TECHNISCHE UNIVERSITÄT DRESDEN

Lessons Learned

Spin Offs of digital teaching experiences

2

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About the Journal

Due to the sudden and huge restrictions in face-to-face teaching brought about by the Corona pandemic starting with the summer term 2020, an unprecedented change and renewal of teaching formats has occurred. Even though these changes were forced by the restrictions due to the pandemic, the experiences and concepts that were developed are of enormous value for a renewal of teaching towards modern, digitally supported forms of teaching and learning and towards more competence-oriented learning. At the beginning of the winter term 2020/21, a conference entitled "Lessons Learned - Spin Offs of a Digital Semester" was held at the Faculty of Mechanical Engineering at the Dresden University of Technology to support this renewal through the exchange of experiences. A conference series has emerged from this first conference and at the same time the journal "Lessons Learned" was launched. The aim of this journal is to discuss new forms of teaching and learning not only in the mathematical and natural sciences and technical sciences, but far beyond in all subject disciplines and thus to create a platform where teachers can inform themselves about new concepts and adapt them for their own teaching.

The journal is deliberately published in two languages, both to make the experience gained accessible to an international audience and to ensure that the linked examples are accompanied by a text in the language of instruction in which they were produced. This means no additional work for the authors, as articles can be submitted in either German or English. Once an article has been accepted, the journal translates it into the other language, so that the authors only have to proofread the translated article.

Editorial Board

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Editorial

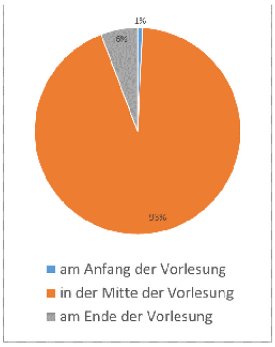
The second issue of the third year of the ***Lessons Learned Journal*** draws on some of the contributions from the fifth ***Lessons Learned conference*** in summer 2023. The contributions show - and this is as surprising as it is gratifying - that the contribution structure has changed over the course of the Lessons Learned conferences. While in the first years the focus was clearly on the findings from the corona semesters and thus clearly structured assignments of articles to individual subject areas were possible, we now see a holistic approach to the renewal of academic teaching, which is actually reflected in all contributions. This leads to the problem that a simple sorting of articles by categories such as "Flipped Classroom" or "Teaching Videos" is no longer possible (this time the sorting is simply by date of receipt). On the other hand, it is the gratifying document of the fact that the momentum created by the developments of the corona crisis has now become a permanent element in the development of academic teaching.

In addition, we see throughout the articles an intense desire on the part of teachers to incorporate student feedback into the development of their teaching. This results in truly student-centered teaching, and this can be seen in a wide variety of teaching and learning forms. The topic of evaluating teaching can be found in many articles and is also the subject of a separate article in this issue - and thus perhaps an impetus to look for evaluation options for teaching yourself, possibly using the modular system proposed in this article in order to go far beyond the standardized teaching evaluations of universities to obtain real feedback from students.

This is only the first part of the contributions to the fifth ***Lessons Learned Conference***. We anticipate that another, more extensive section will be published in the first half of 2024 in the first issue of Volume 4 of the ***Lessons Learned Journal***. And with that, I can already invite you to the ***sixth Lessons Learned Conference***, which will take place in summer 2024 and which we hope - like the previous conference - will have a massive impact on the development of academic teaching.

Stefan Odenbach

Many an experience from the corona period remains in the classroom, which now enriches teaching. And the general realization: "Teaching and learning is fun"!



What is good in teaching? This is a question that arises particularly in the case of changes and which we offer approaches to clarify this time.

Range of topics

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"Mechanics is fun"
Course Technical Mechanics - Statics/Strength of Materials - after 2 years of Corona

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Abstract

Since the winter semester (WS) 2016/17, the established and technically sophisticated teaching concept of technical mechanics at the Chair of Numerical and Experimental Solid Mechanics has been continuously expanded with digital components in order to improve the understanding of the content and increase the attractiveness of the course. These goals were achieved with a combination of classroom teaching and additional digital offerings.
The complete transition to online teaching in winter semester 2020/21 and the parallel provision of face-to-face and online courses in the following semesters led to an increase in failure rates.
Two theses can thus be derived from the experiences of the years 2020 to 2023: On the one hand, online or hybrid teaching in undergraduate studies will lose students, especially from the midfield, and on the other hand, open-ended online courses will promote high-performing students and overburden those with difficulties.

Seit dem Wintersemester (WS) 2016/17 wird das etablierte und fachlich ausgefeilte Lehrkonzept der Technischen Mechanik an der Professur für Numerische und Experimentelle Festköpermechanik stetig durch digitale Komponenten erweitert, um das Verständnis der Inhalte zu verbessern und die Attraktivität der Lehrveranstaltung (LV) zu steigern. Mit einer Kombination aus Präsenzlehre und zusätzlichen digitalen Angeboten wurden diese Ziele erreicht.
Der komplette Übergang in die Online-Lehre im WS 2020/21 und die parallelen Angebote von Präsenz- und Online-Angeboten in den darauffolgenden Semestern führten zu einer Erhöhung der Durchfallquoten.
Damit lassen sich zwei Thesen aus den Erfahrungen der Jahre 2020 bis 2023 ableiten: Zum einen gehen mit Online- bzw. hybrider Lehre im Grundstudium Studierende vor allem aus dem Mittelfeld verloren und zum anderen werden durch unbefristete Online-Angebote die leistungsstarken Studierenden gefördert und diejenigen mit Schwierigkeiten überfordert.

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This article was originally submitted in German.

1. Motivation

In mechanical engineering studies, the courses in technical mechanics (TM) - statics and strength of materials - always take place in the first to third semester. Students of Materials Science and Process and Natural Materials Engineering complete these courses after 2 semesters. In addition, students of mechatronics, electrical engineering, renewable energy systems, transport engineering and industrial engineering are also taught TM in separate courses.

Based on the established, solid, technically sophisticated and coordinated teaching concept of Professors H. Balke and V. Ulbricht, the courses are taught alternately by Professors Wallmersperger and Kästner and conclude with the module examinations after the first (TM Statics) and third semester (TM Strength of Materials). The courses are a prerequisite for the TM Kinematics/Kinetics course in the foundation course (one semester) and various courses in the advanced course, e.g. Numerical Methods, Elastic Structures, Continuum Mechanics and Materials Theory.

To increase the attractiveness of TM lectures, Professor Kästner's team developed various conventional and electronic course offerings and implemented them from the winter semester (WS) 2016/17. These include illustrative and practice-oriented examples and lecture questions to improve students' ability to absorb lecture content. The exercises were supplemented by learning groups for active preparation and more time for students to solve exercises independently. In addition to the quality of teaching, the aim is to make mechanics fun.

2. Teaching concept statics/strength of materials

Various further training courses within the faculty and through the e-learning area of TU Dresden have led to a continuous change in the teaching concept since the winter semester 2016/17. In a first step, the organization of the course was designed with OPAL courses.

Lectures:

The digital user interface of OPAL enables the preparation of lectures by means of corresponding reprints and illustrative animations as well as the publication of the digital script after the lecture.

In order to increase the absorption capacity during the lecture, practically relevant lecture questions are asked in the middle of the lecture, which the students can answer together and upload their solution via a QR code. Once the correct solution has been evaluated, it is possible to return to the lecture without any problems. The Particify software used is an EU-funded ARS system that guarantees compliance with EU data protection guidelines.

In parallel to the lectures, 4 online lecture quizzes, each with 10 questions on technical mechanics, are set each semester, which students can solve independently. After initially being offered on a voluntary basis, the evaluations showed that the majority of students only accepted the use of these tests when they had the opportunity to gain bonus points for the upcoming examinations.

Exercises:

In the TM, the exercises take place weekly in parallel exercise rooms, usually on 2 dates. The respective tutors introduce the topic of the exercise in a 15-30 minute lecture. Afterwards, the focus is on solving the exercises independently with appropriate help from the tutors.

At the suggestion of Professor Odenbach, the formation of learning groups among the students and the joint solution of practical tasks was promoted. On the one hand, this was intended to facilitate joint learning, the solution of practical examples and, on the other, better preparation for the respective exercise. The latter in particular was achieved in conjunction with the offer of a bonus point for the respective examination.

One focus of the TM course is the calculation of internal reactions in different load-bearing structures. In order to convey this to the students in a clear and playful way, a browserbased program (game) was created with which the students are interactively shown the effects of different loads on a beam.

Examinations:

Checking the examinations traditionally represents a major effort for the staff of the professorship. For this reason, the format of the examinations was changed from winter semester 14/15. The focus of the exams is now on mechanical questions and the weight of mathematical problems has been reduced. At the same time, short, structured tasks have been introduced to reduce the problem of subsequent errors and avoid complex tasks. We are aware of the implications of this decision and the discussion within the professorship is still ongoing. The disadvantage of dispensing with complex tasks must be accepted.

The advantage of this approach is the possibility of querying more mechanical content. This is supported by the lecture quizzes, which open up an additional list of questions for the exams. At the same time, this reduces the amount of checking required.

Results:

The implementation of this concept with the expansion of lectures and exercises through e-learning offerings and the change in examination formats primarily increases the attractiveness of the courses and acceptance by students and takes into account the number of budget employees without reducing the quality of teaching. This is reflected in the evaluations of courses by students and the awarding of the prize for innovation in teaching to Professor Kästner in 2017 and 2023.

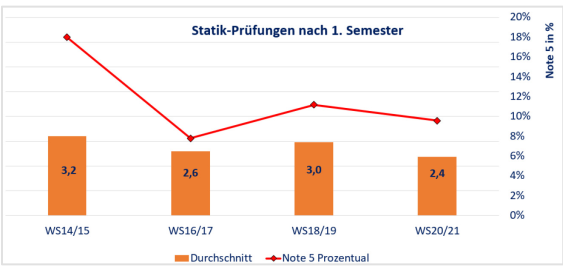

Fig. 1: Comparison of static tests from WS14/15 to WS20/21

A comparison of the examination results from WS14/15 to WS20/21 only reflects this success to a limited extent, see Fig. 1. It is clear that although the average grade has only changed marginally, the failure rate has fallen. It should be noted that significantly more mechanical content was tested in the examinations.

3. Online offers

With the start of the corona pandemic, the use of online offerings for teaching became unavoidable. Based on our previous experience and the expansion of the teaching concept with e-learning methods, we were not unprepared for this change. Nevertheless, the creation of further courses was necessary and the implementation had to be updated.

For some of the lectures, it was possible to use video recordings for distance learning. However, it was necessary to record further courses from the home office. The experience that video recordings are better accepted by students when the lecturer or trainer is visually visible was taken into account.

As a result, digital recordings of all lectures and introductory tutorials were created during this time, which took a very long time. It is worth noting that recordings of Power Point applications set to music lagged behind the live recordings of lectures and exercise introductions in terms of acceptance by the students.

The implementation of the lecture questions, the learning group tasks and lecture quizzes required a corresponding update, but did not present us with problems in terms of content, only time.

Only the TM Statics exam in WS20/21 had to be implemented as an online exam. The implementation showed that this variant of the exam with the means we chose could not fully realize the necessary competencies of a mechanics exam with sketches and free individual solution paths. The result of this exam cannot be used for an evaluation, as our own experience with online exams was too limited and the exam questions were therefore perhaps too easy.

Comparison of presence - online - teaching

Irrespective of the above information on the examination formats, the effect of online teaching in times of Corona can be compared with the results from pure face-to-face teaching. This enables the examination of TM

Strength of Materials from WS19/20 and WS21/22, see Fig. 2.

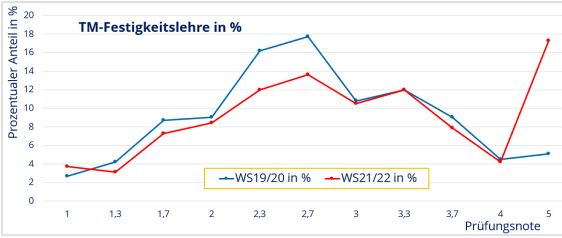

Fig. 2: Comparison of online versus face-to-face teaching

Both exams took place in person and the same exam with identical tasks was deliberately written on both dates.

The percentage results (the number of examinees is different: WS18/19-347 and WS21/22-191) show that online teaching on the one hand greatly increases the failure rate and on the other hand reduces the midfield. This leads us to the following thesis: ***"With online or hybrid teaching, students are mainly lost from the midfield in undergraduate studies."***

Following the requirements for online teaching, it was possible to return to face-to-face teaching in the last few semesters. This step was a great relief for everyone involved on the teaching side. It was finally possible to look at faces again and not just at black screens. Nevertheless, a return to full face-to-face teaching does not appear to be expedient in view of the many online offerings. For this reason, in WS22/23, in addition to the lectures and exercises in presence, the available lecture videos were also made available to students in TM Statics from the presentation date until the examination.

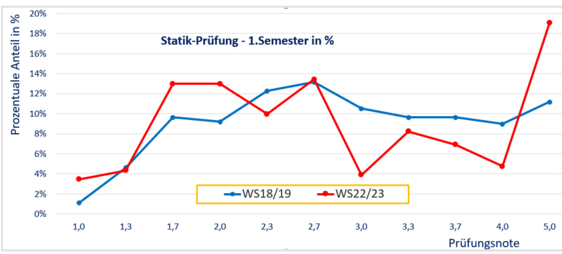

Fig. 3: Comparison with/without online offers

This enables individual learning without restrictions in the acquisition of knowledge and a wider range of courses. This is in line with our understanding of teaching - a wide range of options and students can choose the best way for them to acquire knowledge.

However, a comparison of the examination results of TM Statics from WS18/19 and the last semester WS22/23 shows a different result, see Fig. 3.

It is clear that the number of above-average grades is increasing, while the failure rate has doubled. Apparently, the greater choice of courses on offer for acquiring knowledge leads to a higher failure rate, as not all students make use of the wider range of courses on offer. Some limit themselves to the online offerings (the number of participants in the face-to-face courses is significantly lower than the number of exam participants). An alternative could be temporary online courses that require more continuous learning. These results substantiate another thesis: "***With open-ended online courses, the high-performers are encouraged and students with difficulties are overburdened!***"

4. Outlook

Even if some of the results are very sobering, the online offerings for students should be continued. There will be no problems with the further implementation of the lecture questions as concentration breaks in the lectures, the descriptive animations, the accompanying online tests and the interactive applications. The introduction of new examination regulations is imminent and provides for a significant reduction in technical mechanics in the foundation course as well as restrictions in the assessment design of modules. Against this background, it will be more difficult to anchor the learning group tasks in the future course of study. Due to the reduced scope of our courses in the faculty's training concept, concentrated knowledge transfer must be strengthened in order to provide students with comprehensive and competitive basic mechanical knowledge in the future.

Irrespective of this, our focus will continue to be on conveying the joy of studying technical mechanics. This will automatically increase students' willingness to be active and work independently.

With this in mind, **"Mechanics should be fun in spite of unstable equilibrium!"**

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Use of concept maps in university education in the field of control technology

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Abstract

In the context of this study $n = 16$ students in the diploma program in mechanical engineering created concept maps on the content of the lecture previously given in the module "Control of Production Machines and Systems". The concept maps were then evaluated according to three criteria described in more detail here. As a basis for the evaluation of the individual concept maps, they were compared with a reference map prepared by three experts in the field of mechatronics within the scope of this study. Immediately after the creation of the maps, the students answered a questionnaire that included demographic data as well as a self-assessment survey on concept mapping. The 10 items of this sheet are assigned to the subject characteristics interestingness, usefulness and manageability. The subject characteristics and evaluation criteria were examined for initial dependencies. The tendency showed that the students generally evaluate the method of concept mapping as positive, despite first-time application and shortened introduction.

Im Rahmen dieser Studie erstellten $n = 16$ Studierende, im Diplomstudiengang Maschinenbau, Concept Maps (Cmaps) zum Inhalt der zuvor gehaltenen Vorlesung im Modul "Steuerung von Produktionsmaschinen und Anlagen". Die Cmaps wurden anschließend nach drei hier näher beschriebenen Kriterien bewertet. Als Grundlage für die Bewertung der einzelnen Cmaps, wurden diese mit einer Referenzmap verglichen, die von drei Experten auf dem Gebiet der Mechatronik im Rahmen dieser Studie angefertigt wurde. Unmittelbar nach der Erstellung der Cmaps beantworteten die Studierenden einen Fragenkatalog, der neben demografischen Daten auch einen Selbsteinschätzungsbogen zum Concept Mapping umfasst. Die 10 Items dieses Bogens werden den Probandenmerkmalen Interessantheit, Nützlichkeit und Handhabbarkeit zugeordnet. Die Probandenmerkmale und Bewertungskriterien wurden auf erste Abhängigkeiten untersucht. In der Tendenz zeigte sich, dass die Studierenden die Methode des Concept Mapping, trotz erstmaliger Anwendung und verkürzter Einführung, generell als positiv bewerten.

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1. Introduction and problem definition

During the ongoing digital transformation in manufacturing companies towards "Industry 4.0", engineers in the field of mechatronics are faced with the challenge of dealing with increasingly complex technical machines and systems in their professional work [1]. In addition to working on the devices themselves, the focus is on the physical and virtual networking of the individual technical components and stations. This makes it necessary not to view the systems in isolation, but rather to understand them as an interconnected overall system [2]. The authors Spöttl et al. interviewed personnel in companies in the metal and electrical industry and found that "skilled workers [...] think and optimize systems and their function from the point of view of processes and software. This requires a completely different understanding than was necessary for mechanically and electrically operated systems" [3].

The technical focus of this study is on *the digital twin*, which is becoming increasingly important as an enabler in the construction and design process, in the commissioning of cyber-physical production systems and in their operation. [4]. It serves as a digital image of reality, usually with bidirectional data exchange between the real and digital systems, and can be created and used for processes, products, plant components or entire factories [5]. However, the term itself is not clearly defined, which is why there are always misunderstandings in interdisciplinary collaboration when dealing with the term, as well as associated terms such as "model", "simulation" and others.

Within the university education of prospective engineers in the field of control technology at the Technical University of Dresden, the necessary specialist content and skills are taught in lectures, followed by in-depth study in seminars and assessment at the end of the semester by means of written examinations. As a result, both the lecturers and the students themselves receive little information about the current level of knowledge during the semester, for example to enable the lecturers to adapt the course sequences/content of the courses and the students to adapt their individual learning focus.

This study examines the potential of concept mapping for deepening and reflecting on the content of lectures using the example of the "digital twin". In contrast to many other methods for capturing knowledge, the use of concept maps offers the advantage that not only isolated factual knowledge but also conceptual overview knowledge can be captured [6].

2. Technical background to the digital twin

The digital twin (DT) is one of the technologies that have found their way into the manufacturing industry with digitalization and is counted among the Industry 4.0 technologies. It belongs to the field of modeling technical systems and describes a digital model of a system that is in a bidirectional, automatic data exchange with its physical counterpart (production system, plant, product, process). In contrast to this, the digital shadow (DS) only has an automatic data flow from the physical to the digital object, making the DT an extension of the DS. Depending on the use case and the need for information processing that the DT is to perform, it can contain a functional, behavioral or structural model or a combination of the aforementioned model types.

In general, the DT is used to solve problems or to investigate the effect of operations that are not appropriate, not possible, or too dangerous on the original. In these cases, one speaks of a simulation.

The ability to carry out tests (simulations) on the DT without the need for hardware and very quickly makes it ideal for feasibility analyses, variant investigations, and studies, analyzing interactions between machine and process and pre-commissioning production systems, which is also known as virtual commissioning (VIBN). In the operating phase, the DT can be used for the "virtual measurement" of non-measurable physical variables or production-parallel optimization of the process.

3. Theoretical background and state of research on concept mapping

Concept maps are two-dimensional networks of terms that are usually used to answer a focus question or problem. The task when creating the maps is to link different terms, referred to below as "concepts", with each other in such a way that as many correct statements as possible are created [7]. For this purpose, the concepts can be arranged arbitrarily on the map and connected to each other with arrows if the two terms are related according to the creator's idea. These arrows are then labeled with "relations" to specify the contextual connection between the concepts. Each directed arrow and the labeling then result in a statement known as a "preposition" in the form of a group of words or a sentence. For the example in Figure 1, the following three prepositions result:

- "Simulation enables virtual commissioning",
- "Simulation works with functional model" and
- "Simulation works with behavioral model".

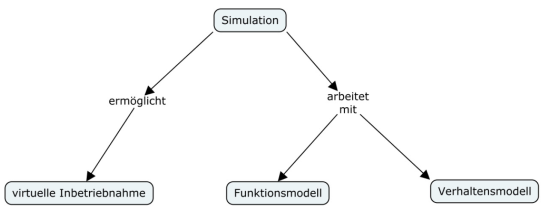

Fig. 1: A section of the reference map created as part of this study is shown.

The origins of this method were first published by Stewart, Van Kirk and Rowell [8], who created a concept network for the article in the journal *The American Biology Teacher* and presented it to the scientific community as a "concept map". Initially, these networks only consisted of terms connected by dashes without arrow connections. As a result, it was impossible to form prepositions and closer analyses of individual concept maps were only possible to a limited extent. One article that significantly advanced concept mapping in relation to the present day was by Joseph D. Novak [9], the then Professor of Education and Biological Sciences at Cornell University, who has always been one of the most important researchers in this field. In the aforementioned article, the concept maps contained directed and labeled arrows for the first time, making it possible to read out meaningful groups of words or sentences. According to his own statement, Novak developed concept mapping as early as 1972 together with students when they were looking for a way to analyze Ausubel's [10, 11] "assimilation theory". looking for a way to better represent "what the learner already knows" better [12]. The *Novakian concept* maps spread across the entire planet from this point onwards, with *Learning how to learn* [13] considered one of the most important early contributions to the field. Since then, the method has become increasingly popular and has been used in many studies, examined in more detail and constantly expanded. For in-depth literature on changes over time in the creation of concept maps, please refer to the article *Varieties of concept mapping* by Mauri Åhlberg [14], who was able to identify ten elements for improving the method compared to the original article by Novak and Gowin [13] in his literature research.

Since the late 1970s and early 1980s, the concept mapping method has been used in a wide variety of research and teaching applications. The main areas of application are:

- as a means of knowledge diagnostics in scientific studies,
- as a teaching method in the teaching-learning process,
- as a feedback method for teachers and learners and
- as an assessment tool.

The meta-analysis conducted by Schröder, Nesbit, Anguiano and Adesope [15], in which experimental studies on concept mapping from 1972 to 2014 were examined in more detail regarding learning success, the mean effect size for concept mapping showed a mean positive effect ($g = 0.58$) in favor of learning activities with concept maps. Additional results that are particularly relevant for use in university education are that the effect is greater if the students create the concept maps themselves ($g = 0.72$) instead of working with ready-made maps ($g = 0.43$ for students and pupils in grades 4 to 12 and $g = 0.32$ especially for students), if the method is used regularly ($g = 0.36$ before and $g = 0.68$ after a week) and that the effect is independent of whether the topic of the concept map is STEM or non-STEM [16].

The use of concept mapping as a feedback method in university education has also been evaluated positively in various studies. For example, the studies by Daley and Torre [17] in the field of medicine, Becker et al. medicine, Becker et al [18] in biology, Joseph et al [19] in physiotherapy, Lachner et al [20] in the field of educational science and Vodovozov and Raud [21] in the field of power electronics.

For use as a diagnostic tool, feedback method and assessment instrument, it must be possible to evaluate the concept maps according to previously defined criteria. In his article, Graf distinguishes between the following evaluation methods [22]:

- global evaluation strategy according to Novak,
- Differential diagnosis of individual terms,
- Aspects of graph theory and
- Comparison with a reference map.

The following table shows which parameters of a concept map are considered in the respective evaluation method used.

These are: *hierarchical organization* (1); *interconnectedness* (2); *structuredness* (3); *degree of interconnectedness* (4); *scope/richness* (5); *linkage density* (6); *fissuredness* (7) and *correspondence coefficients* (8).

Table 1: Comparison of the different concept mapping methods according to Graf

	1	2	3	4	5	6	7	8
Novak	X	X	X					
Differential diagnosis				X	X			
Graph-theor. aspects					X	X	X	
Expert map								X

Graf deduces from this that although the evaluation according to Novak, the examination according to graph-theoretical aspects and the comparison with a reference map created by experts examine different parameters in detail, the focus is on the overall assessment of the concept map, whereby the content of statements made is not considered. In the differential diagnosis of individual terms, on the other hand, the focus is exclusively on analyzing the statements made, which result from the concepts, the direction of the arrow and the preposition and can be technically correct or incorrect. It becomes clear that the methods must be combined to ensure a holistic evaluation of the concept maps, taking into account as many of the parameters as possible.

Important factors to consider when creating a concept map are general guidelines for the structure. Firstly, the maximum number of concepts and secondly, the individual design of the structure of the concept network should be defined. Research results show that a maximum number of 15 to 25 concepts per concept network should not be exceeded in order to ensure clarity in the concept map [23].

In the area of Industry 4.0 and cyber-physical production systems, there have not yet been any experimental studies on the use of concept mapping in engineering education. This justifies the need for studies to be carried out in this area.

4. Research questions

Derived from the previous chapters, the following research questions arise, which are to be answered in the context of the article be answered in this article:

(1) How do students rate the concept mapping method regarding the test subject characteristics *of interest*, *usefulness,* and *manageability*?

(2) In which courses do students consider the concept mapping method to be useful?

(3) What differences are there between the reference map created by experts as part of the study and the novice concept maps created by the students?

5. Research design

The data was collected as part of the second lecture in the module "Control of production machines and systems" on the topic of "Information processing and digital twin".

The study involved $n = 16$ students on the mechanical engineering degree course. Within the first 65 minutes of the 90 minutes course, subject-specific content was taught in a content was taught in a more traditional teaching-learning format. This was followed by a short five-minute introduction based on the *concept mapping training program* by Sumfleth et al [24] to familiarize the students with the method. In the remaining 20 minutes, the students created the concept map with pen on paper and answered the self-assessment questionnaire.

Due to the limited time span of 90 minutes, the training program had to be shortened so that all the subject content relevant to the creation of the concept map could be taught and the students still had enough time to create the concept map and complete the questionnaire. Ten concepts were specified for the concept map about the focus question "How do the following terms relate to the topic of digital twins?". The number of concepts was set at ten to reduce complexity. This was intended to avoid potentially overwhelming the students due to an excessively high number of given terms was to be minimized. In order not to inhibit the participants' creativity and since no special structuring options are presented in the concept mapping training program, it was decided that the concepts could be arranged in any order and related to each other with arbitrary relationships. arbitrary relations to each other.

The following ten terms were jointly selected by the three experts in line with the lecture content:

Model, system, digital model, structural model, behavioral model, functional model, digital twin, digital shadow, virtual commissioning, simulation.

As part of the study, an evaluation procedure was used in which each concept map was analyzed and concept map is analyzed and evaluated according to three criteria. Each evaluation criterion can have a value of 0 to 1 whereby the higher the respective values, the better the result. Based on the findings of McClure et al [25] regarding the reliability of the evaluation of concept maps, a reference map was created and used for the evaluation. To this end, three experts in the field of mechatronics, two university lecturers and one vocational schoolteacher, initially each created a concept map independently of one another. The guidelines were identical to those that the students had to follow. The concept maps were then presented to the other experts one after the other and they then jointly created the concept map shown in Figure 2 using the freely available program *CmapTools*. The advantages of this software tool are described in explained in more detail in the work of Cañas et al [26].

The individual evaluation criteria are listed in more detail below:

(1) *Scope/interconnectedness* x_{UV}:

This value indicates the degree of cross-linking of the concept map in relation to the reference map. For this purpose, the total number of arrow connections $n_{\mathrm{Ü}}$ that match those of the reference map is compared to the total number

$$x_{\mathrm{UV}} = \frac{n_{\mathrm{Ü}}}{n_{\mathrm{Ref}}} \qquad (1)$$

of connections of the reference map n_{Ref} is set.

(2) *Degree of compliance* $x_{\mathrm{ÜG}}$:

The next step is to examine how many of the total number of arrow connections in the concept map created by the test subjects match those in the reference map. To do this, the matching connections are compared

$$x_{\mathrm{ÜG}} = \frac{n_{\mathrm{Ü}}}{n_{\mathrm{V}}} \qquad (2)$$

to the total number n_{V} of connections made.

The criteria scope/interconnectedness and degree of conformity are independent of the selected relations and therefore do not consider the content-related connections between the concepts. As the two values are directly related, they are also multiplied together, resulting in x_{Str} a measure of the general *structuredness* of the concept map:

$$x_{\mathrm{Str}} = x_{\mathrm{UV}} \cdot x_{\mathrm{ÜG}} \qquad (3)$$

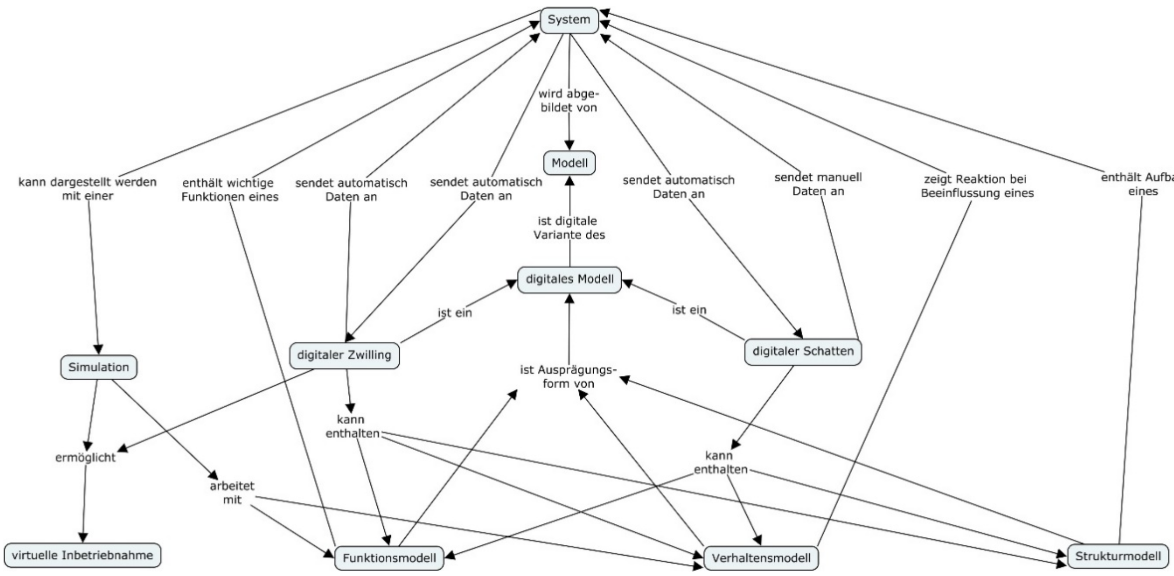

Fig. 2: The illustration shows the concept map on the topic of the "digital twin", which was created by three experts and serves as a reference map for the study. The CmapTools program was used to create the map.

(3) *Consistency of content* $x_{\text{IÜ}}$:

The relations of the matching arrow connections are then checked for professional correctness by matching them with the reference map. The value for $x_{\text{IÜ}}$ results from the ratio

$$x_{\text{IÜ}} = \frac{n_{\text{IÜ}}}{n_{\text{Ü}}} \qquad (4)$$

of the total number of technically correct cross-connections $n_{\text{IÜ}}$ to $n_{\text{Ü}}$.

The use of these three evaluation criteria is intended to ensure that as many of Graf's parameters as possible are considered in the evaluation.

For the self-assessment questionnaire, the *sub-questionnaire for assessing concept mapping was* used, based on the study by Ryssel [27]. The possible answers to the 10 items are coded with numbers ("strongly disagree" = 1"strongly disagree" = 2, "somewhat true = 3" and "strongly agree" = 4), assigned to the respondent characteristics *interestingness*, *manageability* and *usefulness* and then transferred to the SPSS program. The negatively polarized answers are converted beforehand. Assuming an ordinal scale, the mode and median for the individual respondent characteristics can be calculated from the data set.

The questionnaire also included the age, gender, and previous knowledge of concept mapping were also recorded in the questionnaire, as well as possible areas of application for the concept mapping method in university engineering education.

6. Evaluation

The socio-demographic attributes of age and gender recorded in the questionnaire, as well as the proportion of students who have already worked with the concept mapping method, are shown in Table 2. It should be emphasized that the proportion of female students with 18.8 % is very low and only 12.5 % of the students had previous experience with concept mapping.

Table 2: Descriptive description of the participants

Attribute	Students
Quantity	16
Age	24.4 a
Participants	18.8 %
Experienced in concept mapping	12.5 %

The first research question was investigated by means of a self-assessment questionnaire, which had to be completed immediately after the creation of the concept map. From the available data, the mode and median were determined for the subject characteristics from the available data (Table 3). The characteristics *usefulness* and *interestingness*, with values > 2.5 as positive ("rather true") and *manageability* with values < 2.5 as negative ("tends not to apply").

Table 3: Mode and median for the subject characteristics determined in the studies.

Feature	Mode	Median
Usefulness	3	3
Interestingness	3	3
Manageability	2	2

The second research question is answered using an additional, open-ended question. Here, the students were asked to indicate in which university courses they consider the use of the concept mapping method to be useful. Only eleven of the sixteen participants answered the question. The students gave the following answers, with the number of answers in brackets, whereby very similar answers were summarized:

- Lectures in which theoretical content is taught (and no math is done) (4),
- Lectures in which the basics are taught (2),
- in every lecture or in most of the lectures (2),
- Control of production machines and -plants (1) and
- None or I do not think that this deeper knowledge, modeling I achieve it differently (2).

It turns out that $n = 9$ of the students were able to name concrete application examples in which they consider the use of the concept mapping method as part of the university education of engineers.

The third research question was answered by evaluating the students' individual concept maps of the students according to the three evaluation criteria of *scope/interconnectedness*, *degree of conformity* and *consistency of content* as well as the combined criterion *of structuredness*. The calculation of the evaluation criteria is explained in more detail below for the concept maps of two students (Figures 3 and 4). For this purpose, two concept maps were specifically selected that differ significantly at first glance in terms of scope (number of arrow connections) and quality (number of arrow labels):

Scope/Interconnectedness

- for "GS01A" results in $n_{\text{Ü}} = 6$ and $n_{\text{Ref}} = 24$ the value $\boldsymbol{x}_{\mathbf{UV}} = \mathbf{0.25}$ and
- for "HE01B" with $n_{\text{Ü}} = 13$ the value $\boldsymbol{x}_{\mathbf{UV}} = \mathbf{0.54}$.

Degree of Conformity

- for "GS01A" results in $n_{\text{V}} = 10$ the value $\boldsymbol{x}_{\mathbf{ÜG}} = \mathbf{0.60}$ and
- for "HE01B" with $n_{\text{V}} = 17$ the value $\boldsymbol{x}_{\mathbf{ÜG}} = \mathbf{0.76}$.

Structuredness:

- for "GS01A" results in the value $\boldsymbol{x}_{\mathbf{Str}} = \mathbf{0.15}$ and
- for "HE01B" the value $\boldsymbol{x}_{\mathbf{Str}} = \mathbf{0.41}$.

Consistency of Content:

- for "GS01A" results in $n_{\text{IÜ}} = 0$ the value $\boldsymbol{x}_{\mathbf{IÜ}} = \mathbf{0.00}$ and
- for "HE01B" with $n_{\text{IÜ}} = 12$ the value $\boldsymbol{x}_{\mathbf{IÜ}} = \mathbf{0.92}$.

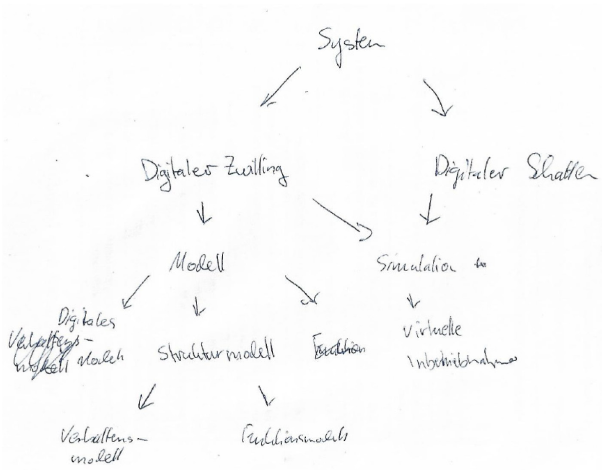

Fig. 3: The concept map of student "GS01A" has 10 arrow connections, 6 of which correspond to the reference map and none of which have been labeled.

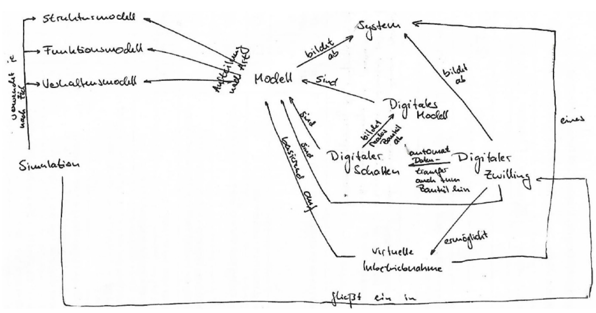

Fig. 4: The concept map of student "HE01B" has 17 arrow connections labeled with relations. Of these, 13 match those of the reference map.

The results of the evaluation are shown in Figure 5 for the individual evaluation criteria in the form of a box plot.

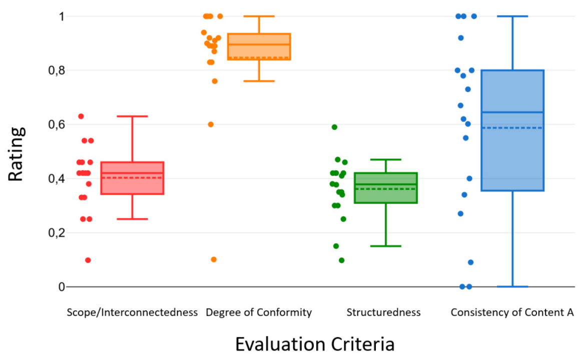

Fig. 5: The evaluation results for the respective criteria are shown in the form of a box plot.

For the criterion *scope/interconnectedness*, the mean value was 0.42 with a standard deviation of 0.1. The students thus made an average of 10.1 ± 2.3 arrow connections, which correspond to those chosen by the experts.

The *degree of conformity* resulted in a mean value of 0.89 also with a standard deviation of 0.1. From this it can be deduced that on average only $11\ \%$ of the arrow connections made by the students do not match those from the expert map.

In order to exclude extremes such as for example, to connect all terms with arrows ($x_{\text{UV}} = 1.0$) or only making an obvious arrow connection ($x_{\text{ÜG}} = 1.0$) are rated as positive, both criteria should criteria should always be set in relation to each other in order to be able to evaluate the structure of the concept map as a whole. For the combined criterion of *structuredness,* a mean value of 0.38 with $s = 0.1$.

Due to the high scatter ($n = 3$ subjects with the value 1 *and* $n = 3$ subjects with values < 0.1) and a large standard deviation of 0.34 for the criterion of *consistency of content A*, the value of *consistency of content B* was also determined (Figure 6). This was done under the assumption that students from whose concept maps no preposition formation was possible for less than 33% of the of the arrow connections made, because they either had no arrow direction and/or no relations were present, had comprehension problems when implementing the concept mapping method or linguistic problems when formulating the prepositions.

For *consistency of content B*, the four students in question were not considered. Under this assumption, the standard deviation could be reduced by $47\ \%$ to $s\ =\ 0{,}18$ could be reduced by this assumption.

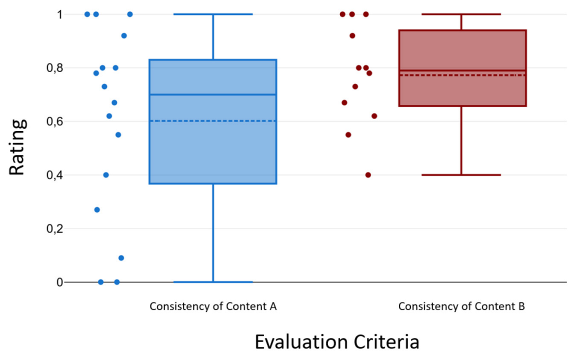

Fig. 6: The evaluation criterion Content match B results from the reduced sample.

For the criterion of *consistency of content A*, the mean value was 0.60. Considering the results of the criterion *scope/interconnectedness,* the students thus formed an average of 6.1 correct relations per concept map. For the reduced sample, the value for *consistency of content B was* 0.77. Based on the assumption made above, it can be that students who were able to internalize the method formed an average of 7.8 correct relations.

7. Discussion/Limitation/Outlook

This study has shown that the use of concept maps in the field of control technology has great potential. potential. To this end, 16 students each created a concept map on the complex topic of digital twins, which were then evaluated by comparing each map with a reference map created by experts according to the three evaluation criteria described here: *scope/interconnectedness*, *degree of conformity* and *consistency of content*.

The evaluation showed that an average concept map of the students has 11.3 arrow connections, of which 10.1 match the reference map and per map 6.1 (7.8 with a reduced sample for the *content match* criterion) can form technically correct prepositions.

In addition, a questionnaire on the assessment of concept mapping, which had to be completed directly to be completed directly after the concept map was created, showed that students find the method interesting and useful. More than half of the students were able to name specific areas of application for university engineering education. The manageability of the method was rated below average, which could be improved, for example, by a more intensive introduction and/or regular use.

In the following, further studies in this in this area, due to the small sample of students $n = 16$ students will be necessary to verify or falsify the results of the study. Only then will it be possible to derive concrete recommendations for action regarding the use of concept mapping in the university education of engineers in the field of control technology. Initial results are also promising results on the use of concept maps by prospective mechatronics engineers as part of vocational school lessons are also promising [28]. Increased work with digital tools (e.g. *CmapTools*) is also very well suited, for example, to develop an automated evaluation procedure that can be use of automatic image recognition.

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The path to creating subject-specific teaching videos for vocational teacher training

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Abstract

The measurement and automation technology module is used as an example to show how a content-adapted, flexible, practice-relevant, practicable and modern teaching and learning format was developed for student teachers at vocational schools. In this context, a guideline is provided to enable the knowledge gained, the necessary work steps and the challenges of such a redesign of a module to be transferred to other modules. On the one hand, the methodology is kept general so that a transfer can take place regardless of the module or field of study, while at the same time explicit assistance, tips and examples are provided.

Anhand des Moduls Mess- und Automatisierungstechnik wird beispielhaft gezeigt, wie für Lehramtsstudierende der Berufsschulen ein inhaltlich angepasstes, flexibles, praxisrelevantes, umsetzbares und modernes Lehr-Lernformat entwickelt wurde. In diesem Zusammenhang wird ein Leitfaden gegeben, um die gewonnenen Erkenntnisse, die notwendigen Arbeitsschritte und die Herausforderungen einer solchen Umgestaltung eines Modules auf weitere Module übertragen zu können. Die Methodik ist einerseits allgemein gehalten, so dass ein Transfer unabhängig vom Modul bzw. der Studienrichtung erfolgen kann, während gleichzeitig explizite Hilfestellungen, Hinweise und Beispiele gegeben werden.

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Why all this?

The design of courses is a constant topic in educational institutions. The demand for practice-oriented teaching tailored to the target group is set against the regulations for creating modules and the (time) limited capacities of teachers.

A small group of people such as the group of prospective vocational school teachers poses a major challenge for every teaching staff. No separate modules are offered for this group, but they are assigned modules from various fields of study that have a certain overlap with the future teaching area. However, these courses do not contain all the relevant topics and/or do not cover the required material. In addition, the combination of modules from different fields of study means that individual courses overlap. However, face-to-face teaching does not offer any flexibility and limits students' ability to attend all of the planned modules within a semester. This leads to students taking significantly longer than planned to complete their studies or even dropping out [1]. In view of the shortage of teachers at vocational schools throughout Germany [2-4], there is an urgent need for action.

To counter this, educational institutions need to develop alternatives. A combination of teaching videos with blended learning formats such as the flipped classroom can meet the demand for subject-specific content for small groups and also give students the opportunity to flexibly design their learning plan in combination with an application-oriented and practice-based examination.

Initial situation

Creating an educational video can be a great way to convey learning content in an innovative way. However, the production of such a video is also a major challenge. Starting with the content preparation and implementation, framework conditions such as the technical equipment are also important elements that need to be carefully planned at the beginning to ensure smooth and efficient video production. We would like to provide a guide from the curriculum analysis to the finished video. The various steps are shown in Fig. 1.

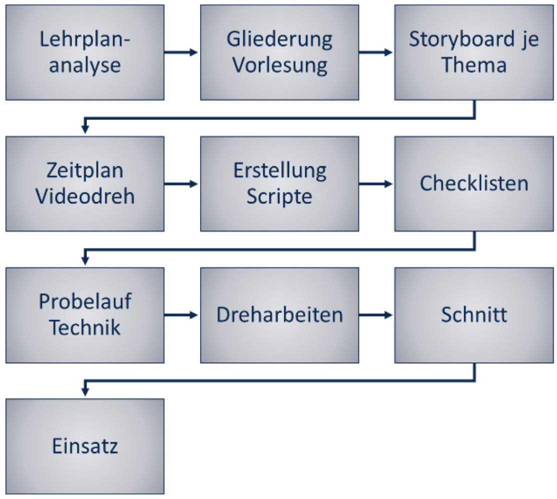
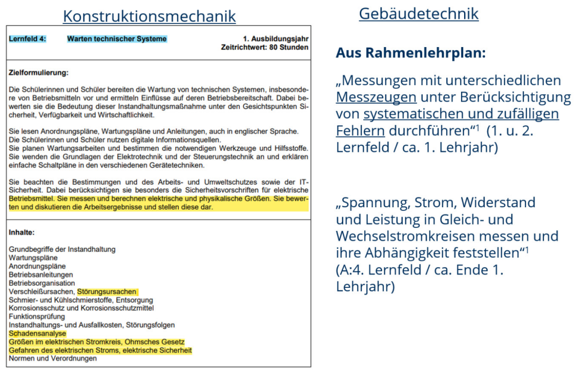


Fig. 1: Work steps for creating teaching videos for a (university) module for vocational school teachers.

1. The curriculum analysis

The first step is to determine what specific content should be included in the videos. The requirements analysis is a suitable method, as it is flexible in its creation and can therefore be adapted precisely to the content to be requested.



Konstruktionsmechanik

Lernfeld 4: Warten technischer Systeme — **1. Ausbildungsjahr, Zeitrichtwert: 80 Stunden**

Zielformulierung:

Die Schülerinnen und Schüler bereiten die Wartung von technischen Systemen, insbesondere von Betriebsmitteln vor und ermitteln Einflüsse auf deren Betriebsbereitschaft. Dabei bewerten sie die Bedeutung dieser Instandhaltungsmaßnahme unter den Gesichtspunkten Sicherheit, Verfügbarkeit und Wirtschaftlichkeit.

Sie lesen Anordnungspläne, Wartungspläne und Anleitungen, auch in englischer Sprache. Die Schülerinnen und Schüler nutzen digitale Informationsquellen. Sie planen Wartungsarbeiten und bestimmen die notwendigen Werkzeuge und Hilfsstoffe. Sie wenden die Grundlagen der Elektrotechnik und der Steuerungstechnik an und erklären einfache Schaltpläne in den verschiedenen Gerätetechniken.

Sie beachten die Bestimmungen und des Arbeits- und Umweltschutzes sowie der IT-Sicherheit. Dabei berücksichtigen sie besonders die Sicherheitsvorschriften für elektrische Betriebsmittel. Sie messen und berechnen elektrische und physikalische Größen. Sie bewerten und diskutieren die Arbeitsergebnisse und stellen diese dar.

Inhalte:

Grundbegriffe der Instandhaltung
Wartungspläne
Anordnungspläne
Betriebsanleitungen
Betriebsorganisation
Verschleißursachen, Störungsursachen
Schmier- und Kühlschmierstoffe, Entsorgung
Korrosionsschutz und Korrosionsschutzmittel
Funktionsprüfung
Instandhaltungs- und Ausfallkosten, Störungsfolgen
Schadensanalyse
Größen im elektrischen Stromkreis, Ohmsches Gesetz
Gefahren des elektrischen Stroms, elektrische Sicherheit
Normen und Verordnungen

Gebäudetechnik

Aus Rahmenlehrplan:

„Messungen mit unterschiedlichen Messzeugen unter Berücksichtigung von systematischen und zufälligen Fehlern durchführen“[1] (1. u. 2. Lernfeld / ca. 1. Lehrjahr)

„Spannung, Strom, Widerstand und Leistung in Gleich- und Wechselstromkreisen messen und ihre Abhängigkeit feststellen“[1] (A:4. Lernfeld / ca. Ende 1. Lehrjahr)

Fig. 2: Two examples of the results from the curriculum analysis.

First, the topic blocks that correspond to the module are selected from the respective curricula. This can be done by simply marking them (Fig. 2 left) or by writing out the relevant points (Fig. 2 right). The topics are then weighted according to frequency and scope.

2. Outline

As soon as the topics are known, the structure of the video series is created. The outline can be based on the existing structure of the module. Depending on how the topics are linked in the respective curricula, it may also make sense to combine or rearrange them.

The duration of a single video is flexible and does not have to be 90 minutes, as the respective topic should be explored instead.

3. Storyboards

Once the rough content concept is in place, the technical preparation as well as the design of the framework story and the reference to practice are now carried out for each topic. The video is classically divided into an introduction, main section and conclusion. The content should be presented briefly and concisely.

It was implemented in the form of storyboards, which for example document the set design,

Szenenbild	Inhalte	Zeit [min]	Hinweise
Prof. in Vollbild (Aufnahme aus MOL) 	- Begrüßung / einleitende Worte zur MAT - Umgebung voller Messtechnik	2 – 3	Video: Wiedererkennung Start im MOL wie bei allen Videos Quelle: Bild 1 Webseite TUD → MFD
→ Messtechnik Autos - Oldtimer → Käfer = wenig Sensorik 	- Entwicklung Sensoren in Autos am Bsp. von Käfer → Moderne - Drucksensoren in Sitzen: von Überwachung Taxifahrern über Anschnallwarnung bis hin zur Sekundenschlafüberwachung	2	Folien: Käfer → evtl. Innenraum dazu Video vom Prof. oben rechts Quelle: Bild 2 Campus Classics

Fig. 3: Example of a storyboard.

content, time and notes as shown in Fig. 3. This provides a simple, clear structure that can be filled in intuitively by the people using it.

Technical contents:

With regard to the technical content, it is important to cover the overlaps between the training occupations and the module content. In this case, this means reconciling various vocational training courses such as machining technology, automotive mechatronics, industrial mechanics and system mechanics for sanitary, heating and air conditioning technology with the measuring and automation technology module. The learners' wishes with regard to required software or tools such as Excel should also be considered. It is important to define the needs of the learners and to decide how deeply the topic should and must be covered. A distinction should be made between what is absolutely necessary and what is merely background knowledge.

Frame story:

First of all, it is important to develop a clear framework that facilitates the introduction to the topic and opens up a problem. Open questions can arouse the learners' interest and motivate them to actively participate. In the final part, the introductory topic should be taken up and a reference to the internship or other relevant topics should be established. If necessary, this reference can already be made during the main part. For example, a thermometer can be shown at the beginning of the video regarding temperature measurement.

Practical relevance:

Another important aspect of the video is the practical relevance. For example, the measuring principles of measuring devices used can be explained here. Examples from various training occupations can also help to illustrate the learning content and strengthen the practical relevance. The elaboration of the teaching material is accompanied by presentations, for example, which contain in-depth technical information and illustrations and can form the basis for the slides used in the video.

Overall, it is important to find a balance between theory and practice, to offer a transfer from theory to practice and vice versa and to make the learning content appealing.

With a clear concept and a structured approach, teachers can create successful educational videos and convey their learning content in an innovative and effective way.

4. Overview of the work steps

In order to organize the shooting days as efficiently as possible, an overview of the individual work steps and scenes is helpful. In this overview, the scenes can be scheduled, responsibilities assigned and further steps for preparation and agreements planned, as shown in Fig. 4, for example.

a)

Name des Videos										
Szene				wann						
Nr	Titel	Ort	Medium	Datum	Uhrzeit	Dauer	Personen	Tätigkeit	Material	Bemerkungen
1	Szenenname									
2	Szenenname									
2.1	Bereich (bei zsg. Aufnahmen)									

b)

Einführungsvideo										
Szene				wann						
Nr	Titel	Ort	Medium	Datum	Uhrzeit	Dauer	Personen	Tätigkeit	Materi	Bemerkungen
1	Begrüßung /	MOL, Brücke	Video	03.04.2023	07:30	00:45	SO	Sprecher	Koffer	zs. mit Szene 5 zu drehen
	einleitende Worte						JM + BB	Video	Ferroigel	
							CC	Regie		
2	Ausgangslage KFZ		Video, Präsentation	03.04.2023	09:30	00:45				
2.1	Erläuterungen Prof	MOL, Büro Prof.					SO	Sprecher		Nahaufnahme oben rechts

Fig. 4: a) Possible structuring of the work steps - a template, b) Example introductory video (excerpt).

5. Checklist

A checklist should be drawn up for the respective day of filming for preparation and execution, which, for example, queries the technical equipment, clothing, transition sets and subject objects. An example of such a checklist is shown in Fig. 5.

6. Script

There are various aspects to consider when creating a script for an instructional video. Firstly, depending on the speaker's preference, it is important to create a coherent text or key points in the video with a clear logic and a common thread. Time can play an important role here, as the creation of such a script can take a lot of time.

Another important aspect is the slide design, which should also be carefully planned. The integration of other media or objects can also increase the students' interest in the learning content and the benefits for everyday working life and should therefore be taken into consideration.

Various methods can be used to create a text-based script as shown in Fig. 6 on the left. One option is to use a dictation machine and special software that facilitates the extraction of the text. Proofreading the script is also important to ensure high quality. Alternatively, the script can also be created by taking notes.

In general, it is important to make sure that the transitions between the sentences or bullet points and the various scenes fit well and are clear (see Fig. 6 on the right).

A teleprompter can be helpful when recording the video, as the speaker has the script in front of them. However, only conditional formatting is possible here, which should be considered when creating the script.

Datum: **26.06.2023**

Ort: **MOL, Büro Prof. Odenbach - Schreibtisch**

Video	**Szene**		**Objekte**	**√**	**letzter Satz vorangegangene Szene**
stat. Ch.	I	Einstieg			Genau das ist die Kalibrierung – das Zusammenführen von Eingangs- und Ausgangssignal in einer Messung.
	III	Kennlinie			
	V	Vgl. R-Fühler			
	VII	Temp.-Messtechnik	Thermokamera		
	VIII	Schluss / Zsf.			

Ort: **MOL, Büro Prof. Odenbach - Konferenztisch (Alternative: Halle 149)**

Video	**Szene**		**Objekte**	**√**	**letzter Satz vorangegangene Szene**
stat. Ch.	II	Messgeräte	Quersilber-thermometer PT100 Referenzsensor Thermokamera Thermoelement		Heute haben wir ganz andere Möglichkeiten. Hier sehen Sie einen kleinen Überblick. Wie solche Messgeräte aussehen können, zeige ich Ihnen an einigen Beispielen.

Ort: **MOL, Halle 149 // Optional Folien →Schreibtisch**

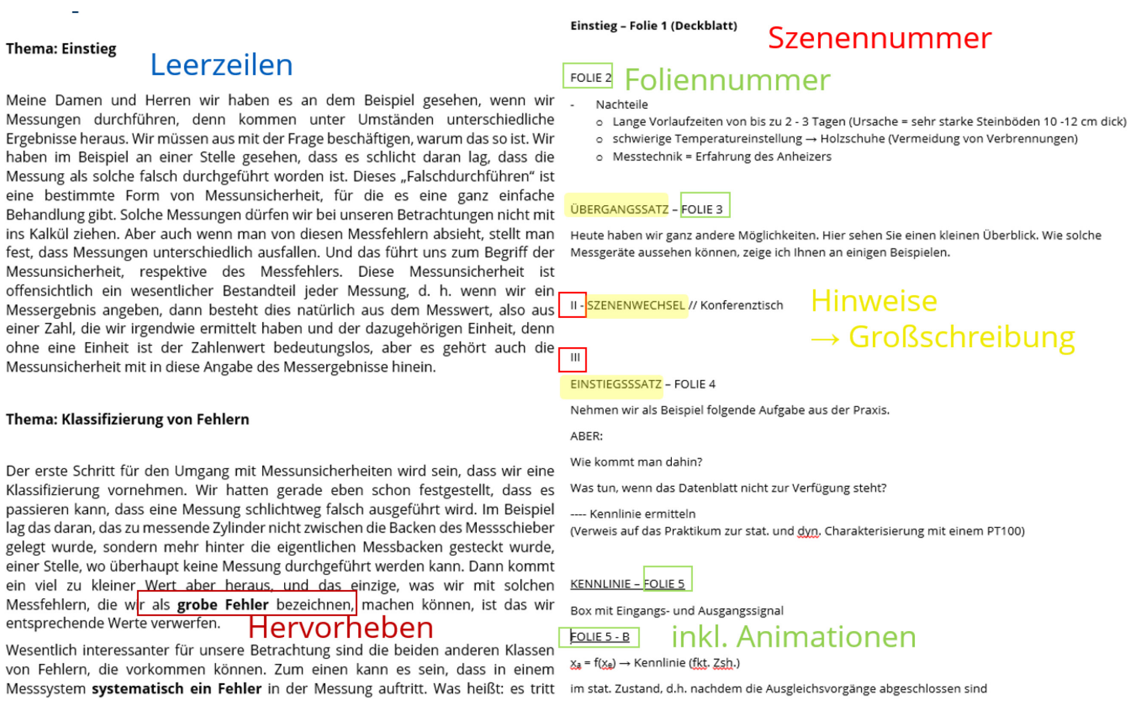
Video	**Szene**		**Objekte**	**√**	**letzter Satz vorangegangene Szene**
stat. Ch.	IV	lin. Kennlinie + Linearisierung	BigTouch PT100		Die lineare Kennlinie schauen wir uns nun einmal genauer an.

VI = praktischer Einsatz z.B. Ihlenfeldt

Kleidung

- graues Hemd
- graue Jacke
- silber-schwarze Brille

Fig. 5: Example of a checklist.


-

Thema: Einstieg

Meine Damen und Herren wir haben es an dem Beispiel gesehen, wenn wir Messungen durchführen, denn kommen unter Umständen unterschiedliche Ergebnisse heraus. Wir müssen aus mit der Frage beschäftigen, warum das so ist. Wir haben im Beispiel an einer Stelle gesehen, dass es schlicht daran lag, dass die Messung als solche falsch durchgeführt worden ist. Dieses „Falschdurchführen" ist eine bestimmte Form von Messunsicherheit, für die es eine ganz einfache Behandlung gibt. Solche Messungen dürfen wir bei unseren Betrachtungen nicht mit ins Kalkül ziehen. Aber auch wenn man von diesen Messfehlern absieht, stellt man fest, dass Messungen unterschiedlich ausfallen. Und das führt uns zum Begriff der Messunsicherheit, respektive des Messfehlers. Diese Messunsicherheit ist offensichtlich ein wesentlicher Bestandteil jeder Messung, d. h. wenn wir ein Messergebnis angeben, dann besteht dies natürlich aus dem Messwert, also aus einer Zahl, die wir irgendwie ermittelt haben und der dazugehörigen Einheit, denn ohne eine Einheit ist der Zahlenwert bedeutungslos, aber es gehört auch die Messunsicherheit mit in diese Angabe des Messergebnisse hinein.

Thema: Klassifizierung von Fehlern

Der erste Schritt für den Umgang mit Messunsicherheiten wird sein, dass wir eine Klassifizierung vornehmen. Wir hatten gerade eben schon festgestellt, dass es passieren kann, dass eine Messung schlichtweg falsch ausgeführt wird. Im Beispiel lag das daran, das zu messende Zylinder nicht zwischen die Backen des Messschieber gelegt wurde, sondern mehr hinter die eigentlichen Messbacken gesteckt wurde, einer Stelle, wo überhaupt keine Messung durchgeführt werden kann. Dann kommt ein viel zu kleiner Wert aber heraus, und das einzige, was wir mit solchen Messfehlern, die wir als **grobe Fehler** bezeichnen, machen können, ist das wir entsprechende Werte verwerfen.

Wesentlich interessanter für unsere Betrachtung sind die beiden anderen Klassen von Fehlern, die vorkommen können. Zum einen kann es sein, dass in einem Messsystem **systematisch ein Fehler** in der Messung auftritt. Was heißt: es tritt

Einstieg – Folie 1 (Deckblatt)

FOLIE 2

- Nachteile
  - Lange Vorlaufzeiten von bis zu 2 - 3 Tagen (Ursache = sehr starke Steinböden 10 -12 cm dick)
  - schwierige Temperatureinstellung → Holzschuhe (Vermeidung von Verbrennungen)
  - Messtechnik = Erfahrung des Anheizers

ÜBERGANGSSATZ – FOLIE 3

Heute haben wir ganz andere Möglichkeiten. Hier sehen Sie einen kleinen Überblick. Wie solche Messgeräte aussehen können, zeige ich Ihnen an einigen Beispielen.

II - SZENENWECHSEL // Konferenztisch

III

EINSTIEGSSSATZ – FOLIE 4

Nehmen wir als Beispiel folgende Aufgabe aus der Praxis.

ABER:

Wie kommt man dahin?

Was tun, wenn das Datenblatt nicht zur Verfügung steht?

---- Kennlinie ermitteln
(Verweis auf das Praktikum zur stat. und dyn. Charakterisierung mit einem PT100)

KENNLINIE – FOLIE 5

Box mit Eingangs- und Ausgangssignal

FOLIE 5 - B

$x_a = f(x_e)$ → Kennlinie (fkt. Zsh.)

im stat. Zustand, d.h. nachdem die Ausgleichsvorgänge abgeschlossen sind

Fig. 6: Examples of scripts with information on the use of a teleprompter.

Any presentation must also be coordinated with the script so that an image track can be recorded at the same time as the slides. A presentation is also a way of supporting the person speaking. It is important that the same format is used as for the camera settings, e.g. 16:9.

7. Test run technology

To ensure that everything runs smoothly during the shoot, the equipment should be set up and checked in advance. This includes charging the batteries, checking the memory cards and a test run on location. In the course of this, the image and sound quality can be checked and the microphones used should be tested. With the camera settings, make sure that the same format is always used, e.g. 16:9.

Once a suitable set-up has been found, it should be documented, e.g. with photos, so that it can be restored quickly for further filming.

Fig. 7 gives an impression of such a turning set.

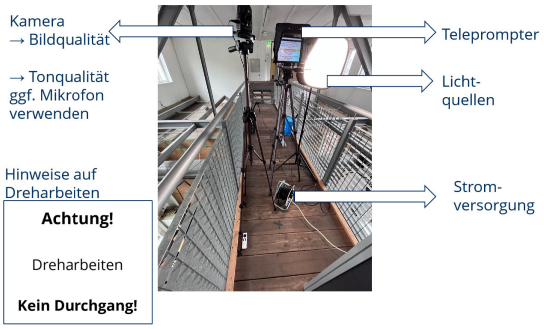


Fig. 7: Test run of the technology.

8. Filming

The actual filming can only start after a test run. Beforehand, however, all employees should be informed about when and where the filming will take place in order to hopefully have a quiet background. In addition to the equipment, other items such as a clapperboard or warning signs can also be helpful, as can a clothing check. The checklist created for support can be used for documentation purposes.

Various camera settings are used during the shoot. In addition to a front camera, other cameras for side, close-up and detail shots are helpful to avoid duplicate filming. However, it is important to ensure that a uniform format is used and that the respective film ends do not appear on the shots from the main camera if possible.

When using presentations or other elements on a screen, it is necessary to record the screen as a separate image track. This ensures the appropriate image quality and simple synchronization with the image or audio track of the person giving the presentation. Suitable software is OBS, for example.

9. Cut

Once all the image and sound data has been collected and saved, the individual scenes can be merged. Different camera angles, close-ups and long-distance shots, scene transitions and synchronization of the soundtrack play a decisive role here. Various software programs such as Matrix (Fig. 8) offer support here.

Fig. 8: Matrix.

10. Implementation

Once the videos have been created, they must be made available to students via a platform. In principle, an evaluation or test run with subsequent feedback from the relevant target group is necessary before general publication for teaching purposes. If only videos are made available, a learning process is only achieved to a limited extent, especially with regard to a deeper understanding. For this reason, a combination with a blended learning format such as the flipped classroom and practicals makes sense. Here, students must first watch the videos and work through the material in order to then present it in their own words in the form of a presentation and, for example, back it up with their own examples. Different topics can be covered using a rotation principle. In addition, future teachers practise applying didactic concepts and preparing teaching content in a clear way. As this is an examination, corresponding assessment sheets (Fig. 9) must be created.

Elemente	Zielstellung
Videos	→ flexibel Informationen aneignen
Praktika	→ Vertiefung Wissen, Praxisbezug
flipped classroom	→ Gelerntes mit eigenen Worten darstellen & erklären (Lehrtätigkeit)

Bewertung Konzept und Darstellung des Lehrinhaltes (flipped Classroom)

Thema / Titel des Videos: Bewertende Person:

Nachnamen der Studierenden: Datum:

Bewertung insgesamt: Was ist gelungen?

- …
- …
- …
- …
- …

Produkt/Punkte	*Fragen zur Bewertung*	*Max. P.*	*Anmerkungen*	*Punkte*
Materialien / Anschauungsbeispiele 5 Punkte	Sind die ***Materialien*** anschaulich gestaltet? Sind alle Quellen nachgewiesen? Passen sie zu den Inhalten? Sind sie fachlich korrekt?	2 1 1 1		
Inhaltliche Gestaltung (siehe Checkliste) 10 Punkte	Ist der ***Aufbau*** nachvollziehbar beschrieben?[1] Sind die relevanten inhaltlichen Bestandteile enthalten und korrekt widergegeben?[2]	4 2 4		
Präsentation / Didaktische Umsetzung 8 Punkte	Ist die Präsentation verständlich? Ist das Sprechtempo angemessen? Fühlen sich die Zuhörenden angesprochen? Wie war der Einsatz weiterer didaktischer Elemente[3]?	2 1 2 3		
			Gesamtpunktzahl:	

Fig. 9: Example of a concept with evaluation form for a flipped classroom.

Summary

A combination of instructional videos with tailored content and blended learning formats such as the flipped classroom can be used to meet the needs of teacher trainees for vocational schools.

This first requires a curriculum analysis to determine which content is relevant and which learning objectives are to be achieved. The structure must then be defined in order to create a clear common thread.

To make the video appealing, it is important to develop a framework and include practical references and examples from various training occupations. The technical content should be designed in such a way that it covers the overlaps between the training occupations and the study module to be adapted.

It is also important to define and schedule the work steps for the individual videos in advance. A checklist for the day of filming and a script can help to structure the process. A technical test run should be carried out before filming to check the positioning of the cameras , the sound and the image quality.

Once filming is complete, the video is edited and published. The video is then evaluated in order to identify possible improvements for future videos.

Finally, it is advisable to implement the video in a suitable blended learning format to create a flexible and effective learning environment.

With this one-time effort to create sustainable and reusable videos, there is only a small amount of effort for the teachers for subsequent semesters with regard to the respective blended learning structures. For the students, however, there is enormous added value.

Acknowledgments

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How good is my teaching (really)? Using student feedback constructively

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Abstract

Student feedback enables a differentiated view of the (perceived) usefulness of teaching and learning offers, methods and tools with regard to students' learning progress. In addition to didactic principles and teaching methodology, student feedback can be used to tailor teaching to students' needs. Evaluation for the further development of teaching and evaluation research are available as tools alongside other types of student feedback. Both types of evaluation are not used to analyze and control the quality of teaching, but can be used as instruments by teachers who want to further develop their teaching. Before a corresponding survey can be planned and carried out, the following questions must be discussed in detail: What specific question is to be answered with the help of the data to be collected? Which influencing factors play a role in the context of the question? What results are conceivable and what consequences would these results have for the design of teaching? Are these consequences relevant? The answers to these questions can be used to determine which form of evaluation is chosen and how it can be specifically designed.

Studentisches Feedback ermöglicht einen differenzierten Blick auf die (wahrgenommene) Nützlichkeit von Lehr-Lern-Angeboten, Methoden und Tools bezüglich des Lernfortschrittes bei den Studierenden. Neben fachdidaktischen Prinzipien und Lehr-Methodik lässt sich auf Basis studentischen Feedbacks Lehre bedarfsgerecht gestalten. Evaluation zur Weiterentwicklung der Lehre und Evaluationsforschung stehen neben anderen Arten studentischer Rückmeldung als Werkzeuge zur Verfügung. Beide Varianten von Evaluation dienen nicht der Analyse und Kontrolle der Qualität von Lehre, sondern können als Instrumente von Lehrenden eingesetzt werden, die ihre Lehre weiterentwickeln wollen. Bevor eine entsprechende Erhebung geplant und durchgeführt werden kann, müssen folgende Fragen ausführlich diskutiert werden: Welche konkrete Fragestellung soll mit Hilfe der zu erhebenden Daten beantwortet werden? Welche Einflussfaktoren spielen im Kontext der Fragestellung eine Rolle? Welche Ergebnisse sind denkbar und welche Konsequenzen hätten diese Ergebnisse für die Gestaltung von Lehre? Sind diese Konsequenzen relevant? Aus den Antworten auf diese Fragen lässt sich ableiten, welche Form der Evaluation gewählt wird und wie diese konkret gestaltet werden kann.

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1. Introduction

The innovations in teaching - driven or intensified by the changed conditions during the pandemic - have been reflected upon, discussed, adapted or even rejected in many ways in recent semesters. There is now a consensus that digital elements enrich our teaching, and that face-to-face courses (abbreviated to LV in the following) are part of good study conditions. Which elements are used in which form and are really suitable for advancing the students' learning process cannot be answered in general terms and is always subject-specific or even module-specific. In order to gain a differentiated insight into this, various types of student feedback can be obtained (classic feedback, tests, evaluation, etc.) In combination with the expertise of the teaching staff, they can lead to a decisive improvement in teaching.
This article is about evaluation and evaluation research as a means of improving teaching. The field of research is outlined, starting with pure evaluation through to empirical research, which requires more expertise in comparison. In section two, the functions of different evaluation approaches are explained by way of example, and then in the two subsequent sections, evaluation for the further development of teaching and evaluation research are discussed in more detail. Specific reference is made here to the workshop of the same name as part of the Lessons Learned Conference 2023. Our vision is for lecturers from different subject areas to jointly develop evaluation modules and use them in their own teaching in order to improve teaching in the long term and, if necessary, to further develop evaluation processes.

2. Functions of evaluation

Course evaluation, such as that carried out at TU Dresden by the Center for Quality Analysis (ZQA), is primarily used to monitor the quality of teaching at a university or higher education institution in all subject areas. The evaluation used by the ZQA is based on the Heidelberg Inventory of Course Quality [1]. This type of evaluation makes it possible to record the current status and compare it with a quality standard that reflects the expectations of teaching. The evaluation form [2] contains statements about the teacher, which are rated by the students on a five-point scale from "strongly agree" to "strongly disagree". Examples of statements are that the teacher "...conveys the course content clearly" or "...is available for consultation if required." In addition, assessments of the course such as "The lecture has expanded my knowledge" as well as assessments of the requirements of the course, workload, student commitment and others are asked. The results of this evaluation give the teacher an impression of the students' views and initial indications of where improvements can be made. However, they cannot be interpreted as to which improvements should be made and in what way. This is not the aim of this type of evaluation.

The type of evaluation presented in this article aims to find indications for the concrete improvement of teaching. Conversely, they allow few conclusions to be drawn about the quality of teaching.

An initial comparative example should illustrate this difference. In the ZQA course evaluation, students are asked under the heading "Use of digital teaching formats" how they rate the digital formats used in the course (page 3 [2]). The formats to be evaluated are livestream, video recordings, PowerPoint presentations, discussion forums and other formats. In the evaluation of the further development of teaching, students are asked about their preferred variant for the course with the option of selecting one of the following answers:

- Lecture only in presence,
- videos only,
- Live broadcast via YouTube only,
- Hybrid variant I: Lecture in presence, online participation,
- Hybrid variant II: Lecture in presence, videos,
- Hybrid variant III: Lecture in presence, online participation, videos,
- Other (with the option to enter something).

Statements on the quality of digital formats can be derived from the results of the ZQA survey. The results of the evaluation on the further development of teaching provide an indication of which format is more suitable for students.

A major limitation of evaluations is the ability to establish causal relationships. Although evaluations can identify correlative relationships, they do not allow reliable statements to be made about cause and effect. For example, an evaluation could show that students who prefer to follow lectures in video format rate their knowledge acquisition as higher. This suggests a connection between the lecture format "video" and the subjective perception of knowledge acquisition, but the actual cause of this phenomenon remains unclear. Specific research designs with control groups are required to determine reliable cause-and-effect relationships.

It should be noted at this point that the development of teaching can never take place purely on the basis of evaluation. The expertise of the teacher is of central importance. On the one hand, it is based on their in-depth understanding of the subject and their research experience, and on the other hand on their didactic and pedagogical know-how. Findings from (subject) didactics and pedagogy provide important pointers for the reorientation and development of teaching. For example, according to Deci and Ryan's self-determination theory, motivation depends on the extent to which the three basic psychological needs of experiencing competence, autonomy and social integration are met [3]. Consequently, in order to motivate students, teaching-learning situations must be created that meet these needs. However, students have different types of needs. This can depend on the subject and also vary according to the content to be taught. In order to find out to what extent the design of the teaching-learning situations actually meets the students' needs, an evaluation should be carried out.

3. Course evaluation for the further development of teaching

Two examples are used below to illustrate the possibilities and limitations of evaluation for the further development of teaching.[1]

Possibilities and limits

Example 1 - the intermediate query

An intermediate question in the course can help to repeat and consolidate knowledge. Possible time periods for interim questions are the beginning, middle or end of the course. Which variant is preferred by the students can be determined by a simple query as part of an evaluation, as in the evaluation of the Measurement and Automation Technology module (abbreviated to MAT in the following). The result for the winter semester 2022 can be seen in Figure 1.

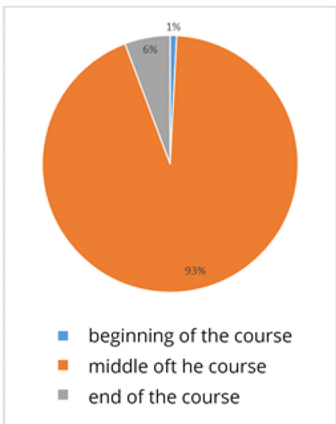


Figure 1: Evaluation example - Interim survey - Question: Which variant do you prefer? n=122

93% of the students surveyed stated that they preferred the mid-lecture question.

What can be deduced from the results obtained?

From this, a design tip can be derived, namely to include the intermediate questions in the middle of the next courses of the module. It is not possible to deduce why the students prefer this variant. Possibly because the process

[1] The student survey takes place online during the course.

of listening and taking notes is interrupted and this "break" has a positive effect on concentration. This is only an assumption and is not confirmed or refuted by the evaluation. The results also do not indicate at what point in the course intermediate questions should generally be included or what function they have in the learning process.

Example 2 - Understanding the students

The aim of teaching is (among other things) for students to understand technical contexts. It is the task of the teacher to support the process of understanding and to create teaching-learning opportunities in which insights are possible. In order to improve the teaching offer, it can be useful to find out in which teaching-learning situation students understand the most. In the evaluation of the MAT module, students were asked to what extent they agreed with the following five statements on a four-point scale from one "disagree" to four "strongly agree":

(1) I was able to follow the teacher's explanations without any problems.
(2) I was able to understand everything from what was written down.
(3) It was only when I worked through my transcript that I was able to understand the connections.
(4) I only really understood the connections through the exercises.
(5) It was only after attending the exercises that I really understood the connections.

The results of the survey are shown in Figure 2.

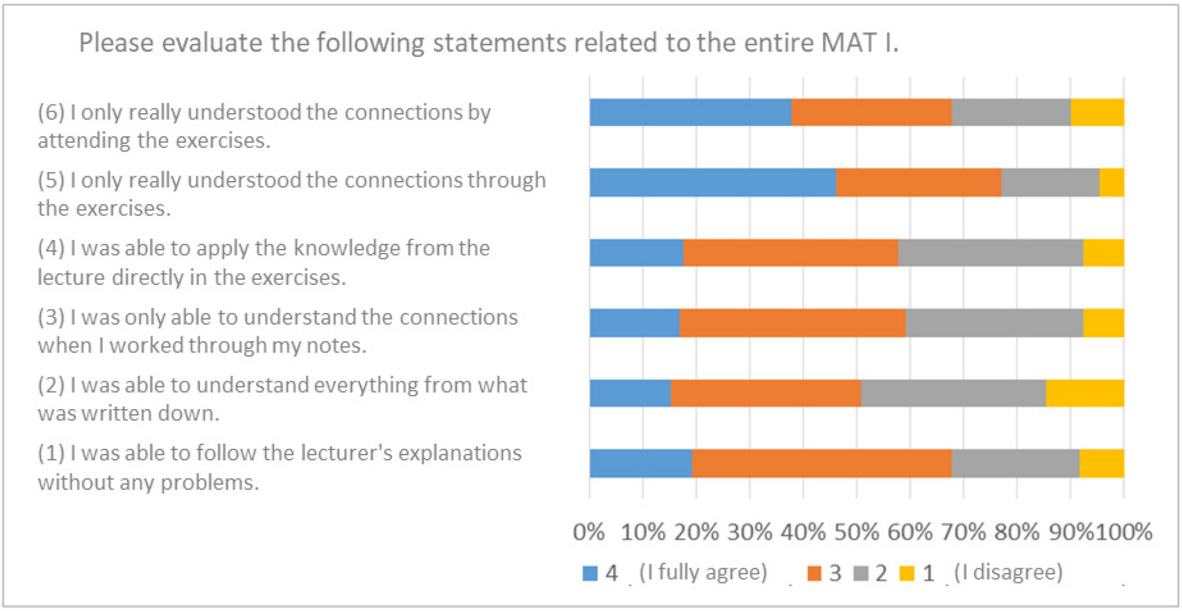


Figure 2: Extract from the results of the evaluation of the MAT module in the winter semester 2023

The first three statements on the teacher's explanations and the notes were rated as "strongly agree" by less than 20%. In comparison, twice as many fully agreed with the statements on the exercises and exercises (statements (4) and (5)). If the results of ratings four (strongly agree) and three are combined, the differences are partially balanced out. For example, the two statements on the explanations (1) and on attending the exercise (5) both achieved almost 70% agreement. The statement "I was able to understand everything from what was written down" received the lowest level of agreement (16% fully agree, four and three together: 51%). The statement "I only really understood the relationships through the exercises" received the highest level of agreement (46% fully agree, four and three in total: 77%).

Students who disagreed or strongly disagreed (one or two) with the statement "I was able to follow the teacher's explanations without any problems" were also asked explicitly why they were not able to follow the explanations very well or at all. The following answers were given, among others:

- Can't keep up with the writing,
- Because I can only write or follow the lecture,
- too fast,
- Too little time was scheduled in the lecture for the amount of material.

What can be deduced from the results obtained?

The students surveyed rated the exercises as more effective for understanding contexts than the lecture. What was written down supported the understanding process significantly less than the other teaching-learning offers. It could therefore be helpful to include more exercises and to integrate practice examples into the course in order to illustrate and apply what has been written down.

Apparently, the amount of material is too large for some students to be able to write and think at the same time in the course. It could be helpful to offer some of the content to be taught in a script so that not all content has to be copied out. It should also be considered whether the amount of material can be reduced.

Limitations: Causal relationships between the design of teaching-learning situations and the support of student learning processes are not examined in this evaluation. Insights gained from the in-depth inquiry of sub-groups are only valid for the student group. They cannot be generalized. Causal deductions and the generalization of findings are only possible in evaluation research, which is the subject of Chapter 4.

<u>Development of an evaluation module</u>

The last section showed examples of the potential that evaluation offers for the development of teaching and its limitations. Evaluation results provide points of reference for decisions and show where changes can be made. More global questions lead to statements that relate to more than one teaching-learning situation. More specific questions provide information on individual aspects. In order to ask precisely tailored questions that lead to usable results, a corresponding development process is required, which is characterized by discussion of the following questions:

- Which teaching/learning situation, method or content is involved? Global or specific?
- What does the teacher want to know from the students?
- What evaluation results are conceivable?
- What are the consequences of each conceivable outcome?
- Are these consequences relevant / interesting and can they be implemented?

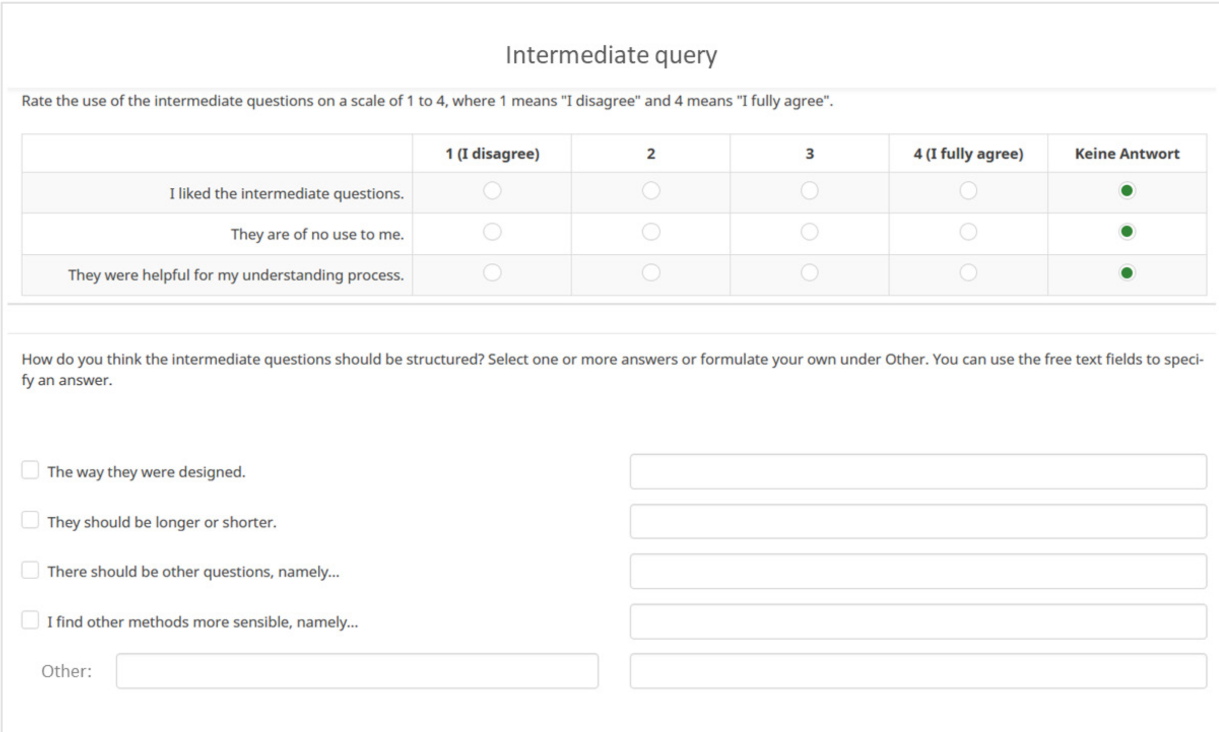
Once these questions have been clarified, the following steps lead to an evaluation module:

<u>Step 1</u>: Search for corresponding modules in existing inventories,
<u>Step 2</u>: Adaptation of modules or new construction,
<u>Step 3</u>: Check whether questions can actually be answered with the module,
<u>Step 4</u>: Test and adjust if necessary.

As part of a workshop at the Lessons Learned Conference 2023, an evaluation module was developed with a group of four lecturers to be used directly in their teaching in future. The aim is to evaluate, interpret and discuss the results of the evaluation together. This type of collaboration enables evaluation and teaching development to take place more constructively, as different groups of students and different perspectives of the teachers can be compared. The questions discussed in the team and the evaluation module developed are presented below. **Teachers are invited to incorporate the module into their own evaluation.**

The team has decided to focus on a method for consolidation and with a high level of student activity that can take up to ten minutes in a course, such as an interim question. The question to be answered with the help of the evaluation is: How is the method accepted by the students? Does it support the process of understanding? It is therefore a concrete question. Possible results are (a) the method is well accepted, or (b) the method is not well accepted, or (c) the method is partially well accepted. The following consequences were derived from the individual results: for the result (a) the method is used more frequently, for (b) the reason for this is investigated and adjusted if necessary, for (c) the method is used in suitable courses but not more frequently. These consequences were assessed by the teachers as relevant and feasible.

Figure 3 shows the evaluation module in the Limesurvey survey tool, which is provided by the Bildungsportal Sachsen for TU Dresden [4].


Intermediate query

Rate the use of the intermediate questions on a scale of 1 to 4, where 1 means "I disagree" and 4 means "I fully agree".

	1 (I disagree)	2	3	4 (I fully agree)	Keine Antwort
I liked the intermediate questions.					
They are of no use to me.					
They were helpful for my understanding process.					

How do you think the intermediate questions should be structured? Select one or more answers or formulate your own under Other. You can use the free text fields to specify an answer.

The way they were designed.

They should be longer or shorter.

There should be other questions, namely...

I find other methods more sensible, namely...

Other:

Figure 3: Evaluation module intermediate query

The module can be part of a course evaluation as part of quality control or also part of a more comprehensive evaluation for the further development of teaching. It is conceivable to use the module as a short evaluation in combination with general information such as subject of specialization, semester, possibly also gender and origin, if corresponding comparisons between student groups are interesting and helpful.

4. Evaluation research

Evaluation research uses both quantitative and qualitative research methods. It can pursue formative objectives to improve ongoing processes or summative objectives to make final assessments. However, evaluation research goes beyond simple feedback. It searches in controlled environments for the causes and mechanisms behind the observed results.

Summative evaluation in particular focuses on two main objectives. On the one hand, it is possible to examine how a treatment condition (independent variable: e.g. the teaching format) influences an observation/measurement (dependent variable: e.g. learning performance). On the other hand, summative evaluations are about carrying out impact analyses or making predictions. Here, for example, questions could arise such as: "How strongly does an increase in weekly quizzes by one task influence learning performance?" or "What can be predicted about learning performance based on the number of quizzes?

The royal road of research

In experiments, specific conditions are controlled and variables are manipulated in order to investigate causal relationships. To ensure that other unexpected variables are not responsible for observed effects, a pre-post control group design with randomized assignment of participants is often used. In a pre-post control group design, the dependent variable is measured before the intervention (pre-test) and after the intervention (post-test), with an additional comparison with a control group that does not receive an intervention. The participants are randomly assigned to the group with or without the intervention. This design prevents not only the independent variable 'teaching format', but also other factors such as prior knowledge, from influencing the dependent variable 'learning performance'.

The ideal research process begins with questions and hypotheses derived from theory. These then determine the research design. Let us assume that we want to investigate the influence of two independent variables - 'teaching format' (with the levels 'flipped classroom' and 'traditional') and 'prior knowledge' (with the levels 'high' and 'low') - on a dependent variable such as 'learning performance'. In this case, a 2x2 design would be suitable, which can evaluate potential interactions between the variables in particular.

		teaching format	
		traditional	Flipped classroom
prior knowledge	low	ab Var. Lernleistung*	ab Var. Lernleistung*
	high	ab Var. Lernleistung*	ab Var. Lernleistung*

** Standardized questionnaire*

Figure 4: Classic 2x2 factorial design

Once the research design has been defined, the next step is to operationalize and select suitable, ideally standardized, measurement instruments such as questionnaires. Recommended sources for standardized measurement instruments are platforms such as www.testarchiv.eu in general and www.physport.org specifically for physical content.

The detailed test plan is then drawn up. This specifies when exactly which steps (e.g. pre-test) are to be carried out using which methods (e.g. questionnaire) for which groups of test subjects (e.g. a group experiencing the classic teaching format with little prior knowledge) and over what period of time (e.g. 45 minutes for a pre-test). Simpler experimental designs, as are often used in evaluations, are limited to the teaching material (treatment) and a subsequent test (post-test). An example of an application would be the investigation of differences in learning performance following the use of a particular teaching format, as shown in Figure 5.

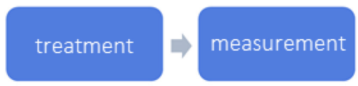


Figure 5: Simple test plan with post-test

A major problem with assessing learning performance using such simple experimental designs is that learning performance could be influenced by other factors, such as prior knowledge. Therefore, it will not be possible to conclude from the results that a specific teaching format leads directly to a specific learning performance.

To address this problem, many research projects rely on pre-night test designs, as shown in Figure 6. However, even these designs do not necessarily allow for a clear causal relationship between the independent variable or treatment (here the teaching format) and the changes observed between the measurements (e.g. learning gains). There could still be an uncontrolled third variable, such as cognitive ability, that explains the difference between the two measurement points.

Figure 6: Simple test plan with pre- and post-test.

In order to exclude uncontrolled third variables, pre-post designs with control groups in conjunction with randomization are helpful, as shown in Figure 7. In this design, the control group does not receive any treatment, but is tested at both measurement times with regard to the dependent variable. However, even this design is not without limitations, especially when it comes to drawing causal conclusions. One potential stumbling block could be that the pre-measurement influences the subsequent treatment. This could happen, for example, if the pre-measurement makes it clear to participants which aspects of the treatment are considered particularly relevant.

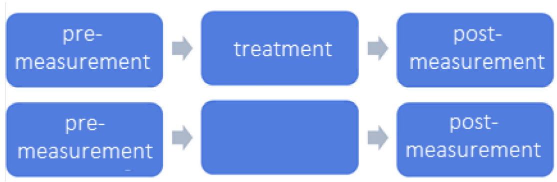


Figure 7: Experimental design with pre-test, post-test and control group.

The Solomon 4 group enplan [5] offers a solution. It not only takes into account the main factors, but also controls the possible effects of the measurements themselves, as shown in Figure 8.

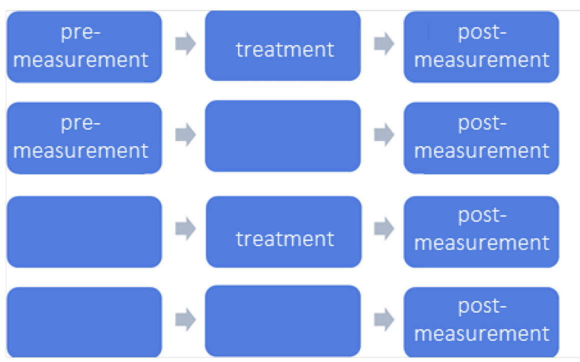


Figure 8: Solomon 4 group plan with double control group (treatment and measurement)

<u>Problems in the implementation of research projects</u>

For many university courses, students register themselves based on their interests, their requirements or their course of study. It would not be practical to randomly assign them to a specific course or teacher.

Randomizing students could be perceived as unfair, especially if one course or teaching method is seen as superior or more desirable. Students may feel disadvantaged if they are randomly assigned to a less favored course (especially if it is the control group).

The implementation of randomization in university courses would require considerable organizational effort. Systems would have to be set up to ensure that the allocation of students is correct and truly random.

Given all of these considerations, conducting randomization in university courses can be so costly and complex that it outweighs the potential benefits, especially when the main goal of the evaluation is to gather feedback to improve teaching and not necessarily to establish causal relationships.

<u>A way out of the dilemma</u>

A simple way to address the problems mentioned is to carry out impact analyses using regression or path analyses. Even if these approaches do not show causalities in the strict sense according to , they make it possible to explain differences in the dependent variables through the influences of independent, confounding and third variables. It is therefore advantageous to have a detailed understanding of potential confounding and third-party variables in addition to the dependent variable and to record these as well. For example, differences in cognitive nitive abilities [6], in men tal cognitive nitive stress [7] or in the men specific prior knowledge could influence the variance of the dependent variable. These factors could also contribute to the differences caused by the independent variable .

5. Conclusion and outlook

The discussion in the last two chapters shows how different the functions and questions of evaluation (research) can be. This results in different approaches to the development and design of the instruments. These differences determine the interpretation of the results and the consequences for teachers. Taking this into account and defining it clearly is the basis of a successful evaluation. In the workshop "How good is my teaching (really)?" as part of the Lessons Learned Conference 2023, teachers discussed evaluation (research), its different functions and how to develop and design it. In a collaborative process, an evaluation module was created that can be used by teachers (description in section section 3). In addition, different research approaches were discussed with regard to their practical bility. The common conclusion was to test fewer difference hypotheses, as these are generally associated with complex and complex designs. Instead, the focus was shifted to impact analyses in order to better explain variations in a dependent variable .

The Lessons Learned Conference 2024 will then focus on the joint evaluation, assessment and discussion of the results. Our vision of joint evaluation development in the Lessons Learned Community will thus be further advanced.

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Upcycling in university teaching - A field report on the didactic preparation of existing teaching videos from the Corona semesters

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Abstract

In the winter semester 2020/21, university teaching moved to the digital space due to the pandemic. The videos created during this time will remain unused after the return to regular operations. As part of the "BauingeniOER digital" project, selected materials from three participating chairs of the Faculty of Civil Engineering have now been didactically prepared, supplemented with interactive elements and upgraded to an attractive element of exam preparation. The resulting materials were then published as OER.

Im Wintersemester 2020/21 zieht die Hochschullehre pandemiebedingt in den digitalen Raum um. Die während dieser Zeit entstandenen Videos liegen nach der Rückkehr in den Regelbetrieb ungenutzt „in den Schiebern". Im Rahmen des Projektes „BauingeniOER digital" wurden nun ausgewählte Materialien dreier beteiligter Lehrstühle der Fakultät Bauingenieurwesen exemplarisch didaktisch aufbereitet, mit interaktiven Elementen ergänzt und zu einem attraktiven Element der Prüfungsvorbereitung aufgewertet. Die entstehenden Materialien wurden anschließend als OER veröffentlicht.

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This article was originally submitted in German.

1. Initial situation

Around 160 students (including around 30 distance learning students) take part in the "Existing Buildings" course run by the Institute of Building Construction of the Faculty of Civil Engineering, a compulsory module of the undergraduate diploma course and the Bachelor's course in Civil Engineering. Some teacher training students for vocational schools and students on the industrial engineering course also take part. The course concludes with a written examination, mainly with case studies that have to be explained or discussed.

From the lecturers' point of view, the solutions to the students' written assignments were not entirely satisfactory; they were often too verbose and vague, used too few technical terms or argued incorrectly. In addition, distance learning students in particular had difficulties dealing with the format (case studies) that was only introduced in winter semester 2020/21. The reason for this is that the majority of distance learning students are working. They were therefore unable to participate in the livestream exercises, or the recordings of the on-site discussions were also difficult to follow acoustically afterwards. For distance learning students, the tension between work, family and (distance) learning with the different expectations in each case is a constant balancing act anyway, which can severely affect study times and success [1].

Due to the suspension of face-to-face teaching in winter semester 2020/21 due to coronavirus, new digital teaching formats had to be tested at short notice. For this purpose, the lecturers of the course "Existing Buildings" recorded the entire lecture material in video form; on the one hand in the form of PPT slides with audio track and on the other hand the creation of sketches with the Visualizer and audio track recorded with OBS. The individual videos were between 20 and 40 minutes long so that they could be watched in smaller "chunks". Shorter instructional videos are recommended to keep students motivated; ideally with an alternation between knowledge presentation and interactive elements [2]. The content of the videos was tested in the subsequent exam using practical tasks or the students had to argue based on the theory covered in the videos.

2. Solution approach

After creating the digital teaching materials under great time pressure, numerous videos were available after returning to the classroom. The lecturers wanted to continue to make these available to the students and at the same time meet their own quality standards for good teaching. Students in particular expressed a desire for interactive or activating teaching material that can be used regardless of time and place. In addition to the clear advantage for distance learning students, on-campus students also predominantly want digital elements to be retained in teaching [3].

The idea for the "Existing buildings" course was to enhance the existing videos by creating interactive elements with Lumi[1] and inserting them into the existing videos. The resulting videos are intended to guide students towards a precisely formulated solution to the exam task on the one hand and to encourage active learning on the other. The videos are intended to serve as long-term exam preparation for the students and thus be didactically prepared in a targeted manner - upcycling in university teaching.

The "BauingeniOER digital" project - funded by the Fund for Digital Learning and Teaching (DLL) in the 2021/2022 funding period - provided the framework for the implementation of the project. The project was managed by the distance learning working group of the Faculty of Civil Engineering.

Fig. 1: Logo of the project

The Institute of Building Construction and two other chairs of the Faculty of Civil Engineering were involved. After an initial review of the available materials with the project coordina-

[1] Lumi is a free software for creating interactive content based on H5P; https://app.lumi.education/

tor, videos were selected that were particularly suitable for processing as part of the project. Each chair was asked to find one or two videos or script sections to work on during the project period. During the project, an E-Scout was available via the ZiLL to support all project participants for 5 hours per week, in particular for the technical implementation.

The main goal of the project was to didactically prepare existing materials from the "Corona semesters", add and edit interactive elements and finally publish the high-quality teaching materials as OER. This means that the materials will continue to be available beyond the crisis period and will be opened up to a wider audience.

As part of the project, with the support of the distance learning working group, practical peer workshops were held to review and select existing materials, revise them didactically, technically and in terms of media law, and finally publish them as OER.

The added value of this project can be seen at various user levels. On the one hand, there are the **distance learning students**. Far away from the additional private and professional burdens, distance learning students benefited from the pandemic-related "relocation" of all teaching to the virtual space and thus the possibility of even more individual and material-rich studies. "Distance learning" became the new normal and many lecturers and those responsible gained an impression for the first time of the challenges that distance learning students have always faced [1]. This wide-ranging offer, as well as the newly created awareness, now had to be not only maintained, but also expanded.

For the **Faculty of Civil Engineering**, international visibility within scientific communities is increasingly determined by the reputation of teaching. Student recruitment is also more and more based on examples of good teaching. In this sense, OER offerings are also instruments of public relations work that should be used more intensively in the future. This makes the performance of teachers more visible. The indexing and integration into the SLUB catalog enables broad reuse, for example by members of other universities, schools, independent educational institutions, citizens, etc. This in turn promotes the ability to meet the challenges and changes of the modern labor market within the framework of lifelong learning [4].

The **institutes** and teaching staff wanted to take the knowledge and achievements of the pandemic with them into the post-corona era. A lot of time and energy was invested in the materials - too good to disappear in a drawer. There was a lack of resources and the necessary overview to initiate reflection processes (What should be kept? What didn't work?) within or across teams. Thanks to interdisciplinary coordination and the active and didactically sound support of the "BauingeniOER digital" project, the hurdles were quickly overcome. The practical peer workshops not only met the need for collegial exchange, which had become very clear due to the pandemic situation, but also offered a low-threshold training opportunity for teachers on media didactics, technology and legal issues.

For **students**, OER generally opens up more flexible and individualized studies beyond the boundaries of individual educational institutions. The added value results not only from the low-threshold provision, but also from the availability of particularly high-quality materials - both technically and didactically. The development of digital skills is also an added value that should not be neglected through high-quality interactive teaching materials to prepare students for their entry into professional life [5].

3. The upcycling

<u>Work steps</u>:

Before interactive elements could be inserted with Lumi, the videos first had to be cut and the transitions to the slides that originally followed deleted so that a self-contained sequence was created. The intro and foreword had to be designed, coordinated with the content and layout and inserted. The task of the fictitious case study was inserted between the foreword and the actual video with the sketches. The outro ends the video with the CC-BY-SA license and an explanation of the license. For this purpose, the license conditions of all materials used, such as photos taken by the former chair holder, had to be clarified.

Once the video was completed, interactive elements were added using the Lumi program, which offers numerous options for this. For example, single-choice questions, selection questions or cloze texts were used for these videos. Additional explanatory information in the form of animations or photos (own or from external websites) of completed constructions can be called up via a button. Figures 2 to 4 show excerpts from the interactive video with the inserted interactive elements.

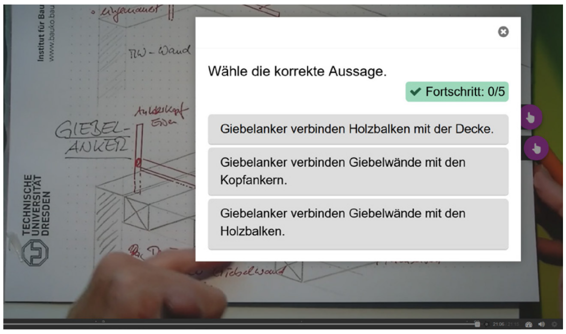

Fig. 2: Excerpt from the video with single-choice questions.

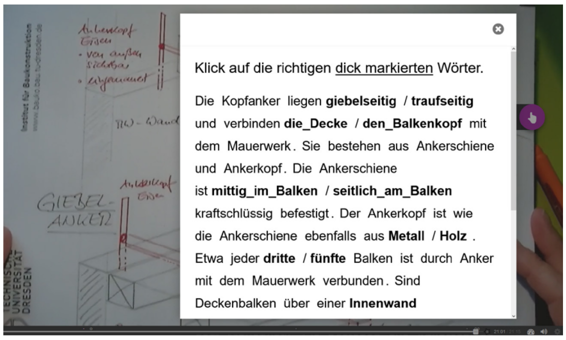

Fig. 3: Excerpt from the video with words to be marked.

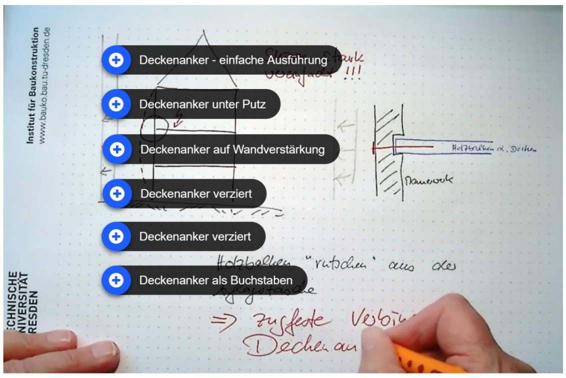

Fig. 4: Excerpt from the video with buttons with photos.

The editing time for the first video was longer than planned, as the basics had to be researched, the procedure discussed and the possibilities of Lumi (automatic continuation, allowing repetitions and skipping back, ...) considered from a didactic point of view.

Once the procedure and the possibilities were known, the second video was completed very quickly; the editing time was now around 30% compared to the first video. Further videos would probably be completed even faster. Even during the creation process, didactic improvement potentials were recognized, which could be directly implemented in the second video: At the beginning there is a quiz as a knowledge test before the theory is explained using the existing videos. For an intensive explanation and visualization of materials or components, such as stakes with clay wrapping, reed mats and rafter formwork, photos or links to explanatory websites are provided. Finally, the theory ends with a summary in the form of a quiz. This allows students to see their learning progress directly compared to the initial quiz.

<u>Summary</u>:

The existing videos from the Corona semesters were specifically enriched with interactive elements to encourage students to take active action. In contrast to the "classic" lecture, in which knowledge is conveyed passively, a reaction from the participant is now consciously demanded. This increases attention and what has been learned is remembered for longer [6]. Ideally, this learned knowledge is remembered for years to come.

It is also important that the learning process extends over a longer period of time, as the interactive videos are already accessible during the semester. The integrated questions and quizzes provide participants with an interim status of their knowledge and allow them to work specifically on their knowledge gaps during the lecture period. Thanks to the extensive preparation, they can start the examination phase with less stress.

These newly created opportunities generate a supportive learning environment. Students can work on and repeat the material individually, at their own pace, at flexible times and in a familiar environment. Nevertheless, they are guided and the subject matter is focused on what is important. The integrated feedback gives them a continuous assessment of their level of knowledge. However, this is only visible to them and they can therefore manage their learning process independently. The two revised videos provide a good basis on which to enrich other existing videos with interactive elements in the future.

The interactive videos are licensed under CC-BY-SA. They can be accessed via the SLUB OER display: https://www.slub-dresden.de/veroeffentlichen/open-educational-resources/oer-display

Fig. 5: Outro with licensing

4. Feedback from students

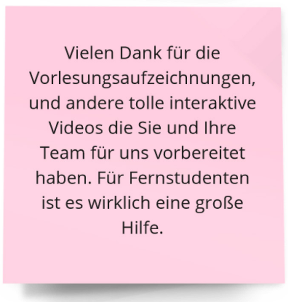

Fig. 6: Feedback of a distance learning student from summer semester 2023

These two interactive videos are available to both on-campus and distance learning students as additional material for exam preparation. After the project, the students were asked about their evaluation of the added value of the videos. It turned out that any additional learning material is particularly beneficial for distance learning students who have to acquire the lecture content through self-study. Interactive videos offer an appealing change from traditional learning materials such as lecture notes or lecture recordings, which usually have a duration of 60 to 90 minutes. Assistance such as these interactive videos, which provide targeted guidance on possible exam questions, is gladly accepted.

5. Lessons Learned

The preparatory work for the upcycling in particular was very lengthy - multiple consultations with the project partners were necessary and the methodological approach had to be clarified according to didactic requirements. As soon as the individual "components" (intro, outro, videos) were available, the integration of the interactive elements could be implemented quite quickly using Lumi. The tool itself is designed to be user-friendly and is easy to use after a short training period. This means that the video material available from the "Corona semesters" can be easily processed and used sustainably as additional learning material.

Interactive videos offer significant added value for both on-campus and distance learning students. The required interaction and active participation increase attention and what has been learned is remembered for longer. Immediate feedback within the videos allows students to assess their level of knowledge - before the actual exam. This gives them the opportunity to work on their knowledge deficits in a targeted and timely manner and start the exam with confidence.

Valuable expertise from interdisciplinary teams (ZiLL, SLUB, TDL BU) was utilized in the creation and implementation of the concept. These resources are available at TU Dresden and can be consulted if questions arise outside your own department.

The amount of work involved in editing the videos varied greatly. After establishing the basics of video editing, the legal framework for OER and familiarization with the Lumi tool, the learning curve was enormous. Editing the second video took around 70% less time than the first. It is assumed that the average editing time for a complete lecture series is reduced from video to video until a certain routine is established.

As part of the project, an E-Scout from the ZiLL provided support to all project partners for a total of 5 hours per week. This was very helpful as the lecturers were able to concentrate on the subject-related work. The lecturers themselves worked on the project for a variable number of hours during the semester.

Acknowledgments

We would like to thank the Center for Interdisciplinary Learning and Teaching (ZiLL) for funding within the framework of the Fund for Digital Learning and Teaching in the 2021/2022 funding period (project duration 01.10.2021-30.09.2022). The ZiLL supported the project with an E-Scout, who took over large parts of the technical implementation for all project participants.

In cooperation with the SLUB, individual training sessions were held with all participants on the basics and framework conditions for OER creation and publication. The Digital Teaching Team of the Building and Environment Departement (TDL BU) provided support in familiarizing participants with the free Lumi program, among other things.

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Creativity as a driver for learning computer-aided working methods in the engineering sciences

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The low effectiveness of mere frontal teaching when teaching software for computer-aided work is a challenge for learners and teachers. This article presents how active participation in the seminar and self-study could be improved with little additional effort through the consciously required creative use of the software used.

Die geringe Effektivität bloßen Frontalunterrichts bei der Vermittlung von Software für computergestütztes Arbeiten ist eine Herausforderung für Lernende und Lehrende. In diesem Artikel wird vorgestellt, wie durch den bewusst geforderten kreativen Umgang mit der verwendeten Software aktive Beteiligung am Seminar und Selbststudium mit geringem Zusatzaufwand verbessert werden konnten.

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This article was originally submitted in German.

1. Computer programs in teaching

The confident use of various computer programs is an integral part of the profile of most academic professions. Engineering graduates in particular should not only be trained in the use of standard programs, but should also be proficient in more complex special software such as CAD programs, as a large part of the practical application of the skills acquired during their studies is now software-supported or software-based. In order to actually obtain a professionally qualifying degree, dealing with specialized software common in the industry is already part of the course. However, many students find this difficult.

The "digital natives" have a good command of the programs and services they are used to using. However, everyday use of digital technologies cannot be equated with digital literacy. [1] In its report "The fallacy of the 'digital native'", the *ICDL Foundation* argued that the use of digital media by digital natives is primarily lifestyle-related and that the skills acquired in this way do not represent a significant qualification for the job market. [2]

2. Motivation when learning computer-aided working methods

"Motivation" encompasses the setting of goals and the subsequent, goal-oriented action. It is used to explain why actions are started, continued, ended or even omitted. [3, 4]
Motivation and demotivation have many different causes. One possible way of classifying these causes is to divide motivation into extrinsic and intrinsic motivation. Extrinsic motivation" includes the factors that contribute to or detract from motivation that lie outside the individual. "Intrinsic motivation", on the other hand, includes all factors that contribute to or detract from motivation that originate from the individual themselves. [3-5]
Positive motivation is a critical prerequisite for a successful learning process. [6, p. 109f.]

When learning new software, learners focus more on the results achieved and less on the learning progress made. The software is a tool and learners are eager to try it out and use it. Successfully carrying out actions in the software independently increases intrinsic motivation. Longer explanations or demonstrations covering several aspects of the software and without practical use of the software, on the other hand, cause impatience, as there is no visible learning success. This reduces intrinsic motivation. [7]
Accordingly, independent, practical use of the program while learning the program is desirable from the learner's point of view.

The independent practical use of the software should be instructed in such a way that learning successes become *visible* and set goals can be achieved relatively easily. Failures can quickly lead to learners feeling overwhelmed and incompetent. Perceived incompetence reduces intrinsic motivation to learn, which in turn has a direct negative impact on learning success [7-9].

3. Ways to improve motivation

Teachers can create extrinsic motivation through intermediate tests or additional services. [5] Positive feedback and support, as well as setting learning goals and making successes visible can promote intrinsic motivation. [5, 6, S. 133]

However, when preparing and delivering courses, teachers are subject to time, financial and personnel constraints, which make it difficult to put in the extra effort to motivate students.

This raises the question of what possibilities teachers have to increase the extrinsic or intrinsic motivation of students with little additional effort. The following describes how the special characteristics of computer-aided working methods were utilized or addressed in a block seminar in order to increase students' motivation in learning them through creativity and autonomy.

4. Course

WE-TEAM is a two-year Erasmus Mundus Joint Master Degree program to train the next generation of textile engineers. The program is aimed at people with a Bachelor's degree in engineering or natural sciences and has a strong international focus. This is reflected in the heterogeneous distribution of nationalities (class of 2023/2024: 20 students from a total of 15 different countries) and in the fact that students study at a different university in a different country each semester. The participating universities are located in the EU and Japan.

The Chair of Development and Assembly of Textile Products contributes to this program with a four-day block seminar on modeling and simulation of textile products. This is one of the Chair's standard topics, which, due to its scope, is usually dealt with in various courses lasting an entire semester.

The aim of the block seminar is to impart theoretical knowledge and practical skills in the fields of modeling and simulation of textile products, which students can develop and apply independently. Previous knowledge in these areas will be tested at the beginning of the seminar. As a rule, one or two participants have limited knowledge in these areas. The block seminar takes place in the first semester of the Master's course and is held at the University of Ghent.

5. Procedure to date

In the first three years, the seminar was organized as a classic frontal lesson. The lecturers demonstrated various programs for simulating textiles and imparted basic background knowledge in a lecture format.

As the students are not in Dresden, they cannot use the professorship's PC pool. Instead, they must use their own laptops. As access to a Windows laptop is one of the admission requirements for the course, it can be assumed when preparing for the seminar that all students will be able to participate in the seminar with their own laptop. However, there are two main restrictions: The software programs must not make excessive demands on PC resources and must not require licenses that cannot be provided due to low availability at the chair. Therefore, preference is given to software programs during the seminar that students can use without a license and that still run on less well-equipped PCs (e.g. Texgen [10]Blender [11]Python [12]). However, license-based programs (e.g. TexMind Braider [13], VStitcher [14]) are also used, for which a license can be provided by the chair.

The skills learned were tested in the form of a take-home exam, in which the students had to complete defined tasks with the software they had learned and submit the solutions. The students had several weeks to complete the tasks. In this format, collaboration between students when completing the assignments cannot be ruled out and is not undesirable in terms of mutual assistance. However, students are given individualized tasks; for example, different tissue connections to model or different bodies to be included in a simulation.

The longer processing time for the tasks should enable students to develop their skills independently. At the same time, the tasks should not demand significantly more than was taught in the course.

The resulting artifacts were closely oriented to the minimum of the task, were very similar to each other and the functions used were almost exclusively limited to those that had been explicitly demonstrated during the course. The

Figure 1 3D model of a heart-shaped 3D mesh

aim of imparting basic skills in the fields of textile modeling and simulation was thus achieved. However, it was not clear from the results whether the students had developed their skills independently or could do so and whether they were able to apply the knowledge they had acquired confidently or replicate demonstrations from the course.

Overall, they did not appear to have been motivated to learn independently as a result of the course.

6. Modified procedure

The seminar was modified in the fourth edition with the aim of motivating students to engage more independently with the material and making their learning process and learning success more transparent.

(1) In order to achieve a greater sense of achievement during the initial exploration of the programs, the focus was initially placed more on processes and functions that **quickly** deliver **visible results. For** example, instead of explaining the functions of the *TexMind Braiding Machine Configurator* and the underlying theory of braiding in detail, initially only a simple braiding machine was modeled and a 3D braid was created. These work steps can be implemented in the software with just a few clicks.

(2) In order to encourage the students to use the software confidently, the students were asked to explore the other functions of the programs themselves in a free work phase after learning the basic concepts and to work **creatively** and, for example, to create personalized or comical scenes. The possible self-realization and self-efficacy should increase intrinsic motivation. Figure 1 shows an example from a similar task with the *TexMind Braiding Machine Configurator*: The student has built a braiding machine that creates a heart-shaped braid and dyes it pink. In order to achieve this result, she had to make significantly more use of the program's range of functions than had been demonstrated by the lecturer.

The lecturer and fellow students present were able to provide quick assistance during this free phase in order to keep the students motivated.

(3) In order to provide an incentive to put creative ideas into practice, the results achieved could be **shared voluntarily** and were discussed together at the end of the lesson. This was done with the intention of using the recognition of the seminar group as extrinsic motivation. (4) The Take Home Exam was supplemented by a learning diary, assessed for completeness, expression, form and design, in which the students should record their learning progress and reflect on it themselves in order to be able to better understand it during the assessment.

(5) As far as possible, students were offered the prospect of bonus points for creativity in the assignment. The assignment was broken down into points for this purpose, so that the assessment was transparent for the students from the outset. The tasks that allowed for creative engagement (e.g. modeling a fabric, simulating a scarf, modeling a bracelet and simulating a product presentation) were each awarded one bonus point for creativity. The point was awarded if the artefacts were designed, e.g. through color or shape (see e.g. Figure 2).

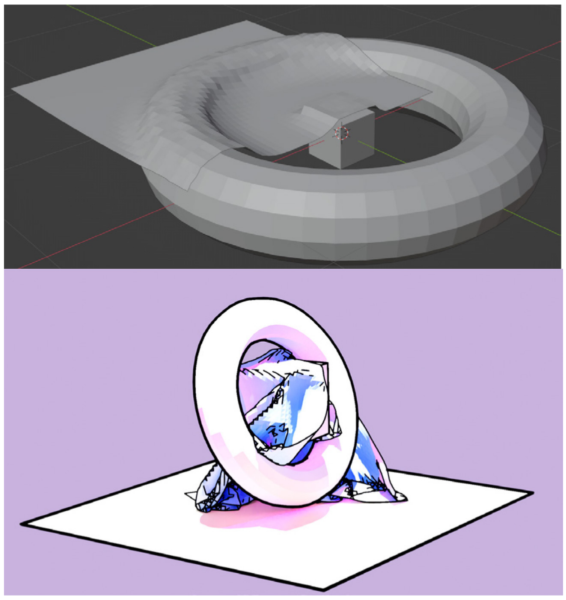

Figure 2 Screenshots from two draping simulations. Top: Implementation of the minimal task (recreation by the author) Bottom: Implementation by the student. The surfaces are changed by the creative use of shader effects, the material parameters of the cloth are modified, the cube rotates around itself, the torus rotates around the cube.

7. Results

According to the lecturer's impression, the participation and commitment of the students during the presented edition of the block seminar noticeably exceeded that of the previous editions. The students quickly became actively involved in the course and were motivated to explore the possibilities and limits of the programs. The joint debriefing of the results was very well received by the students and enjoyed lively participation. Both were reflected in the fact that during the free work phases, most students submitted at least one and usually several different artefacts for joint discussion, in which not only the previously demonstrated program functions were tested, but also new functions were used that the students had used on their own initiative.

When taking the exams, i.e. creating the artefacts in accordance with the task, the candidates applied the programs they had learned with a degree of experimentation and confidence that went far beyond the level taught in the course. In some cases, even the learning diaries were creatively designed.

The students were not only able to apply the knowledge imparted during the seminar, but had also independently acquired and implemented new knowledge. Despite a lack of prior knowledge in the application of the programs presented, the students quickly built up skills in the areas of modeling and simulation. This was mainly due to successful self-study. This was also evident in the learning diaries during the assessment. The students rated their personal learning progress and the course as such very positively.

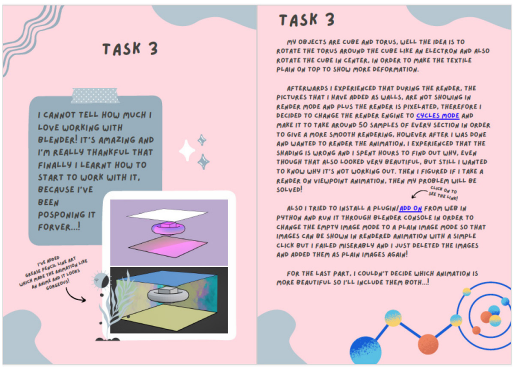

Figure 3 Creatively designed page from a learning diary

8. Discussion

In the course presented here, the students were asked to explore the demonstrated and, if necessary, other functions of the software themselves in a free work phase after short familiarization and demonstration phases to teach them practical skills in using computer programs. This was done with the aim of motivating the students and encouraging them to learn more independently. During the free work phases, they were encouraged to implement creative ideas wherever possible. The results were then discussed together afterwards. While the independent implementation of their own ideas was intended to increase the intrinsic motivation of the students, the joint comparison was intended to achieve extrinsic motivation through the recognition of the group. When the examination was taken, it became apparent that the students had deepened their knowledge and learned new skills following the course itself. This could be due to the fact that the students were motivated by the aforementioned measures.

The examination was carried out in the form of a take-home exam in which the students recorded and reflected on their own learning progress. This made it easier to understand how the performance had been achieved during the assessment.

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Blended labs in the engineering sciences - the development of an alternative to laboratory courses using the design-based research approach

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Abstract

There is a great demand for educational formats that can be carried out regardless of location, and inclusion in teaching is becoming increasingly important. Teaching methods should appeal to different types of learners and be accessible to people from different backgrounds. While there are numerous approaches for lectures, seminars and tutorials, the implementation of laboratory courses in alternative formats is still comparatively new and complex.
The compulsory module "Measurement and Automation Technology" at TU Dresden, attended by around 300 students per semester, was faced with the challenge of offering laboratory courses in alternative formats during the COVID-19 pandemic. The choice fell on a blended learning format due to the number of students and because the handling of devices is an essential learning objective.
The research objective is to develop a blended-learning laboratory course on the topic of strain measurement. The study is designed according to the design-based research approach and pursues research questions on the supervision of students and learning obstacles that arise. The evaluation results show that the use of logbooks has led to an improvement in supervision. In addition, initial obstacles to learning were identified during the Blended Lab.

Die Nachfrage nach Bildungsformaten, die ortsunabhängig durchführbar sind, ist groß, und die Inklusion in der Lehre gewinnt an Bedeutung. Lehrmethoden sollten sowohl verschiedene Lerntypen ansprechen als auch für Menschen aus unterschiedlichen Lebensumstände zugänglich sein. Während es zahlreiche Ansätze für Vorlesungen, Seminare und Übungen gibt, ist die Umsetzung von Laborpraktika in alternativen Formaten noch vergleichsweise neu und aufwendig.
Das Pflichtmodul "Mess- und Automationstechnik" der TU Dresden, besucht von ca. 300 Studierenden pro Semester, stand vor der Herausforderung, Praktika während der COVID-19-Pandemie in alternativen Formaten anzubieten. Die Wahl fiel, aufgrund der Studierendenzahl und da die Handhabung von Geräten ein wesentliches Lernziel ist, auf ein Blended-Learning-Format.
Das Forschungsziel ist die Entwicklung eines Blended-Learning-Praktikums zum Thema Dehnungsmessung. Die Studie ist entsprechend dem Design-Based-Research-Ansatz angelegt und verfolgt Forschungsfragen zur Betreuung der Studierenden und auftretenden Lernhindernissen. Die Evaluationsergebnisse zeigen, dass durch den Einsatz von Logbüchern eine Verbesserung der Betreuung erreicht wurde. Außerdem konnten erste Lernhindernisse bei der Bearbeitung des Praktikums identifiziert werden.

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1. Problem definition

There is a great need for teaching formats that can be delivered from any location. The topic of inclusion is also becoming increasingly important - teaching should not only appeal to different types of learners, but also be flexible enough to be accessible and manageable for groups of people from different backgrounds.

While there are many approaches and research into the implementation of lectures, seminars and exercises, the implementation of laboratory courses in an alternative format is still comparatively new and complex. Alternatives include, for example, laboratory courses as virtual reality or augmented reality [1], remote [2], in blended learning format [3, 4] and as pure simulation [2]. These laboratory formats are explained in detail in the following section.

The Measurement and Automation Technology course is a compulsory module of the Mechanical Engineering degree course at TU Dresden, which is attended by around 300 students each semester. In addition to lectures and exercises, the module includes six laboratory courses. Triggered by the need during the corona pandemic to offer the laboratory courses in an alternative form, the experiments were to be transferred to a new format.

2. Background

When laboratory courses are implemented as **virtual reality** (VR) or **augmented reality** (AR), virtual elements are added to the face-to-face laboratory or even replaced entirely. The advantage of this approach is that even very complex scenarios can be depicted realistically and authentically. While fully immersive scenarios require the use of VR or AR glasses, partially immersive scenarios can already be realized using computers or smartphones. In both cases, considerable programming effort is required to create these scenarios. One disadvantage of VR scenarios is that students do not learn how to handle the real devices and the errors that occur, as these are only represented virtually. If access to a real laboratory is made possible via a web interface, this is referred to as a **remote** laboratory course. This allows students to operate the real tools, machines or equipment from any workstation. For such a system, the equipment must be equipped with the appropriate interfaces. In addition, the setup should be carried out in co-operation with the IT department of the respective institution, as access to the university network must be guaranteed. This option is also only suitable for smaller groups of students due to the limited number of remotely equipped workstations in the laboratory [5].

If a laboratory course is implemented in a **blended learning format**, students carry out the experiments at home with the help of the experimental materials provided and digital teaching/learning materials. The exchange about the work process can take place either in person or digitally. As the experiments are no longer carried out in the laboratory or with the equipment available there, the Blended Lab can, in principle, be carried out by any number of students at the same time. As the students no longer have to be supervised for the entire duration of the course, but only at fixed consultation times, there is less need for rooms and the supervision effort is reduced. However, depending on the experiment and the size of the student group, this implementation is associated with high acquisition and maintenance costs.

A laboratory course offered as a purely virtual **simulation** offers the advantage of scalability and enables easy adaptation to a larger number of students. As with the Blended Lab, there is less supervision required and no more rooms are needed to carry out the experiment. As the experiment is simulated by software, there are no material costs for equipping laboratory workstations. However, the students do not practise using equipment or tools. The processes that take place are also simulated and cannot be observed in reality.

The corona pandemic requires a format for laboratory courses that allows to carry them out from any location. In addition, this format must be scalable to a number of participants of approx. 300 students and enable the planning and construction of real experiments. The blended learning format is the only one that meets all criteria and was therefore selected for the new concept.

3. Objective and research question

Teaching-learning formats such as blended learning are becoming increasingly important in higher education. An understanding of the opportunities and challenges as well as concrete experience in the development of Blended Labs are essential for improving the courses offered to students.

Blended learning courses are often characterized by long phases of self-study in which students work independently. In order to provide students with appropriate support during these phases, it is important to be aware of the learning obstacles that arise. This is the only way to improve the support offered and adapt the teaching and learning materials accordingly.

The research objective is to develop a design for an engineering laboratory course on the topic of strain measurement in a blended learning format. The following research questions are derived from this objective:

- How should the supervision of students be implemented in order to provide them with the best possible support in completing their Blended Lab?
- What learning obstacles do students encounter when completing the Blended Lab?

The design guidelines derived from the research presented here can serve as a guide or basis for other teachers to develop their own Blended Lab. They provide important information on the structuring of self-study and attendance phases, the use of digital media and the design of work placement tasks. Overall, answering the research questions contributes to improving higher education in engineering by providing evidence-based insights into the design and implementation of Blended Labs.

The study presented in this paper was conducted according to the design-based research approach. This combines the development and evaluation of innovative teaching-learning approaches in order to generate practice-oriented solutions to real-world problems. A key aspect is the close collaboration between researchers and implementers. The study is carried out in several iteration cycles, each of which includes the following phases [6]:

1. Design or redesign
2. Evaluation
3. Analysis

The evaluation was carried out using a questionnaire containing closed questions and one open question. The closed questions were evaluated quantitatively using descriptive statistics. Qualitative content analysis according to Mayring [7] was used to evaluate the free comments. In addition, interviews were conducted with the caregivers and recorded in the form of key points.

4. Laboratory course (until 2020)

Until the massive restrictions on university operations during the coronavirus pandemic, the laboratory courses in the Measurement and Automation Technology module were carried out traditionally.

The students prepared for the laboratory course independently. After a short technical introduction, the suitability of the students to take part in the experiment was checked by means of a test. After passing the test, the experiment was carried out, evaluated and recorded over a period of three hours. The protocol constituted the graded examination performance.

Figure 1: Structure of the laboratory course "Strain measurement". The positions of the strain gauges are marked with arrows.

The main advantage of the laboratory course is the high-quality equipment that can be used, which enables precise measurements. This enables students to record reliable and reproducible results. In Figure 1 shows the set-up for the "Strain measurement" laboratory course. The load can be applied via a rotary control and precisely controlled via the force gauge.

5. Methodology

The strain gauges can be connected to the Figure 2 to form a Wheatstone measuring bridge. The disadvantage of this setup is that the actual wiring of the strain gauges is not visible and therefore remains abstract.

The students' task is to select the correct strain gauges, place them correctly in the Wheatstone measuring bridge and thus determine the different proportions of tension or compression, torsion or elongation in isolation.

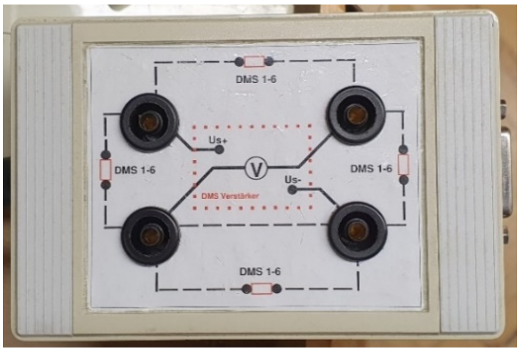

Figure 2: Slots for connecting the strain gauges to the Wheatstone measuring bridge

6. Start design (SoSe2022)

Due to the different prerequisites and framework conditions, the experiments of the traditional laboratory course cannot be adapted unchanged for the Blended Lab. In order to provide all students with the required materials, approx. 300 sets of the experimental setup must be procured. For cost reasons, the set-up should therefore be kept as simple as possible. In addition, the restrictions resulting from carrying out the experiment at home must be taken into account. For example, the introduction of defined loads for certain load types is difficult to implement. Various superstructures with superimposed loads (torsion/bending and tension/bending) were used in the laboratory course. However, torsion, tension and compression cannot be implemented precisely using simple means. The best load to implement is simple bending.

Bending can be generated in different ways. Two variants that were considered during conceptual design were (a) bending by deflection by a certain distance and (b) bending by applying a defined load. The deflection by a certain distance could be achieved using a set screw, for example. However, this setup requires a comparatively complex test geometry.

Bending by load can be generated by attaching a defined mass to the measuring geometry. This can be realized with very simple geometries, such as the bending beam. The bending stress can then be determined using the lever arm, the acceleration due to gravity and the mass used. All that is needed to determine the mass is a kitchen scale, which can also be found in most student households.

The advantage of the bending beam is also that the calculation of the stress state was practiced extensively in the basic course and is therefore familiar to the students.

Another prerequisite for the design of the experiment resulted from the existing laboratory courses. As the Arduino microcontroller is already used in these, it should also be used in the "Strain measurement" Blended Lab to record the measured values.

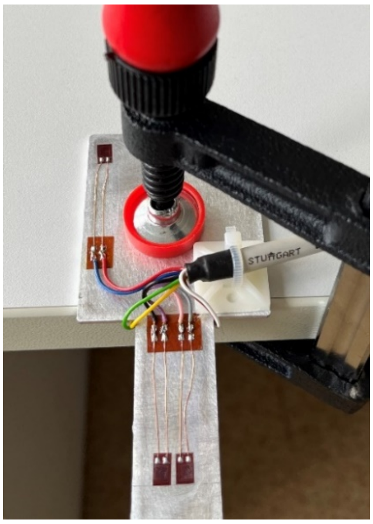

Figure 3: Arrangement of the strain gauges on the bending beam

A design was chosen that allows all Wheatstone measuring bridges to be implemented and requires the fewest strain gauges. A total of five strain gauges were therefore attached to the bending beam. Two are located on the top side, two on the bottom side and one passive strain gauge on the mounting plate. The arrangement of the strain gages is shown in Figure 3 to recognize.

The principle and the actual wiring of the Wheatstone measuring bridge should also be made directly visible in the newly designed experimental setup. This is easy to implement using the Arduino. Depending on the task, the students can plug together the appropriate Wheatstone measuring bridge on the breadboard. In Figure 4 shows how three fixed resistors are connected to an active strain gauge to form a quarter measuring bridge.

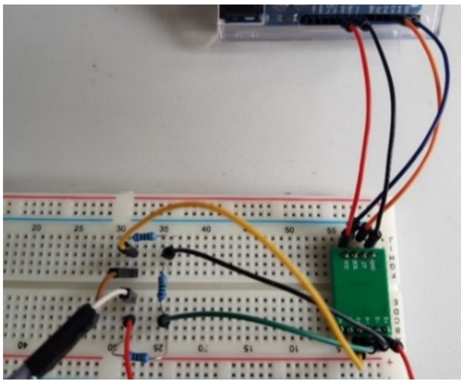

Figure 4: Electrical circuit for the "Strain measurement" experiment

In Figure 5 shows the overall setup of the experiment. The bending beam is attached to the table top with a clamp. A water bottle is attached to the hole using a thread as a weight. A bottle is advantageous as it can be filled with water to increase the load. The analog-to-digital converter converts the analog measurement signal and simultaneously amplifies

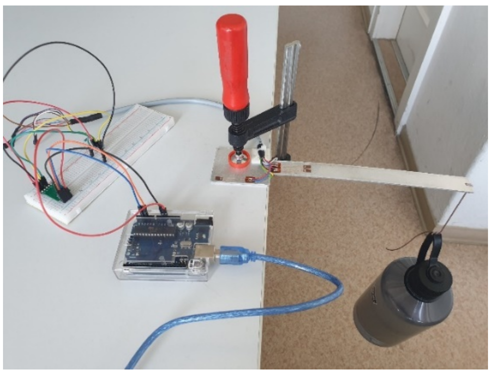

Figure 5: Overall setup of the "Strain measurement" experiment

The diagonal voltage of the quarter-bridge. The values are recorded using an Arduino script and output via the serial monitor.

Procedure

The biggest difference compared to the laboratory course is that the Blended Lab is completed at home in partner work using the components and digital materials provided. Students borrow the experimental materials from the department at the beginning of the semester.

Two face-to-face meetings are offered to support students in their work. One during the processing time (interim meeting), the other after the submission of the protocol (debriefing).

In the interim discussion, the participants solve sub-problems that serve to bring the students into an exchange and to intercept hurdles in the processing in advance.

The students only have one interim meeting, and it is not possible to predict what level of work and knowledge they will bring with them. The tasks are intended to draw their attention to problems that they may not yet have encountered.

The debriefing serves to clarify any questions that remain unanswered and thus ensure the technical accuracy. In addition, the minutes should be returned here and individual feedback given at the same time.

The processing period extends over three weeks and starts with the upload of the digital materials. After one week, the interim meetings begin, which are offered over a period of seven days. Students then have another week to finalize their work and submit the report. The debriefing sessions take place in the week following the submission of the report.

Task

The main objective of the Blended Lab is to enable students to carry out independent scientific experiments. For this reason, the tasks have been designed to resemble the procedure for working on a research paper. The following tasks are to be completed in groups of two:

- Calculation of the theoretical model
- Characterization of the system in the unloaded state

- Comparison of quarter and full gage bridge
- Investigation of interference
- Design of an own circuit for temperature compensation

First, the students should find a model for the theoretical description of the test object in order to be able to validate their measurement results later.

Since the strain gauges were all manually glued to the side beams and therefore behave differently, the system is then characterized in an unloaded state.

In the third task, the bending beam is loaded step by step. The measurement is carried out successively with a quarter and a full measuring bridge. The experimentally determined data are compared with each other and with the theoretically expected values.

When carrying out experiments, it is also important to consider which factors can influence the measurement results. This is the only way to avoid them. Therefore, in the fourth task, the students should consider what interferences exist and examine the effects of three influences in more detail.

In task 5, the students use the knowledge they have gained to plan an experimental setup for temperature compensation and demonstrate the correct functioning of their circuit.

According to the module description, students should spend a total of eleven hours on the Blended Lab, with four hours for carrying out the experiment and seven hours for preparing, evaluating and writing the report.

Results of the evaluation

The evaluation of the initial design focused primarily on the implementation and assessment of the support services. In the evaluation, 53% of students stated that their questions were not answered in the support services. At the same time, the supervisors criticized the fact that the current design of the interim meeting required them to spontaneously provide correct answers to unforeseeable questions.

The feedback also showed that the debriefing does not work as intended. It is not possible to check the protocols in the short period between submission and debriefing. This means that there is no basis for the feedback discussion with the students. In addition, there is little demand from students for this support service.

The feedback from students and supervisors shows that the supervision concept needs to be adapted for the next round. The students' questions must be answered more reliably. At the same time, the supervisors must be given adequate preparation.

Another major point of criticism was identified from the free comments. 40% of all comments related to the time required to complete the Blended Lab, which students felt was too high ("implementation was far too time-consuming"). To check this, the evaluation will be adapted for the redesign. In the future, students will be able to indicate the amount of time they spent on the Blended Lab so that this can be compared with the planned workload.

7. Redesign (winter semester 2022/2023)

In the next iteration, several measures were taken to improve support. These include the introduction of a logbook to accompany and structure the self-study phase and the submission of student questions before the attendance date to enable the supervisors to prepare in a targeted manner.

The logbooks in which the students write down their questions about the Blended Lab must be uploaded to the OPAL learning platform before the consultation appointment. This allows the group of supervisors to deal with the questions in advance and collaboratively develop a question-and-answer catalog. This is intended to reduce preparation time and the workload of those responsible, as well as to create a uniform quality standard for supervision. The questions also form the basis of the student-centered consultation. In line with the principle of just-in-time teaching, the questions are taken one-to-one from the logbooks and printed on cards. This ensures the authenticity of the event, as the participants can find their own questions and thus recognize that the consultation is about solving actual current student problems.

Due to the low demand and in order to relieve the supervisors, the debriefing is omitted from the redesign, so that the interim meeting is the only consultation appointment for the students.

The so-called "semester overview" has been introduced to support time management during the self-study phases. This is shown at the beginning of each lecture and places the course in the context of the semester as a whole. The principle is illustrated in Figure 6 illustrates the principle.

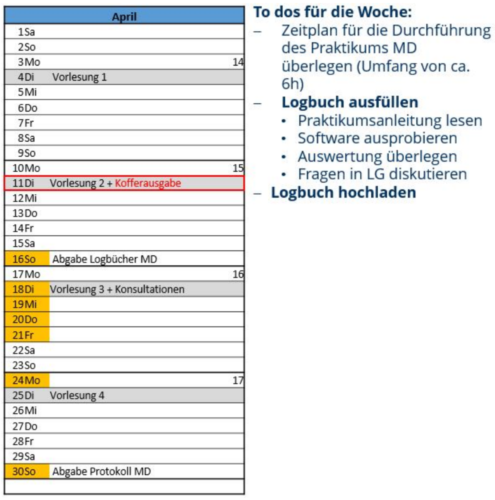

Figure 6: Semester schedule with the tasks to be completed in each week. The abbreviation MD denotes the "Measurement Dynamics" Blended Lab. LG stands for learning group.

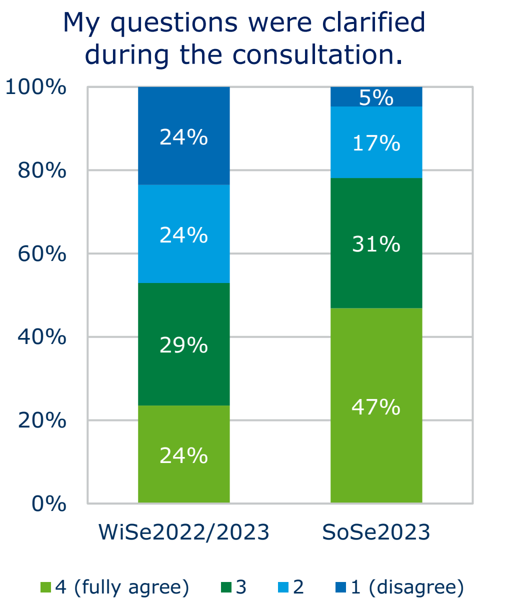

Figure 7: Comparison of the results for the item "My questions were clarified in the consultation" between the consultation in winter semester 2022/2023 and the consultation in summer semester 2023.

This draws attention to important upcoming events such as consultation dates or deadlines. In addition, to dos are listed for the respective week, which are not mandatory, but give students an indication of the tasks to be completed and the workload involved.

Procedure

In contrast to the initial design, the digital materials will be made available at the start of the lecture period in the winter semester 2022/2023. Students will therefore be able to work on the Blended Lab from the start of the semester. In practice, however, the starting time is determined by when the Blended Lab's topic is covered in the lecture.

A new addition is the processing of the logbook, which must be handed in at the weekend before the start of the consultation.

By adapting the care, there is now only one round of consultation appointments, which extend over a week.

Task definition

As the students criticized the time required to complete the Blended Lab in the first run, the task "Investigation of interferences" was shortened for the redesign. Now only two instead of three interferences are to be investigated. The students are also free to choose the bridge circuit, so that the comparison between quarter and full measurement bridges is no longer necessary.

Results of the evaluation

The starting point for the changes to the support described was the result of the first evaluation, in which only 53% of students agreed that their questions were clarified. This was assessed using the item "My questions were clarified during the consultation", for which the students were able to indicate their assessment on a Likert scale from 1 (disagree) to 4 (strongly agree). Values 3 and 4 are rated as agreement, while values 1 and 2 are interpreted as disagreement.

The consultation was then adapted in line with the concept described above. If the result is compared with the information from the evaluation in the summer semester 2023 after the new consultation concept was implemented, a significant increase in approval to 78% can be seen. It should be particularly emphasized that the largest increase is in the 4 rating (strongly agree) at the expense of the lowest rating 1 (disagree) (cf. Figure 7). The items were rated from $n_{\text{alt}} = 68$ respectively $n_{\text{neu}} = 64$ students. This trend can also be seen in the free comments. In the first evaluation, 31 participants used the feedback function. Six comments criticized the fact that questions were not answered during the consultation. Four other comments emphasized the need to clarify open questions outside of the consultation: "As no questions were answered by email, we felt very alone."

In the second evaluation, 31 participants also used the free comments. However, only two comments stated that questions were not answered in the consultation. Lack of time was cited once as the reason: "Questions not clarified in consultation due to lack of time." In contrast to the first evaluation, there is also positive feedback in which the consultation is praised ("Consultation is great").

During the evaluation of the redesign, learning obstacles in the preparation, implementation and evaluation of the Blended Lab were also recorded. It was particularly noticeable that the students were very unsettled by errors in the implementation and deviations in the measured values. In addition, there were major difficulties in the evaluation when using Excel. The learning obstacles identified are shown in Figure 8 listed.

When the processing time was surveyed, the students also stated that they needed an average of 21.6 hours for the "Strain measurement" Blended Lab. This is significantly more than expected.

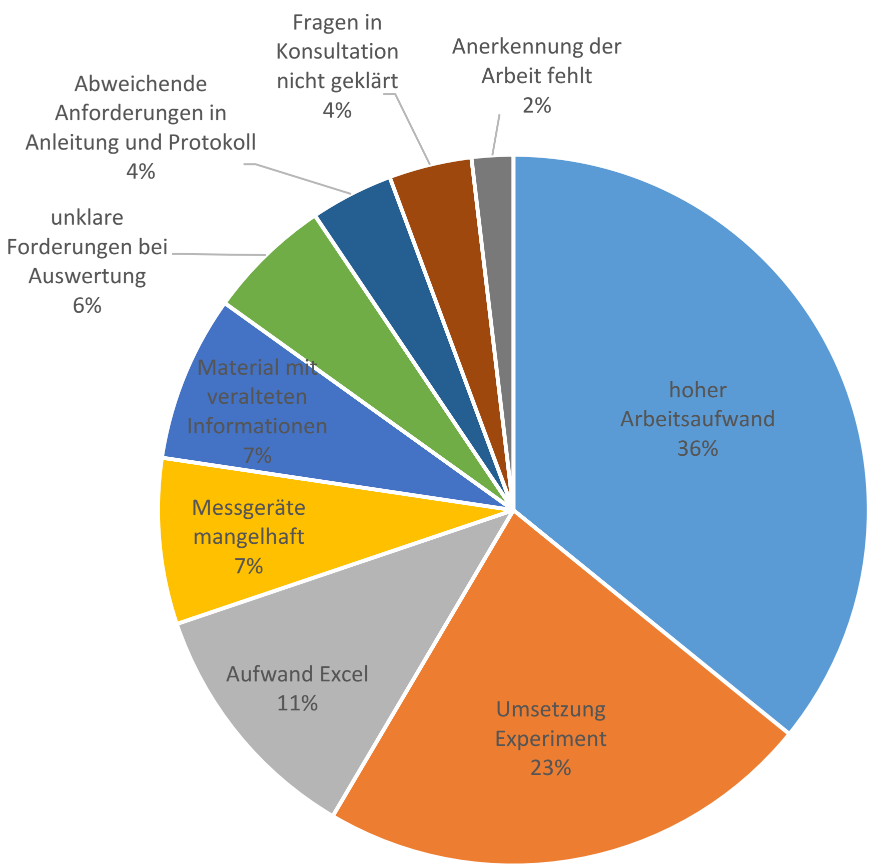

Figure 8: Students' learning obstacles when working on the "Strain measurement" Blended Lab

8. Summary

The results of the evaluation show that the redesign has significantly improved support. The use of logbooks was particularly successful, not only relieving the burden on the supervisors, but also making the consultation more student-centered. Initial obstacles to learning were also identified by students when working on the Blended Lab, which can be taken into account in subsequent iterations. The biggest point of criticism from students is currently the high workload. Another aspect is that many students have problems with the implementation of the Blended Lab experiment. There is a great deal of uncertainty when errors occur or results do not meet expectations. In addition, the use of Excel, which is used for evaluation and logging, poses a challenge, as many students are still inexperienced in using this program.

The learning obstacles identified with the help of the evaluation indicate that the Blended Lab requires more planning and organization of one's own work processes and the coordination of partner work. Time management also differs from that of conventional laboratory work placements, which have a clear start and end time. The changed laboratory course format alone means that the skills and abilities required for the work shift. The greatest challenge of the Blended Lab is no longer the pure acquisition of knowledge. Instead, the changed format requires the acquisition and application of so-called 21st century skills. These include independence, the ability to work in a team, initiative, creativity in solving problems, competence in dealing with media, data, information and technologies as well as strong communication skills, which also include the ability to convey one's own thinking in an understandable way [8, 9]. The skills shift towards 21st century skills is a positive development that supports sustainable engineering education. The acquisition of skills made possible by blended labs should be promoted by further adapting the work tasks and supported by a suitable digital presentation.

9. Outlook

The change in requirements due to the format of the Blended Labs was not taken into account in the initial design of the laboratory course. For this reason, the next step is to define the concept of competence in the Department of Engineering in a uniform manner and to re-examine the content, examination performance and competence-oriented learning objectives for coherence in accordance with constructive alignment.

In addition, it should be clarified whether the acquisition of certain skills can be brought forward. For example, the use of Excel could already be trained in the calculation exercises, which would reduce the Blended Lab's workload. One way of dealing with students' uncertainty in the event of deviating measured values would be to list certain types of errors and their causes in an FAQ. This could make it easier for students to assess and rectify errors.

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Project integration of students through open problem tasks in competence-oriented courses

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Abstract

The everyday life of academic staff is characterized by the duality between teaching and project work. Modules usually consist of lecture and practical components. These are often repeated over several semesters and are the same for all students. Research assistants or students in higher semesters supervise these without direct added value in projects, and as part of the Master's degree program in Textiles, the possibility of replacing prefabricated internships with changing tasks adapted in advance to current research projects is being evaluated. These are presented in the form of an open problem assignment at the beginning of the semester. The students work on their personal tasks during the course. The lecture content enables students to use industry-relevant software packages independently. The didactic analysis according to Klafki takes place after completion of the course [1, 2]. All participating students were able to successfully complete their assignments. The research assistants received high-quality results that could be used in ongoing projects. The practical exam task was successfully completed by all students with individual approaches.
The results of this first trial show that individual and project-related tasks lead to increased competence and at the same time provide usable results for the lecturers. Working on research projects gives students practical insights into current research.

Der Alltag wissenschaftlicher Mitarbeiter:innen wird durch die Dualität zwischen Lehre und Projektarbeit geprägt. Module bestehen meist aus Vorlesungs- und Praxisteilen. Diese werden oft über mehrere Semester wiederholt und sind für alle Studierenden gleich. Wissenschaftliche Mitarbeiter: innen oder Studierende höheren Semesters betreuen diese, ohne direkten Mehrwert in Projekten.Im Rahmen des Masterstudiengangs Textil wird die Möglichkeit evaluiert, vorgefertigte Praktika durch, im Vorfeld an aktuelle Forschungsprojekte angepasste, wechselnde Aufgabenstellungen zu ersetzen. Diese werden in Form einer offenen Problemaufgabe am Anfang des Semesters präsentiert. Die Studierenden bearbeiten ihre persönliche Aufgabenstellung im Zuge der Lehrveranstaltung. Die Vorlesungsinhalte befähigen zur selbstständigen Nutzung industrierelevanter Softwarepakete. Die didaktische Analyse nach Klafki erfolgt nach Abschluss der Lehrveranstaltung [1, 2]. Alle teilnehmenden Studierenden konnten ihre Aufgabenstellung erfolgreich bearbeiten. Die wissenschaftlichen Mitarbeiter: innen erhielten qualitativ hochwertige Ergebnisse, welche in laufenden Projekten verwendet werden konnten. Die praktische Klausuraufgabe wurde von allen Studierenden erfolgreich und mit individuellen Ansätzen bearbeitet.
Die Ergebnisse dieses ersten Versuches zeigen, dass individuelle und projektbezogene Aufgabenstellungen zu gesteigerten Kompetenzgewinnen führen und gleichzeitig verwertbare Ergebnisse für die Dozenten liefern. Die Mitarbeit an Forschungsprojekten gibt den Studierenden praktische Einblicke in die aktuelle Forschung.

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1. Preparation

The working group meets for a joint brainstorming session before the start of the semester. The first step is to discuss the module content and what knowledge the students should acquire. In the next step, the research assistants present their projects with work packages and subtasks. The group identifies task packages that can be worked on with the content taught in the lecture. Corresponding tasks are then developed. There are always more tasks than students are expected to complete. The aim is to meet the expectations of academic staff and students with regard to the course and to generate added value for all parties, as shown in Figure 1.

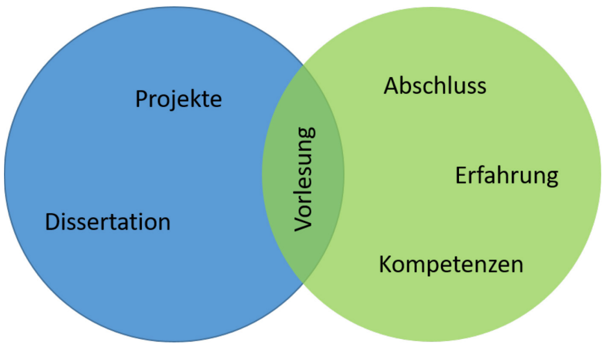

Figure 1 : Venn diagram of academic staff versus students

The selected course deals with the design of clothing using 3D CAE software. Accordingly, clothing design is the focus of the tasks, as shown in Table 1.

Table 1 : Tasks for the students and corresponding projects

Subtask	Project
Construction of a particle-filtering half mask	Project on medical protective equipment
Construction of a sports bra	Project on soft part simulation
Construction of a surgical gown	Project on medical protective equipment
Construction of trousers with integrated protectors	Project on protective equipment in the sports sector
Construction of a jacket with integrated protectors	Project on protective equipment in the sports sector

2. Course schedule

In the first course, the concept is explained to the students. They choose one of the previously presented topics.

The course provides the content required to complete the task. The students independently work out the existing requirements for their product, e.g. existing standards for particle-filtering half masks. The lecture teaches the digital construction of clothing close to the body and away from the body.

3. Learning studio

Both the lecture materials and introductions to the programs presented for digital garment construction are available in a so-called learning studio. The learning studio is an internal wiki with all the lecture materials, additional explanations and examples of how to use the software packages required for the course. Students can work on their tasks independently outside of the lecture. The interaction between the lecture and the learning studio is shown in Figure 2.

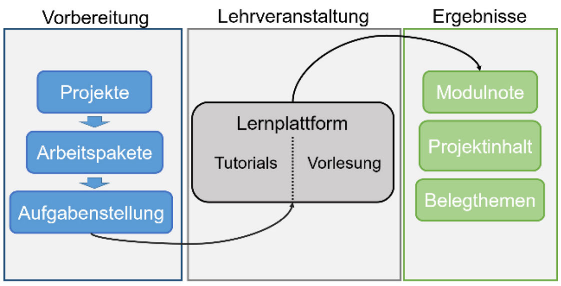

Figure 2 : Event schedule

4. Didactic analysis

The teaching topic of the lecture course is to teach students how to solve individual tasks from current research projects independently. The main objective is to provide students with the necessary knowledge, skills and abilities to work independently on their tasks. They are supported in this by individual consultations.

Klafki's didactic analysis places particular emphasis on the formation of key qualifications and the teaching of values in the classroom. Klafki emphasizes the importance of general education and the development of discernment in learners. When applied to these courses, the following categories emerge:

Professional competence: Students should develop the necessary professional knowledge and skills to understand and successfully work on their individual tasks from current research projects.

Independent work: Students should learn to work independently on their tasks and to identify problems and develop solution strategies.

Communicative competence: By using the learning studio and receiving individual support, students should learn to present their work results, give and receive feedback and communicate their ideas.
The didactic decisions made are named and justified below.

Individual and open problem assignments: Each student receives an individual assignment from current research projects. This emphasizes the relevance and practical relevance of the learning content and increases student motivation.

Individual support: Students receive individual support during the semester to help them solve their assignments. This ensures that every student receives the support they need and that individual difficulties and questions can be addressed.

Tutorials in the wiki: Students have access to tutorials in a wiki to help them work on their assignment. These tutorials provide step-by-step instructions, practical examples and resources to help students implement their solution strategies.

Examination task: The examination consists of the students applying what they have learned by means of a comparable task. This ensures that students can actually apply and use the knowledge and skills they have acquired.

5. Results

The product concepts developed by the students were used for a total of three different products. Two of the five students who took part in the course subsequently began working on a document assignment in the corresponding projects at the professorship. The products developed are shown in Fig. igure 3 can be seen.

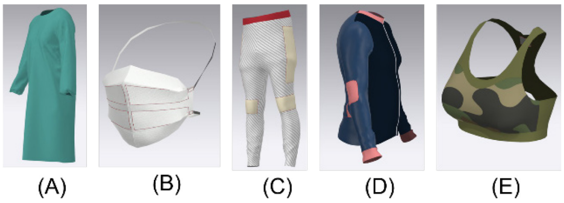

Figure 3 : Results of the project work: (A) surgical gown; (B) particle-filtering half mask; (C) cycling shorts with protectors; (D) cycling jacket with protectors; (E) sports bra

The practical part of the module examination consisted of the construction of an arm cuff. Material parameters and optical key points, such as an elbow patch, were specified. The students were all able to solve this task with individual approaches, but with very good results.

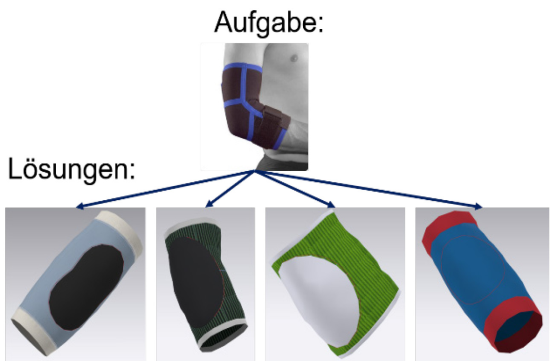

Figure 4: Results of the practical examination task

The didactic analysis according to Klafki shows that the lecture course addresses the goals of professional competence, independent work and communicative competence of the students through its focus on individual tasks, supportive supervision, tutorials in the wiki and the application of what has been learned in an examination task. This approach creates a practical and motivating learning environment in which students can successfully complete their assignments.

The approach presented here for integrating students in project work can be applied to any module with a practical component. The course must impart knowledge that is directly applied or practiced. There must also be a framework for task-specific consultations, i.e. courses with large numbers of students will not work for this concept.

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