achieved grades in the part exams

Of the cohort considered so far, n = 34 students participated in both knowledge tests. The descriptive statistics of this subgroup are listed in Tab. 5. In addition to the number of clicks on the videos or JACK, the person ability achieved in the paper and pencil knowledge test at MP 1 and MP 2 are described.

The video click numbers with 3.26 are one click larger compared to the total cohort, the JACK clicks with 86.50 almost twice as large (cf. Tab. 2). This shows that the students in the subgroup are those who appear to have more motivation to participate in support measures, such as the performance tests or the IOM. The person ability achieved at the knowledge tests has improved as expected. It turns out that students who have used the IOM achieved better results in the knowledge test at MP 2. Unfortunately, a statement regarding the effectiveness of the IOM cannot be made at this point, because the control group consists of only two students and is thus too low for corresponding statements.

	n	M	SD	min	max
clicks videos	34	3.26	3.74	0	15
clicks JACK	34	86.50	73.47	0	271
person ability MP 1	34	.05	.60	-.93	1.73
person ability MP 2	34	.73	.76	-.90	2.51

Table 5. Descriptive statistics regarding IOM clicks (videos and JACK) and person ability achieved in the knowledge tests at MP 1 and MP 2

Summary

The results shown in the previous chapter indicate that the IOM are well accepted by the students. The cohort recorded an average of 0.56 clicks on each of the four available videos and 0.60 clicks on each of the 77 JACK. It is also interesting to take a look at the corresponding maximum values: accordingly, there were to a maximum extent 28 clicks on the videos, that is an average of seven clicks per video. At JACK, a maximum of 313 clicks were recorded, thus an average of almost 4 clicks per exercise.

In-depth statements regarding the effectiveness of IOM are not yet possible, because the number of students in the control group is too low. The first indications of an increase of the individual learning success already exist due to the higher person ability achieved in the paper and pencil test at MP 2 compared to the test at MP 1.

The presented results also point to the main problem of the study that, from a longitudinal perspective, it was not possible to convince a large number of students to participate in the individual paper and pencil tests at the MP. Already in the piloting this problem presented itself and could be attenuated by various changes to the research design. For example, the tests were changed from online tests to paper and pencil tests, and the subject compensation is now paid every MP and no longer after the participation in the entire study. With these changes it has been possible to collect data from 187 students at MP 1, however, it was only one third at MP 2. This number is reduced again by the fact that not all participants in MP 2 participated in MP 1, also not all granted their consent regarding the use of the IOM. These factors reduce the number of the considered subgroup to 34 students (Tab. 5) and result in a control group of just 2 students.

Another problem arises in the tracking of the use of the IOM. The operationalization used is based on the fact that the clicks on links in the EM moodle courses are interpreted as a complete viewing of a video or execution of JACK. As a result, only the pure clicks on a link are recorded, so it is not possible to see if a student completely watched the video at all. It would also be possible that, for example, a study group of several students looks at one screen, but this would count only as one click of one of these students. With JACK the recording of the usage is a bit more extensive, so it is possible to see if an exercise has actually been finished, also if the submission was correct or wrong. However, these data are not yet available, but will be examined in future analyzes.

The next steps in the framework of the collaborative research project are the collection of data at MP3 and related the verification of the effectiveness of the IOM in the second semester. Also, there will be profound analyzes of the data already available and still to be collected. Here, the data can be approached both site-specific as well as across both locations, in order to give generalizable statements regarding the developed digital support concept.

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