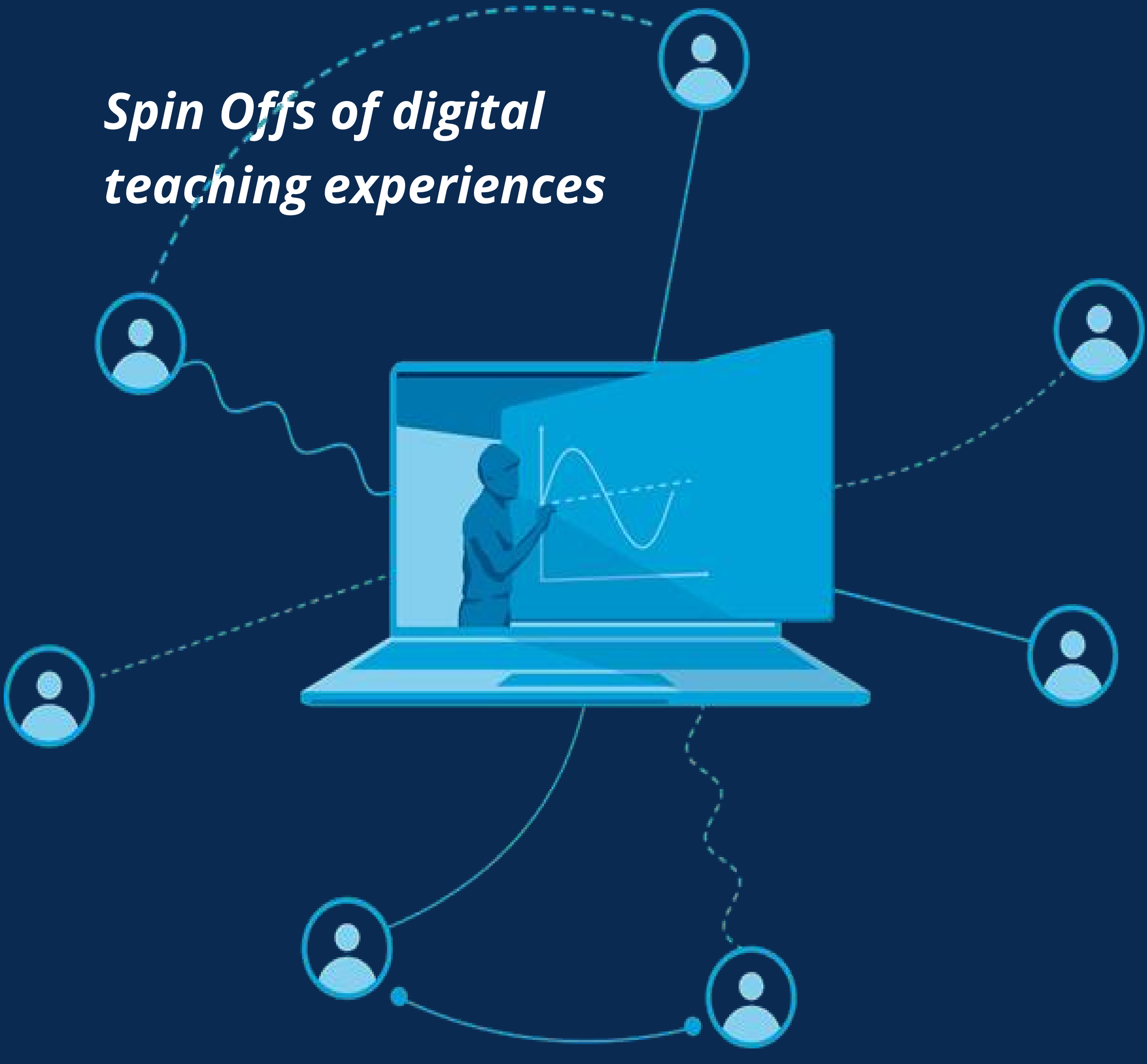
TECHNISCHE UNIVERSITÄT DRESDEN

Lessons Learned

Spin Offs of digital teaching experiences



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Volume 2 | 2022

FAKULTÄT MASCHINENWESEN

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 semester 2020, an unprecedented change and renewal of teaching formats has occurred. Although these changes have been forced by the constraints imposed by the pandemic, the experiences and concepts that have been developed are of tremendous value in renewing teaching towards modern, digitally supported forms of teaching and learning and towards more competency-based learning. At the beginning of the winter semester 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. From this first conference, a conference series has emerged 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 natural sciences and technical sciences, but far beyond in all subject disciplines and thus to create a platform where teachers can find out 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, it is translated into the other language by the journal, which means that the authors only have to proofread the translated article.

Editorial Board

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Editorial

The fourth issue of the ***Lessons Learned Journal***, the second issue in the second volume. This means, strictly speaking, a milestone for the development of the Journal. With this issue, a state has been reached in which two issues per year have been published in two consecutive years. This now quasi-established structure shows at the same time the interest that exists in the further development of teaching even after the end of the Corona Pandemic. Thus, this interest is not only driven by the necessities generated by the Corona Pandemic, but an intrinsic willingness to modernize university teaching has developed.

The current issue shows that this development has gained importance and interest far beyond the Faculty of Mechanical Engineering, where the ***Lessons Learned*** concept originated, and far beyond the TU Dresden.

The first part of the fourth ***Lessons Learned conference*** is published in this issue. The second part, which will contain the further contributions to ***Lessons Learned IV**, is* planned for early summer 2023. This will result in the future structure for the issues of the Journal: two issues will regularly result from a ***Lessons Learned conference.*** One will be published about half a year after the conference at the end of the year, the second in the following spring. Thus, the Journal's structure takes into account the workload that faculty face at universities today. Notwithstanding this, all contributors can now choose the date of publication of their contribution to the conference and clock it into their work schedules. This should make it possible in the future to comprehensively record and make available the valuable results that result from the further development of university teaching.

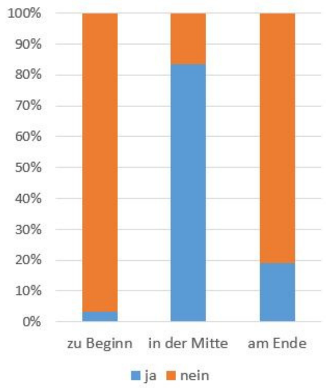
In terms of content, the current issue shows that the development of new teaching concepts using digital components has not slowed down after the Corona pandemic, but rather increased. It also becomes clear that the effort to combine the use of digital elements with face-to-face teaching and thus to keep the focus on academic exchange in presence has taken on a central role, irrespective of the renewal of individual teaching components with digital elements. In addition, it is apparent - and this can already be seen from the covers of the contributions - that the further development of modernized teaching concepts is accompanied by evaluation across the board. That is, the new development of components of university teaching is carried out with the student perspective in mind, and the components developed are optimized on the basis of the experience gained from the evaluations.

Through the Design Based Research approach that is clear from many articles - even if this term is not usually used - the name of the journal retains its meaning even after the pandemic. It is no longer just about describing the ***Lessons Learned*** that emerged from the pandemic. Rather, it is about discussing the lessons learned that emerge from the renewal of teaching in interaction with students and sharing and making available the relevant experiences.

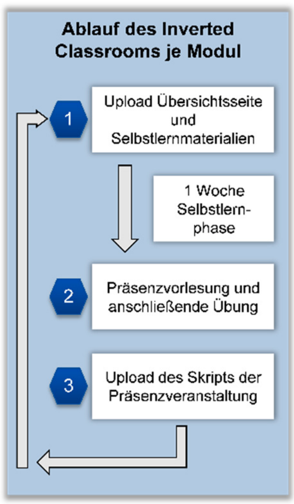
But this issue does not just highlight current developments in the use of digital components in university teaching. Rather, Cornelia Breitkopf's article shows that digital components in teaching are nothing really new. Ten years of ThermoE are a sign that the possibilities of digital teaching are immense and sustainable. At the same time, they show that there is an inertia in the transformation of university teaching at universities, since the corresponding possibilities were already pointed out ten years ago, but were not recognized. Now it is possible to learn from these immense experiences!

With this in mind, we look forward to welcoming you to the fifth ***Lessons Learned Conference*** in Dresden in the summer of 2023, with written papers available in the late 2023 and early 2024 editions.

Stefan Odenbach



The redesign of university teaching using digital components continues. What is new is that this further development is massively accompanied by evaluations and that the new components are optimized on the basis of the evaluation results, i.e. with the addition of the student perspective.



Inverted classroom concepts are a logical consequence of the development of teaching formats in the pandemic. Their possibilities and pitfalls will be with us for a few more semesters.

Range of topics

Novel formats and evaluation

B. Watzka
Interactive exercise tasks in physics education Comparison between online, face-to-face and self-study instruction

M. Bleckmann, D. Schumann, P. Nyhuis
Lessons Learned – Constructive Alignment meets Lean & Green Production

C. Wermann, B. Schlegel, S. Odenbach
Development and analysis of the evaluation of Praktika@home

B. Schlegel, C. Wermann, S. Odenbach
Evaluation of the effectiveness of teaching in the module Measurement and Automation Technology

B. Kruppke, S. Apelt, C. E. Hartwig, A. Koch, J. Mai, A. L. Schumann, T. J. Ulbricht, M. Ullmann, H.-P. Wiesmann
The competence studio as an agile teaching format - Biomechanics project work up to the prototype

C. Breitkopf
10 years thermoE - A survey of the online-based support of the basic lecture thermodynamics

M. Kuhtz, N. Modler, M. Gude
Digital, collaborative small group work in Active Plenary - a contradiction?

C. D. Deters, A. M. Menzel
Digital Media versus Blackboard and Chalk - Online and Hybrid Teaching in Theoretical Physics

Inverted Classroom Concepts

D. Schumann, T. Kämpfer, M. Bleckmann, V. K. Kuprat
Lessons Learned from Implementing an Inverted Classroom Model.

J. Brose
Blended Learning with Jupyter Notebooks

New teaching concepts with digital components require digital competencies among all participants - a complex topic with groundbreaking significance for the further development of university teaching.

Development of digital formats and competencies

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Interactive exercise tasks in physics education: comparison between online, face-to-face and self-study instruction

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Abstract

Lernen ist ein aktiver und konstruktiver Prozess. Interaktive Aufgaben erlauben eine Aktivierung der Lernenden in jedem Lehrformat. Offen ist die Frage, ob es Unterschiede im Bearbeitungserfolg und der Änderung des Professionswissens beim Lernen mit interaktiven Aufgaben unter verschiedenen Lehrformaten gibt. Ebenso ist offen, inwieweit sich angehende Lehrkräfte vorstellen können, mit Hilfe eines Tools solche Aufgaben selbst zu erstellen und in ihrem späteren Berufsleben als Lehrmittel einzusetzen.
Ein interaktives Aufgabenset wurde mittels drei verschiedener Methoden gelehrt und evaluiert. Die Stichprobe (N=66) stellten Lehramtsstudierende der Physik. Sie bearbeiteten einen Lernpfad mit interaktiven Aufgaben, um sich fachdidaktisches Wissen zu einem Thema zu erarbeiten und zugleich ein Tool für die Entwicklung solcher Aufgaben kennen zu lernen.
Die Ergebnisse zeigten keine signifikanten Unterschiede im Bearbeitungserfolg und Professionswissen zwischen der Online- und Präsenzlehre. Jedoch zeigten die im Selbststudium Lernenden signifikant kürzere Bearbeitungszeiten, ein chaotischeres Lernverhalten, einen geringeren Bearbeitungserfolg und geringere Zuwächse im Professionswissen. Die Akzeptanz der Studierenden in Bezug auf interaktive Aufgaben und das exemplarische Tool stieg durch die Arbeit mit dem Aufgabenset in allen Gruppen an.

Learning is an active and constructive process. Interactive exercise tasks (IET) enable the activation of learners in any teaching format. It is an open question whether there are differences in the task success and the change of professional knowledge when learning with IET under different teaching formats. It is also open to what extent prospective teachers can imagine creating such tasks themselves with the help of a tool and using such tasks in their later professional lives.
An IET set was taught using three different methods and evaluated. The sample (N=66) consisted of student teachers of physics. They worked on a learning path with IET to acquire educational knowledge and at the same time to get to know a tool for the development of IET. The results showed no significant differences in task success and professional knowledge between online and face-to-face teaching. However, self-study learners showed significantly shorter learning times, more chaotic learning behaviour, lower task scores, and lower increase in TPACK. The students' acceptance of IET and the exemplary tool increased in all groups as a result of working with the tasks.

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1. Introduction

The COVID-19 pandemic challenged lecturers to break the rather passive consumer attitude of some students in online/distance learning [1] and instead promote active student engagement with the learning materials.

This paper describes the evaluation of learning paths with interactive elements/tasks in asynchronous and synchronous online and face-to-face teaching in teacher education. The main goal of the courses is to teach physics educational knowledge and technology-related physics educational knowledge. The procedure of the course extends cyclically over two sessions. In the first session, students work on physics educational topics, which are prepared by the lecturer via a tool. In the second session, the students acquire practical knowledge about the tool that was used to prepare the learning content in the previous session. In this way, the students can take on the roles of learners (first session) and teachers (second session).

In this article, an excerpt from the area of the first sessions is presented. With an interactive learning path, physics educational knowledge about the transistor is taught. The learning path is implemented with the tool H5P.

2. H5P

H5P enables the creation of interactive learning content and is a freely accessible and open-source software. It is available as a plugin for various content management systems (CMS) such as WordPress and learning management systems (LMS) such as Moodle [2].

H5P is configured with an LTI and an xAPI interface.

LTI stands for Learning Tools Interoperability and is a universal standard that enables the integration of a system (here a H5P task) into other systems (e.g. Moodle) [3].

xAPI stands for Experience API and is also known as TinCan [4]. The xAPI interface passes data to a learning activity database, also known as a Learning Record Store (LRS). The xAPI statements are based on the simple pattern: subject verb object. This allows tracking of any activity of a learner in the learning environment [3].

3. Effects of active learning

Active learning is anything that gets students to do things and to think about what they are doing [5].

Initiating learning activities in lectures can improve learning performance [6]. For example, Hake [7] shows that student performance increased significantly in introductory physics courses, when interactive methods were frequently used.

The learning benefits of interactive content have been recently explored by several users from different academic disciplines (including Watzka et al. [2], Pereira et al. [8], Chen et al. [9], Rama Devi et al. [10], Unsworth and Posner [11], López et al. [12], Sinnayah et al. [13], Wilkie et al. [14], Wicaksono et al. [15], MacFarlane and Ballantyne [16], Mir et al. [17], Thurner et al. [18], and Santos et al. [19]). In the following, only the results of evaluations of H5P content, that were measured in a standardized way with log files or xAPI data, questionnaires, or interviews are reported.

Thuner et al. [18] conducted a mixed-method study on the effect of interactive videos [18]. They collected log files, questionnaires, and problem-based interviews. Among other things, they investigated learning behavior and learning outcomes when working with interactive or non-interactive H5P videos. Their results show that H5P quizzes implemented in videos influence learning behavior. Compared to the group without H5P quizzes, the group with the quizzes used the questions as navigation aids. The log files show that quite a few users, for example, first jump to the quiz questions to check the expectations set for them. After that, they decide if it makes sense for them to watch the video sections. In the interviews, the users confirm the focusing effect of the quiz questions and they state that they help them to process the video content.

Wicaksono et al. [15] conducted questionnaire studies with open and closed questions. They investigated for 19 students whether their motivation and learning performance in English is influenced by the use of H5P content. Their results show that 90% of the participants agree with the question about whether H5P content helps them to focus on relevant details. Similarly, 90% of participants feel more interested and attentive to the learning content because of the use of H5P content. Another 74% say they are more motivated by using H5P content. A large number of the motivated students also have achieved good learning performance, which Wicaksono et al. [15] see as a trend towards a positive relationship between motivation and learning performance.

Sinnayah et al. [13] asked 250 students about the use of H5P content in physiology courses by using a questionnaire. Their results show that 80% of the students perceive the H5P content to be more time-consuming compared to the multiple-choice questions they usually use. Despite the increased effort, 90% of students report that their knowledge has improved through repeated practice with H5P, and that H5P content helps them to keep up in the course.

Santos et al. [19] used the H5P template *Branching Scenario* in terms of interactive problem-based simulations in a network course with 30 students. They captured the learning behavior of the students using xAPI. They also compared the final grades of the course with H5P content with the grades of previous courses without H5P content. The results show that students who learn with H5P content achieve better grades on an average while being extremely satisfied with their exercises. Students also believe that learning with H5P content helps them to learn concepts faster.

4. Learning paths and routes

Learning paths are idealized, often linearly structured learning opportunities. They are often implemented as web-based learning environments in a modular way. They provide binding learning goals and contain various interactive learning materials with coordinated tasks. They also include feedback and offer help to achieve the goals. Depending on their interests and level of performance, learners can independently select units or tasks and thus direct their individual learning process toward the given goals [20]. Learning paths do not force the learner to work through the material in a linear way; rather, they leave it up to the learner to decide on varying individual learning routes [21].

Learning routes show the sequences of the units called up and the tasks worked on as a function of time. Despite a linear learning path, learning routes often do not run in a linear way. They can oscillate and are characterized by jumps [21]. Causes for different learning routes are not only individual knowledge structures of the learners, which have already been formed due to previous experience and knowledge [21]. Affective components such as interests or attitudes can also influence the selection of a learning path. Analyzing learning routes is not just about examining the successes and failures at the end of a learning process. Rather, the goal is to visualize the genesis of successes/failures during the learning process.

Measures of learning routes are, for example:

- Time points and durations of the processing of tasks / units
- Frequencies incl. repetitions and omissions of tasks / units
- Sequences of the activities
- Achieved scores, deductions due to errors
- Frequency of the call for help
- Log files e.g. for using the navigation options etc.

5. Teaching objectives and evaluation goal

The seminar aims at applying educational theories to a concrete teaching content and enhance the students' competencies in the field of multimedia learning.

The aim of the evaluation is to record the learning outcomes (the scores for tasks and changes in the professional knowledge), the acceptance and relevance in relation to the interactive tasks and the chosen learning routes. The theoretical basis is based on TAM models extended by TPACK as described by Mayer et al. [22].

A comparison of the learning effect between learning with interactive tasks and a classical lecture style or an experimental practical course is not of interest here. Also, possible connections between the choice within a learning path and interest characteristics or motivational dispositions are not in question here.

6. Sample and procedure

The sample consists a total of 66 student teachers studying physics for the teaching profession at LMU Munich (n=55, 33 of them male) and OVGU Magdeburg (n=11, 8 of them male). The Munich students were between the 7th and 9th semester, the Magdeburg students had completed the 6-semester Bachelor's program and were in the 1st semester of the Master's program. All students had already attended the physics experimental lectures, the introductory to physics education lecture and the experimental laboratory courses as well as two seminars on typical school experiments. Furthermore, all students were familiar with the processing of interactive tasks.

The evaluation took place in three winter terms (19/20, 20/21, and 21/22) in a 90-minute compulsory course. The distribution of the students to the teaching format was not done randomly, but according to the Corona regulations at that time. An overview of the number of participants per teaching format is shown in the following table (Tab. 1).

Tab. 1: Sample

	Guided Online	**Guided Face-to-face**	**Not guided Online (self-study)**
M	33	10	12
MD	--	8	3

Prior to learning with the interactive learning path, all three groups were initially asked about their professional knowledge, their acceptance of interactive tasks in general, and the perceived relevance of such tasks for their later professional life. Also control variables such as gender, semester, and degree program were asked (pre-test).

Subsequently, guided learning through the learning path with the interactive tasks took place in the online and face-to-face teaching groups. For this purpose, the students and the lecturer opened the web-based learning path on their own devices. The lecturer moderated the routes through the learning path by initiating changes between slides or tasks. The learning activities of the students were continuously recorded. Immediately after completing the learning path, the participants completed the post-test.

The self-study group worked through the learning path with the interactive tasks at home without instructional guidance. The post-test directly followed the completion of the learning path.

7. Learning path with interactive tasks

The learning path uses the H5P template Branching Scenario and is designed for a processing time of 90 minutes. It contains elements that build on each other and three specialized educational topics. Fig. 1 shows the external structure of a learning path in editing mode. The black boxes stand for interactive presentations that can contain one or more learning contents and interactive tasks. The blue boxes stand for selection questions, which then lead to the different educational topics. The arrows contained in the red circles represent the possibility to return to the selection question after a topic has been worked on. The red flag marks the end.

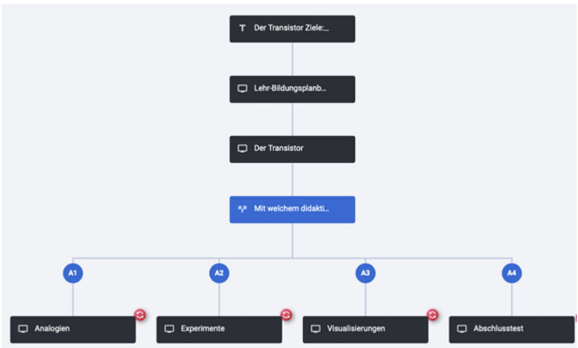

Fig. 1: Structure of a simple learning path. The path is linear, but leaves the option open for jumps.

In addition to information, the interactive presentations also contain literature references, supplementary aids and tasks for exercises (see Figs. 2 and 3). In interactive presentations, as shown in Fig. 2, the content is always at the center of the slides. The blue circles with an i in them lead to additional help. The purple circles stand for interactive tasks (see Fig. 3).

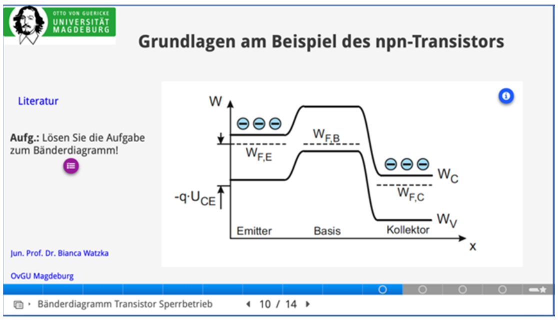

Fig. 2: Excerpt from the interactive presentation on the basics of the npn transistor. In the center you can see the band model. Literature references and interactive tasks can be opened on the left. On the right, help can be displayed.

The interactive tasks were selected according to the needs of the content and are therefore mostly implemented in multiple-choice or drag-and-drop format.

In the case of multiple-choice questions, known misconceptions can be used as response alternatives. In this way, it is also possible to search for incorrect thought patterns during the analysis.

Drag-and-drop formats are suitable for iconic representations of models, because here the mapping of reality into the model can be done by assigning.

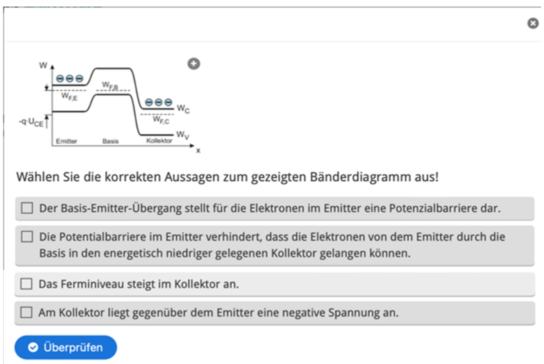

Fig. 3: Example of an interactive multiple-choice task on the band model showing a npn transistor.

Each unit is followed by a summary with the scores achieved on the tasks, which are then also automatically documented in the LMS (see Fig. 4).

Fig. 4: Example of a summary. The achieved scores are summed up here. There is also the possibility to display the task solutions and to repeat the section.

The selection questions (Fig. 5) are the trademark of the Branching Scenario template. They are formulated neutrally and lead to the educational topics. Due to the various requirements, each topic contains different task formats.

Fig. 5: Selection question with in-depth options. The question is: "What didactic issue do you want to deal with?" Choice options are: analogies, experiments, visualizations and final test.

For example, in the *Experiments* section interactive experimental videos are included as a task format (see Fig. 6), because they can be used to replicate how experiments are set up and performed.

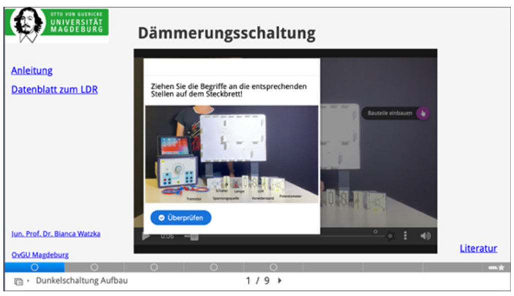

Fig. 6: Excerpt from an interactive video showing the setup of a light-sensitive circuit. The components can be placed on the board via drag-and-drop.

The situation is different for the topics V*isualizations* and A*nalogies*. Here, visualizations have to be classified according to image types and then their function in learning processes has to be determined or analogies have to be evaluated according to Issing's criteria. For such activities, cloze exercises, multiple-choice tasks, and true/false statements are particularly suitable task formats.

Fig. 7: Example of true/false statements for the evaluation of analogies according to Issing. In the background you can see the water lock analogy. In the front there is a statement about the familiarity of the image.

The final test at the end of the learning path is based on the TPACK questionnaire [20] and has been specified regarding to the topic of *transistors*. It is a student self-assessment which can provide information about the learning success in addition to the scores achieved on the tasks.

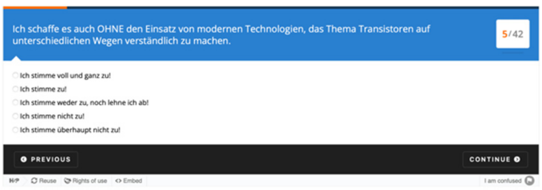

Fig. 8: Exemplary student self-assessment question at the end of the learning path. Statement: "I manage to make the subject of transistors understandable in different ways even without the use of modern technologies."

8. Variables and instruments

The measurement captured outcome and process variables. Outcome variables included perceived acceptance towards interactive H5P content and its relevance for later professional life as well as facets of teacher professional knowledge (TPACK).

Established scales were used to collect the outcome variables, including:

- Perceived acceptance towards the interactive learning material (cf. [22], 2 items),
- Perceived relevance of interactive learning materials for later professional life (cf. [22], 8 items) and
- TPACK (cf. [22], 32 items).

The standardized survey instruments are 5-level Likert scales. They range from "I fully agree" to "I strongly disagree”.

For the analysis of the learning routes, the following variables recorded by the xAPI interface were assigned to the process variables category: Processing times, processing successes / scores, repetitions, sequences, and aborts, as well as jumps between information units and tasks, etc.

9. Data Analysis

Changes in professional teacher knowledge as well as changes in acceptance and relevance were determined by the Hake factor *g*, which indicates the average normalized increase. It is defined as the ratio between the average increase, resulting from the difference of post- and pre-test, and the maximum possible increase, resulting from the difference of the maximum value and the pre-test value [6].

Independent samples *t-tests* were used to test whether there were differences in the increases in perceived acceptance and relevance between the teaching formats. Due to the small sample, a bootstrapping procedure with 10.000 simple random samples and a 95% confidence interval was chosen. If variance heterogeneity was found, a correction for degrees of freedom (Welch correction) was applied. Cohen's *d* was calculated as the effect size measure. For multiple testing related to a null hypothesis, a Bonferroni alpha error correction was applied.

The analysis of the learning routes was performed semi-quantitatively (see Fig. 8-10). For this purpose, chord diagrams were programmed in Python. The colored elements of the outer ring correspond to the units or task sets of the learning environment. The sizes of the circular arcs plotted proportionally to the mean processing times. The colored chords in the circle between the units / task sets represent jumps between units or tasks. A chord always starts at the same colored unit / task set and ends with a different colored unit / task set. The chord width is proportional to the frequency of the jump within a group.

10. Results

Table 2 shows the mean values and standard deviations for the processing time and the reached scores as well as the relative increases of TPACK, acceptance and relevance.

Results of paired samples *t-tests* each show significant increases with a small effect size between pre- and post-test for ...:

- the change in perceived acceptance (t_{62} = 13.17, p < .001, 95% CI [.499, .678], d = 0.35).
- the change in perceived relevance (t_{62} = 7.70, p < .001, 95% CI [.150, .255], d = 0.21).
- the change in TPACK (t_{62} = 9.13, p < .001, 95% CI [.267, .417], d = 0.30).

Results of *t-tests for* independent samples show for ...:

- the processing time a significant difference with a high effect size between the guided groups (online + face-to-face) and the self-study group (t_{60} = 10.88, p < .001, 95 % CI [14.17, 20.56], d = 5.4). Self-study learners discontinue their activity earlier than learners guided in face-to-face or online teaching.
- the scores a significant difference with a high effect size between the guided groups (online + face-to-face) and the self-study group (t_{60} = 10.49, p < .001, 95 % CI [20.58, 30.28], d = 8.2). Learners in the self-study group score lower than learners working in the guided face-to-face or the guided online teaching group.
- the change in perceived acceptance a significant difference with a small effect size between the guided groups (online + face-to-face) and the self-study group (t_{60} = 2.46, p = .017, 95% CI [.022, .209], d = 0.16).
- the change in perceived relevance no significant difference between the guided groups (online + face-to-face) and the self-study group (t_{60} = 1.35, p = .183, 95% CI [-.027, .141], d = 0.14).
- the change in TPACK a significant difference with a small effect size between the guided groups (online + face-to-face) and the self-study group (t_{60} = 3.89, p = .032, 95% CI [.073, .228], d = 0.13).

As expected, processing time and scores correlate highly with each other (Pearson r = .698, p < .001, 95% CI [.609, .830]).
Students spend the most time on the pages with the basic knowledge and the least time on the historical excursus.

Tab. 2: Selected mean values and standard deviations

	Online guided		**Face-to-face guided**		**Online Self-study not guided**	
	M	*SD*	*M*	*SD*	*M*	*SD*
Processing time	76.25	2.04	74.41	1.32	58.23	10.59
Scores	98.30	5.05	94.00	5.74	71.40	13.45
Hake acceptance	0.36	0.16	0.27	0.17	0.21	0.18
Hake relevance	0.20	0.14	0.07	0.11	0.11	0.08
Hake TPACK	0.26	0.14	0.10	0.08	0.06	0.08

11. Visualizations of the learning routes

Differences in the learning routes chosen by the students in the three groups are visualized by the following chord diagrams (Fig. 8, Fig. 9, and Fig. 10).

The learning units / task sets of the outer ring are: (1) learning goals, (2) applications of transistors, (3) functions of transistors, (4) visualizations, (5) basic knowledge / physics, (6) task set 1, (7) task set 2, (8) task set 3, (9) task set 4, and las but not least (10) history.

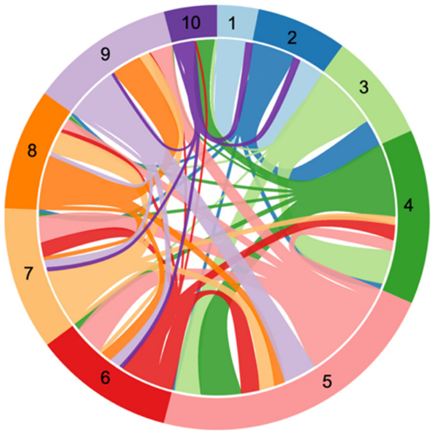

Fig. 8: Learning routes in guided online teaching.

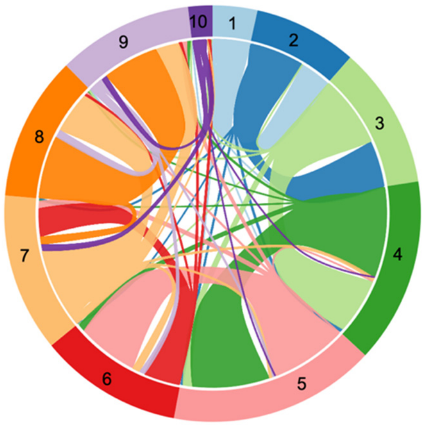

Fig. 9: Learning routes in guided face-to-face teaching.

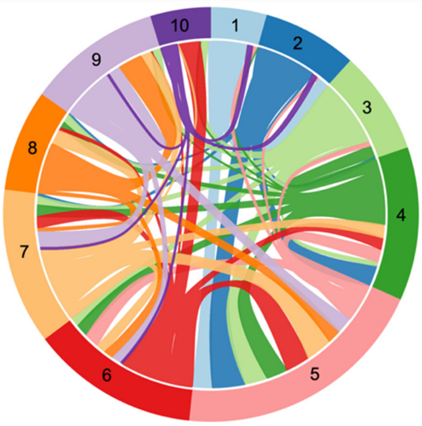

Fig. 10: Learning routes during self-study.

Comparing the three chord diagrams with each other, the following similarities or distinctions in the three groups are noticeable.

Common to all groups is the fairly uniform distribution of processing time among the individual learning units. Thus, all students spend the main part of their time processing the basic knowledge unit (segment no. 5) and working on the *task sets* (segments no. 6-9).

However, the jumping behavior of the students in the three groups is clearly different.

In the guided face-to-face teaching group (Fig. 9), the students predominantly followed the instructions of the lecturer. Here, the chords mostly end at the next higher learning unit / task set. In the guided face-to-face teaching group, there are few jumps from the tasks back to the basic knowledge section (unit 5).

In the guided online teaching group (Fig. 8), as in the guided face-to-face teaching group, jumps to the next higher learning unit can be seen. However, the relative frequency of these jumps is smaller than in the guided face-to-face group. Instead, the guided online teaching group also shows a tendency for backward jumps, especially between the tasks and the basic knowledge sections. As an example, the purple-colored chord from learning unit 9 back to unit 5 in Fig. 8 shows this particularly clearly.

In the self-study group (Fig. 10), forward and backward jumps balanced out. The jumping behavior looks rather chaotic here. It is striking that the units *basic knowledge section* (No. 5) and *task sets* (No. 6-9) are chosen very early in the learning process by the students. Especially from unit 3 (functions of transistors) quite a few jumps (light green chords) go to the different tasks instead of to the next higher unit.

12. Discussion

The evaluation should answer the question whether learning with interactive tasks and getting to know a tool for creating these tasks in different teaching formats differs in terms of learning processes and learning success and whether the own learning with interactive tasks and getting to know the tool positively influence the perceived acceptance and relevance.

In summary, the evaluation shows a significant increase in acceptance and relevance of the interactive tasks and the H5P tool after learning with these tasks and becoming familiar with the tool. This positive development can be seen in all groups, so that there are no differences here with regard to relevance and rather unimportant differences with regard to acceptance between the three groups. This result is not surprising overall, since experience with a technology influences the intention to use it directly and indirectly via perceived usefulness [e.g., 22].

The results show an increase in professional knowledge. The TPACK can be another factor for the acceptance towards a technology, especially if the users (here prospective teachers) are still inexperienced [22]. The effect strength is small, which is not surprising after learning with one application example and only a short tool description. There are also small differences between the groups, but these are of little importance and presumably disappear after the second session, when the tool is used in an active way.

Regarding learning successes and processing times, the results do not show any significant differences between the guided online and the guided face-to-face courses. However, here the self-study group performs significantly worse on both measures. Since both active learning time and guidance influence learning success [23], the differences here seem particularly noteworthy. The question of the causes of the differences in processing time and learning success between the self-study group on the one hand and the two guided groups on the other hand cannot be answered finally. However, assumptions can be made. It cannot generally be assumed that a long processing time is equivalent to a longer (cognitively) active processing. One could also let the time pass and do nothing. On the other hand, a short processing time does not allow an in-depth learning. The results show a positive correlation of high effect size between processing time and learning success, which suggests that an adequate processing time is a necessary condition for learning success (although it is not sufficient). One reason for the low processing time in the self-study group could be due to the lack of guidance through the learning path. To answer this question, one would need to test a full experimental design. This means that in addition to the groups mentioned above, another group would have to work with the learning path in presence but without guidance. Another reason for the lower performance of the self-study group could be the playful format. Especially in the self-study group, there might be a temptation to be as fast as possible rather than as thorough as possible. In the guided groups, the tight guidance makes it less possible to hurry through. A third reason could be a cost-benefit consideration by the students. Comparable behavior is also shown in another study [e.g., 18]. In the self-study group, the students have the freedom to take their learning into their own hands and to assess for themselves whether the expected return for the effort to be expended seems worthwhile to them or not.

13. Limits and outlook

The evaluation is limited to aspects of acceptance development with a focus on professional knowledge and perception of relevance. Questions on affective components of learning or on design criteria of tasks are not presented.

The measurement of professional knowledge is based on the established procedure for measuring acceptance and TPACK. It is therefore carried out by self-assessment. Without further data material, it would remain open which competencies have developed. In this study, however, the results of the tasks in the learning process are also available, so there are further indications of the competencies.

The teaching format varies corona-dependently and not systematically, so both the control of confounding variables is limited and the group design is incomplete. Therefore, no causalities can be derived from the evaluation results. Their use rather lies in generating hypotheses for an empirical study on the one hand and in optimizing the learning material in the sense of a design-based research approach on the other hand.

The sample is neither representative nor completely homogeneous. In addition, the small sample size sets limits to the analyses.

Further studies and interviews should explore the differences in learning times and their causes. In doing so, these results can provide cues for possible research questions that can then be systematically addressed empirically in a full experimental design. In addition, with new technical possibilities in the field of AI, it would be interesting to identify patterns in learning routes that then allow instantaneous predictions of learning outcome in the learning process.

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Lessons Learned - Constructive Alignment meets Lean & Green Production

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Abstract

Die Qualität einer Lehrveranstaltung zeichnet sich neben den Lehrinhalten insbesondere durch die Elemente des Constructive Alignments aus. Dieses umfasst die drei gleichwertigen Bestandteile: Lernziele, Lernumgebung sowie Methoden und die anschließende Prüfung. Zum Gelingen einer ganzheitlich geschlossenen Lehrveranstaltung ist eine hinreichende Planung erforderlich, welche ein Ineinandergreifen dieser Bestandteile ermöglicht. Im Rahmen der Umstrukturierung der Lehrveranstaltung „Lean & Green Production“ an der Leibniz Universität Hannover wurden die Erfahrungen gesammelt, welche Bestandteil dieses Papers sind. Die Anpassung der Lehrveranstaltung hinsichtlich des Constructive Alignments hat gute Ergebnisse erzielt und ist auf positive Resonanz gestoßen.

In addition to the course content, the course's quality is characterised mainly by the elements of constructive alignment. This comprises the three equally important components: Learning goals, learning environment, methods, and the subsequent examination. For the success of a holistically closed course, sufficient planning is necessary, which makes an interlocking of these components possible. The course adaptation concerning constructive alignment has achieved good results and has met with a positive response. In restructuring the course "Lean & Green Production" at the Leibniz University of Hanover, the experiences were gathered, which are part of this paper.

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1. Components of Constructive Alignment

According to the Constructive Alignment teaching model, learning goals, setting, and assessment components appear as equal elements of courses. The primary intention is to harmonise their contents and interactions. For example, the setting of a course should be designed through methods in a coordinated sequence to align with the learning goals. Likewise, it is essential to unite the examination requirements with the learning goals to create a holistically coherent course. [1]

In order to implement constructive alignment, sufficient instructional planning is required before the start of the semester to develop a uniform and coordinated concept. Likewise, planning must consider the design for a purely face-to-face semester and the transition to a concept for hybrid or purely digital teaching. In this respect, it makes sense to weigh the options early to avoid last-minute changes in the current semester. This applies in particular to the setting, as the teaching methods for interacting with students change and require preparation for the transition.

The Institute of Production Systems and Logistics (IFA) implemented this concept in the *"Lean & Green Production"* course. For this purpose, a complete linkage of the three components was implemented as part of a funded project. The project was made possible by a funding program to improve teaching at the Mechanical Engineering Faculty of Leibniz Universität Hannover (LUH). Students evaluated it in the current semester and in the context of accompanying advanced teaching training, including observation. Most of the experience gained in the process has already been implemented in the current semester and is the subject of this paper.

2. Learning goals in the event

The course *"Lean & Green Production"* has been redesigned for the summer semester of 2022, but its contents have been part of the curricula of the engineering programs of the Faculty of Mechanical Engineering for a long time. The course has approximately 60 participants per semester. As an elective module, the course can be taken by Master's students of different courses and as a compulsory elective module by Bachelor's students of the "Sustainable Engineering" course. Due to diverging theoretical prior knowledge and practical experience of the participants, e. g. through internships or working student activities, the definition of common learning goals was elementary as a consensus.

Determining the learning goals is an essential prerequisite for successfully implementing Constructive Alignment. It forms the basis for the selection of the setting and the examination. The learning goals are derived from the overarching mission statement (guidline goals, broad goals) as detailed goals. [2]

A **guideline goal** describes the intention of an education or a study program. The following central guideline goal was described for the event under consideration:

An essential qualification goal of engineering science courses at LUH is to enable students to evaluate processes based on a scientific-systematic approach. This is achieved through an analytical understanding of complex issues to identify socio-technical design options.

The **broad goal** derived from the guideline goal makes concrete reference to the course. In this exemplary case, this was directly linked to cognitive learning goals:

Starting with considering the philosophy of lean production and the development of lean production systems, the fundamentals of production system planning are covered, taking into account the megatrend of sustainability. The focus is on analysing, evaluating and selecting lean methods for specific use cases.

The **detailed goals of** the course modules are explained at the beginning of each course date and refer to one module each, which consists of a combination of a lecture and exercise unit. Depending on the module content, different cognitive learning goals are described, which build on each other. The basic knowledge is taught in 90-minute lectures on eleven dates. These lectures address the cognitive learning goals of level1 1 (remembering) and level 2 (understanding). For example, after the introductory module, students should be able to explain the forms of waste in production systems. A classification of the cognitive learning goals can be found in Figure 1 below.

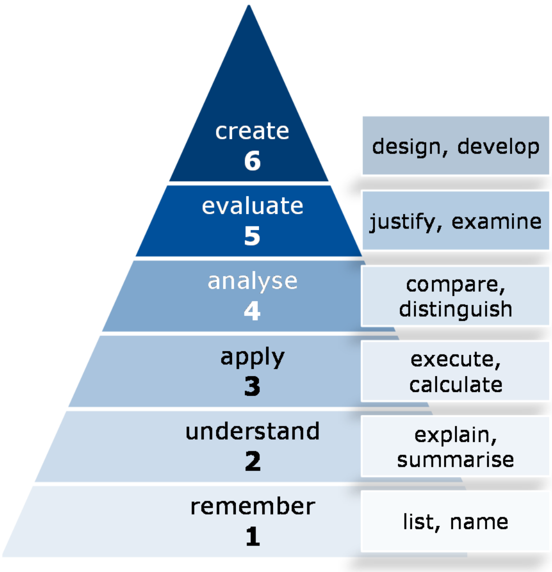

Figure 1: Taxonomy of cognitive learning goals [3].

In the subsequent 45-minute exercises, the content is deepened as students apply it (learning goal level 3) and analyse it (learning goal level 4). During a one-day workshop in the advanced part of the course, students learn about the cognitive learning goals of levels 5 and 6 in groups (approx. 15 participants). [3]

A detailed description of the workshop takes place in the following chapter 3.

3. Learning environment and methods

The teaching philosophy of the course includes integrating practical parts into the course and thus follows the motto *theoria cum pra*xi (engl.: theory and practice) of the LUH. Furthermore, frontal teaching is avoided wherever possible and instead replaced by activating teaching methods (e. g. by footnote presentations[1] with practical examples instead of slide presentations by the lecturers). Students receive stimuli from industrial applications through guest lectures, which provide insight into the complexity of implementation in actual industrial companies. In addition, the practical components are represented by business games on production system design in the exercise sessions. The assumption of different roles in the business games and the staging of workshop formats are intended to impart interdisciplinary competencies. The *concept of competence* can be understood as *"a combination of knowledge and skills in coping with action requirements"* [4].

The course is designed to provide students with methodological competencies for later use in the profession (industry, science, consulting) and technical competencies. An essential part of the course is participating in the 1-day workshop *Production Trainer* in groups of about 15 participants. The workshop takes place in the institute's IFA Learning Factory, shown in Figure 2. The simulation game *Production Trainer* takes up the workshop idea from the exercises already completed in the courses and offers the students the opportunity to analyse a production system independently as a group, to plan it subsequently and finally to implement it directly. Following this procedure, they can run through the optimisation cycle using lean methods over several rounds of the game and thus acquire teamwork, problem-solving, moderation skills, and technical competence.

Due to its structure based on the principle of changeability of assembly systems, the IFA learning factory allows the mapping of diverse business game scenarios in the context of lean production and can thus be adapted to specific groups. In this context, students should also learn to operate in a constantly changing environment. The term *changeability* describes the efficient performance within defined limits (flexibility) plus the potential for structural adaptation (transformability) of systems that can be activated when necessary [5]. The course is intended to enable students to be universally deployable in later professional life (personnel changeability) and to familiarise themselves quickly with new topics.

4. Examination

Due to the planning uncertainty in the winter semester of 2020/2021 regarding implementing classroom examinations at LUH, the course examination took place for the first time as an

[1] Reproduction by students of the brief definition of a pre-assigned technical term in a few sentences once the instructor has used it in the lecture.

electronic examination via the teaching platform LUH-Ilias. The initial effort to create the exam questions, as well as the smooth processing of the exam via a digital teaching platform, was excellent. The exchange of experiences within the institute, with the Mechanical Engineering Faculty and with institutes of other faculties of the LUH can be regarded as an essential lesson learned. Only this made the short-term conversion of the examination medium possible. The consultation with other examiners at the university in the context of teaching exchange formats has thus contributed significantly to this change. The experiences with the examination format and the teaching platform were considered in the following semesters when implementing the digital examination (open-book principle). The requirements of past exams were focused on knowledge reproduction, whereas the digital exam contains a more significant proportion of application tasks. The examination format has since been retained. It contains single- and multiple-choice questions, free-text and cloze-text application tasks for calculations and process analyses.

Figure 2: Photo of the working environment for implementing the "Production Trainer" business game in the IFA Learning Factory.

The change in the examination format also resulted in a change in the question's content and the student's learning behaviour and has not yet been taken into account in the implementation of the course. The change from memorisation to comprehension and transfer questions through the examination design must continue to be strongly supported. This circumstance needs to be eliminated or mitigated through Constructive Alignment. Reference to the upcoming digital exam was made early in the course of the preparation. A comprehensive exam session is intended to familiarise students with the teaching platform and the type of questions. The students will be given a sample exam under natural conditions that can be repeated as often as desired and discussed together at the beginning. As part of the "Pro Teaching" program of the university's internal teaching development, the quality of the examination questions could be increased and the misunderstandability of formulations reduced.

This must be evaluated after the examination and adjusted regarding the examination requirements concerning the course's learning goals.

5. Evaluation and experiences from the current semester

It was integrating a semester consultation hour to actively incorporate student feedback allowed for slight adjustments to the concept for the current semester's outstanding deadlines. This allowed for direct student feedback on the use of the footnote referees addressed in Chapter 3. Due to the high number, these have significantly shifted the time frame of a lecture date. The lesson learned from this is more targeted scheduling in the future by setting presentation limits. In addition, the content must be suitable for applying the methodology. In this case, this requirement was not readily met, as the students were not dependent on the explanations in the footnote presentations due to the lecture notes and, according to their statements, did not have to follow the presentations attentively.

It should be noted that even small changes in the course can significantly impact the transfer of knowledge. This does not necessarily require a change in the lecture content. The interaction with the students and the integration of the practical units will be evaluated positively according to their own experiences and the students' feedback and should be maintained for the coming semesters. The current examination in the form of a written exam (regardless of the medium) can almost exclusively consider technical competence and only little methodological competence. This is difficult because it represents an inconsistency in the Constructive Alignment framework throughout. Implementing the other Constructive Alignment elements has worked well according to student feedback and teaching observation.

6. Conclusion and outlook for future semesters

The concept of Constructive Alignment has achieved good results and increased the quality of the course as well as the motivation of the students. Therefore, the implementation of the concept will be continued in the following semesters. It has been shown that even small changes in knowledge transfer can increase the attractiveness of courses. However, the methodology must be chosen depending on the respective detailed goals (cf. Chapter 1).

In the future, the learning goals are to be formulated even more precisely so that the method selected for the respective contents of the lecture can be made more precisely. In addition, the experiences of lecturers and observers and the students' feedback can be used for the ongoing teaching design. In the future, students will also be offered the opportunity to participate in research studies in the IFA Learning Factory in the area of production system design and learning behaviour so that they can also deal with the practical scientific side in addition to the practical industrial side. Initial results have already been achieved in a preliminary study [6].

Integrating guest lectures suitable in content and methodology to strengthen the guiding principle of *theoria cum praxi represents* a core task for the upcoming semester planning. The current guest lecture is interesting in content and popular with students but does not fit naturally into the Constructive Alignment of the course and is not a component of the exam. The current exam has the potential to be expanded to include additional sub-credits, thus providing more focused control over aspects of methodological competence. The design of questions requires special care in the area of knowledge reproduction in an open-book exam. If necessary, these could be integrated into the workshop and thus provide an opportunity to check the cognitive learning goals *Assessment* and *Creation* (learning goals levels 5 and 6, cf. Figure 1).

Course planning and course teaching concepts are often based on autodidactic knowledge. For this reason, participation in internal university offers to improve the quality of courses is recommended for all persons involved in university teaching. The exchange with lecturers from other departments is equally advisable, as they often have a methodologically influenced perspective on the course instead of a purely content-based one.

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Development and analysis of the evaluation of Praktika@home

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Abstract

Aufgrund der Corona-Pandemie wurden viele Lehrveranstaltungen auf neue Formate umgestellt, häufig kurzfristig und ohne die Möglichkeit einer strukturierten Erprobung. Im Modul Mess- und Automatisierungstechnik wurden die Praktika@home entwickelt, die nach dem Blended-Learning-Konzept durchgeführt werden. Um zu evaluieren, wie gut das Lehrangebot die Studierenden bei der Erreichung der Lernziele unterstützt, wurde ein Fragebogen erarbeitet. Die Gestaltung und Auswertung der Ergebnisse werden anhand des erstmals im Sommersemester 2022 durchgeführten Experiments ‚Dehnungsmessung' beschrieben und kritisch diskutiert.
Die Ergebnisse der Evaluation zeigen, dass das Betreuungskonzept während der Praktika überarbeitet werden muss. Aus den Freitext-Kommentaren, die von den Studierenden ausgiebig genutzt wurden, konnten Ansatzpunkte für diese Veränderung identifiziert werden. Darüber hinaus kann abgeleitet werden, dass eine bessere Abstimmung zwischen Vorlesung und Praktikum notwendig ist. Zuletzt wurden Vorschläge zur Verbesserung des Fragebogens erarbeitet.

Due to the Corona pandemic, many courses were converted to new formats, often at short notice and without the possibility of structured testing. In the Measuring and Automation Technology module, the Praktika@home were developed, which are conducted according to the blended learning concept. A questionnaire was developed, to evaluate how well the teaching offer supports the students in achieving the learning objectives. The design and evaluation of the results are described and critically discussed on the basis of the experiment 'strain measurement', which was conducted for the first time in the summer semester 2022.
The results of the evaluation show that the supervision concept during the practical course needs to be revised. Starting points for this change could be identified by evaluating the free text comments, which were used extensively by the students. . Furthermore, it can be deduced that a better coordination between lecture and practical course is necessary. Finally, suggestions for improving the questionnaire were developed.

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1. Initial situation and motivation

The Corona pandemic has massively changed teaching at colleges and universities. Within a few weeks, the majority of courses had to be converted to a digital format, with little time for testing. This was both a challenge as well as an opportunity to modernize teaching and try new teaching-learning concepts. Now, that face-to-face teaching can again take place in many places, the question also arises in what form courses should be implemented. In this context, evaluations are an important tool for examining events and incorporating the learners' input as well as their perspective.

Students of mechanical engineering can evaluate their course at the end of the semester via the standardized 'Course Evaluation' developed by the Center for Quality Analysis. Although this offers a high degree of comparability between courses, it cannot take into account structural differences and individual issues. In the module Measurement and Automation Technology, so-called practical courses are offered in addition to the lecture and the calculation exercises, in which the students are to apply their knowledge experimentally.

Due to the severe restrictions during the Corona semesters, the concept of practical courses was significantly modified. The so-called Praktika@home were introduced [1, 2]. In the 'classical' implementation of practical courses, years of experience can be drawn upon. However, the change to Praktika@home meant a drastic change in teaching for both students and teachers. For this reason, an evaluation was developed to examine not the entire module, but specifically the practical courses.

The article presents the approach used to prepare the evaluation as well as the results of the evaluation. Finally, the evaluation is critically reflected. In the outlook, various approaches are discussed which can be used to remedy the problems that were identified.

The evaluation presented here is limited to one of the six experiments, the experiment on strain measurement.

2. Object of investigation

Praktika@home is part of the compulsory module 'Measurement and Automation Technology' of the diploma and bachelor courses Mechanical Engineering as well as Process Engineering and Natural Materials Technology of the Faculty of Mechanical Engineering at TU Dresden. This course is scheduled for students during their fifth and sixth semester and is attended on average by 400 students. The practical courses blend learning formats, with students conducting experiments at home in teams of two and coming to the university for supervision appointments. The students need to submit a handwritten report to collect the examination credit. A practical course begins with materials being made available online via OPAL (Online Platform for Academic Teaching and Learning) or YouTube. There is an introductory video for each experiment to help students get started with the topic and experiment on their own. The instructions include the task and a summary of the theoretical background.

After uploading the video and the instructions, the students have one week to execute the experiment. Afterwards, there is an interim discussion in which the students can clarify their questions among themselves or with the support of the supervisor. After another week, the protocol needs to be handed in. Finally, there is a debriefing session in which open questions can be discussed and the technical accuracy of the results is ensured. The sequence of events is depicted in Figure 1.

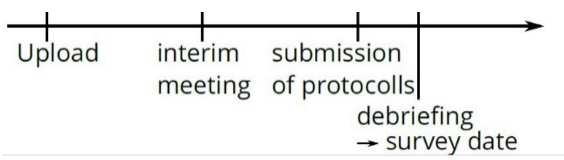

Figure 1: Sequence of events in the practical course

The aim of the practical courses is to let the students apply the lectures theoretical contents in practice. In the experiment 'Strain Measurement', the setting up of various electrical circuits with the Arduino microcontroller is planned. With these circuits, the diagonal voltage of a Wheatstone's measuring bridge is recorded automatically and from this the mechanical stress in the component is determined. The data is then analyzed and interpreted by the students. The practical course 'Strain Measurement' was carried out by students for the first time in the summer semester of 2022. The evaluation results are presented below.

The implementation of the practical courses in a blended learning format is intended to support individualized learning (independent of time and location). The design of the interim and debriefing sessions aims to promote communication, collaboration and networking among students. Altogether, the teaching-learning opportunities are intended to introduce students to the scientific way of working.

The evaluation's interest is to find out whether the teaching-learning materials and supervision provided are designed such that they support students in achieving the learning objectives.

3. Study Design

The evaluation of Praktika@home is carried out by a follow-up survey. Due to the large number of students in the course, a questionnaire was developed.

Both closed questions and free texts were used in the questionnaire. The free texts were used, despite the higher evaluation effort, to obtain justifications for answers and a more precise representation of the mood. Furthermore, additional information or new aspects can be recorded that were not considered when the questionnaire was created.

A four-point Likert scale was used. The items (tasks or questions of a test) are formulated as positive or negative statements. The multilevel response scale is used to measure the respondents' personal attitude, i.e. how strongly they agree or disagree with the item. A symmetrical scale was chosen, as this means that no abstention is possible and the participants have to choose one side [3].

The questionnaire was handed out after the debriefing. Thus, the evaluation has both formative and summative character. For the students, the summative character is dominant, as they are only asked for feedback after the completion of the practical course and no longer benefit from the results of the evaluation themselves. For the development team, however, the survey is formative, since the results can be used continuously to improve the basic conception of the practical courses as well as the design of the teaching-learning materials of the respective experiments. Survey and processing are done using LimeSurvey, an online survey application supported by the TU Dresden [4]. The survey was anonymous.

The following aspects were derived from the overall evaluation objective, which, in addition to the socio-demographic data, should be determined by the survey:

(a) subject-specific declarative knowledge
(b) subject-specific procedural knowledge
(c) Usefulness of the provided teaching-learning materials.
(d) Supervision during interim and debriefing session
(e) Experience with guided learning activities
(f) Connection of the practical courses contents to the lecture
(g) Performance of the practical courses

It must be taken into account that the results of the survey do not provide information about the actual knowledge of the students. Instead, the self-assessment is surveyed.

Two to four items were formulated for each of the aspects to be recorded. The results of the evaluation are presented as examples.

4. Evaluation procedure

The qualitative content analysis method was used to evaluate the free comments. Therefor the content of the comments is summarized and categorized [5, 6]. Categories can be formed either deductively or inductively. In the analysis of this evaluation, the categories were not given deductively, but were derived inductively from responses. For this purpose, only a part of the data was categorized in a test run at the beginning. Subsequently, the remaining comments were classified into the preliminary category system. It can happen that several aspects are listed in comments. Accordingly, these comments were assigned to multiple categories. After all comments were assigned to one or more categories, they were screened again to merge or subsequently differentiate similar categories. Finally, the categories were quantified.

With regard to the goal of the evaluation to further develop the practical courses, demands or instructions for action were derived from the categories that contribute to the improvement of the practical courses from the student's point of view. These instructions for action are discussed in the section 'free comments'.

The frequency distribution of the closed questions was used for the evaluation..

5. Results

Since up to 325 students (out of a total of 430) participated in the debriefing in the winter semester 2021/2022, the survey date of the evaluation was set to the end of this event. However, in the summer semester of 2022, the number of participants reduced drastically to 109, of which 91 completed the questionnaire in full (of which 65 were male, 19 female, 7 no response). In contrast to the previous semester, no additional points were awarded for attending the consultation during the period under consideration. This could be a reason for the lower participation.

Subject-specific declarative knowledge

First and foremost, the practical course is intended to pick up teaching content from the lecture and to deal with these main topics in more detail. The students thus acquire declarative knowledge ("knowledge that") in the practical course. Declarative knowledge comprises both individual facts (e.g. key figures, formulas) and complex contextual knowledge (e.g. understanding the influence of environmental conditions on the measurement result). Firstly, this is supported by the practical instructions, which tie in with the lecture content and in which the theoretical background of the experiment is summarized. In addition, the students experiment independently and acquire knowledge that was not made explicit in the lecture or the materials provided, but results from solving the problems. Based on the students' self-assessment of whether they possess subject-specific declarative knowledge, it is intended to verify whether the learning objectives have been achieved. Therefore, it was analyzed which knowledge the students should have acquired after carrying out the practical course. These were then formulated as items. Figure 2 depicts the results of the students' self-assessment of three queried pieces of knowledge. The construction and operation of strain gauges (SGs) are covered in both the lecture and the instructions.

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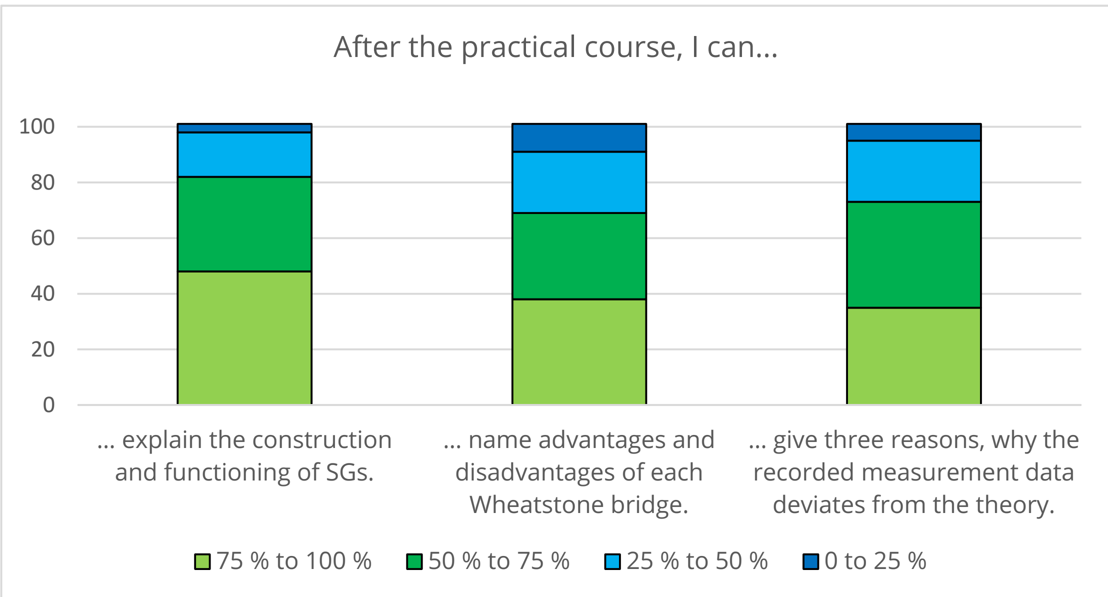

Figure 2: Self-assessment on declarative knowledge.

The advantages and disadvantages of the respective Wheatstone's bridge of measurement are addressed in the lecture and in the practical course, while the knowledge of why the recorded measurement data deviates from the theory is acquired only in the practical course by completing the tasks. It can be assumed that the effort required to acquire this knowledge varies. Furthermore, the queried knowledge differs in its complexity (pure factual knowledge compared to conceptual knowledge)

48% of the students rate their knowledge as particularly high (75% to 100%) for the question on structure and functioning. For the question on the advantages and disadvantages of bridge constellations, the percentage is 38 % and for the difference between theory and practice, the percentage is 35 %.

The number of students who rate their knowledge as high decreases as the complexity of the knowledge and the learning effort required increases. Here, the incremental knowledge gained by also covering topics in the lecture is minimal when compared with the knowledge acquired by only working on the practical course. . At this point it must be taken into account, that in the evaluation the previous knowledge of the students is not assessed. Therefore, based on the questionnaire, it is not possible to distinguish whether the respondents already knew, for example, the advantages and disadvantages of Wheatstone's measuring bridge before working on the practical course or whether this knowledge was acquired during the practical course.

Subject-specific procedural knowledge

In addition to declarative knowledge, students primarily acquire procedural knowledge ("knowing how") during the practical course. Procedural knowledge is also colloquially referred to as skill and thus describes the ability to link declarative knowledge and apply it as a course of action. Examples of this are calculating tasks or writing a protocol. Analogous to the procedure for declarative knowledge, the most important skills to be acquired in the practical course were defined.

The items for procedural knowledge are listed in Figure 3. Two of the items ask for skills that were practiced in the lectures "Measurement and Automation Technology" and "Technical Mechanics" by writing them down.

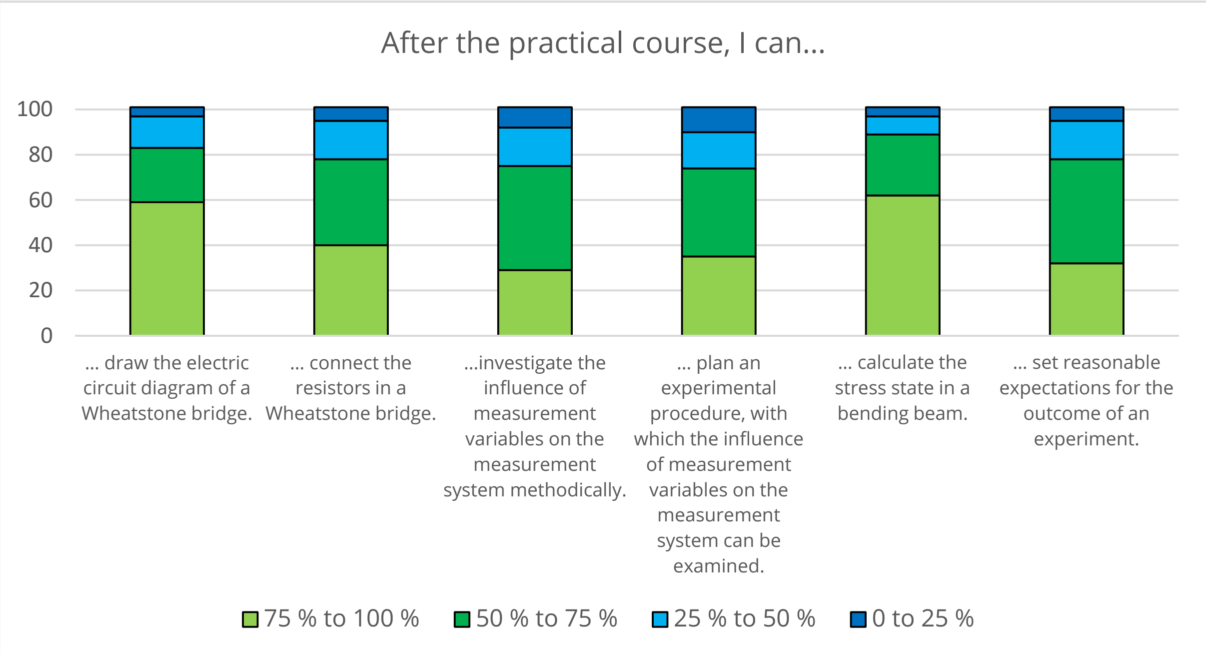

Figure 3: Self-assessment on procedural knowledge.

This concerns the ability to draw the circuit diagram of a Wheatstone measuring bridge and to determine the stress state in a bending beam by calculation. It is estimated by 59% and 62% of the students, respectively, that their knowledge of this is very high. The other questions relate to procedures that are only used in the practical course and have therefore not been practiced or trained beforehand. This is also reflected in the students' self-assessment. The ability to methodically investigate the influence of measurement variables on the measurement system is rated as very high by 29% of the students. The ability to plan an experimental procedure or to set reasonable expectations for the outcome of an experiment is also rated as very high by only 35% and 32% respectively

Overall, however, students rate both their declarative and procedural knowledge highly. These agreement values can have various causes. Since this is the first run of the evaluation, only the core contents of the practical course were formulated as learning objectives. Therefore, it is conceivable that these learning objectives were actually met by a majority of the students. This would mean that further learning objectives can be included in the evaluation in the future. At the same time, however, the formulation of the existing learning objectives should also be reviewed and consideration given to further specifying them.

In addition, the timing of the evaluation survey should be considered. Since this takes place at the end of the debriefing, only students who also attend this intervention participate in the survey. It can be assumed that these are predominantly motivated students. This suggests a selection bias that could be causing the high learning target rates.

Supervision in interim and debriefing sessions

An important aspect of the evaluation is the assessment of the interim and debriefing sessions by the students. Since the learning process of the students no longer takes place in presence at the university, but at home, the support services are of particular importance. Interim and debriefing meetings are the only times when there is direct contact between students and supervisors. The goal of the interim meeting is to guide students to resolve issues collaboratively. During the debriefing, open questions should be clarified with the students. In Figure 4 is the students' assessment of the supervision in the interim and debriefing sessions.

47 % of the students reported that their questions were not answered in the interim meeting[1] . This result contrasts with the indication that 66 % of students felt well supported by their supervisor. In comparison, 76 % of students indicated that they were able to complete their understanding of the practical course in the debriefing. This indicates that the design of this event is meaningful.

Another explanation may lie in the wording of the item. It is not clear from the wording whether feedback should be given for the supervisor’s performance during the interim or the debriefing session. For some students the supervisor may be consistent, but this is not necessarily the case.

Thus, it is possible that students only evaluated the supervisor in the context of the debriefing. In addition, students may be reluctant to rate their supervisor poorly after face-to-face contact. In addition, it may be unclear to respondents what the support is related to. The item should therefore be reworded to avoid these problems.

Experience with guided learning activities

The students assess the newly introduced group work phases very positively.. The results can be seen on Figure 5. 76% of the students agree that they have understood the purpose of the group work. This indicates that the instruction and motivation of this method was well done. Furthermore, 85% of the students state that it was easy for them to get involved in the group work. At the same time, 77% agree that they have intensively dealt with the practical courses contents through the group work.

The results indicate that the students had a positive experience with group work and gained a subjective benefit from the way of working. Therefore, this group work will also be used in future consultations.

[1] A statement is considered to be an agreement if "tends to agree" or "fully agrees" is ticked. This corresponds to levels 3 and 4 on the Likert scale.

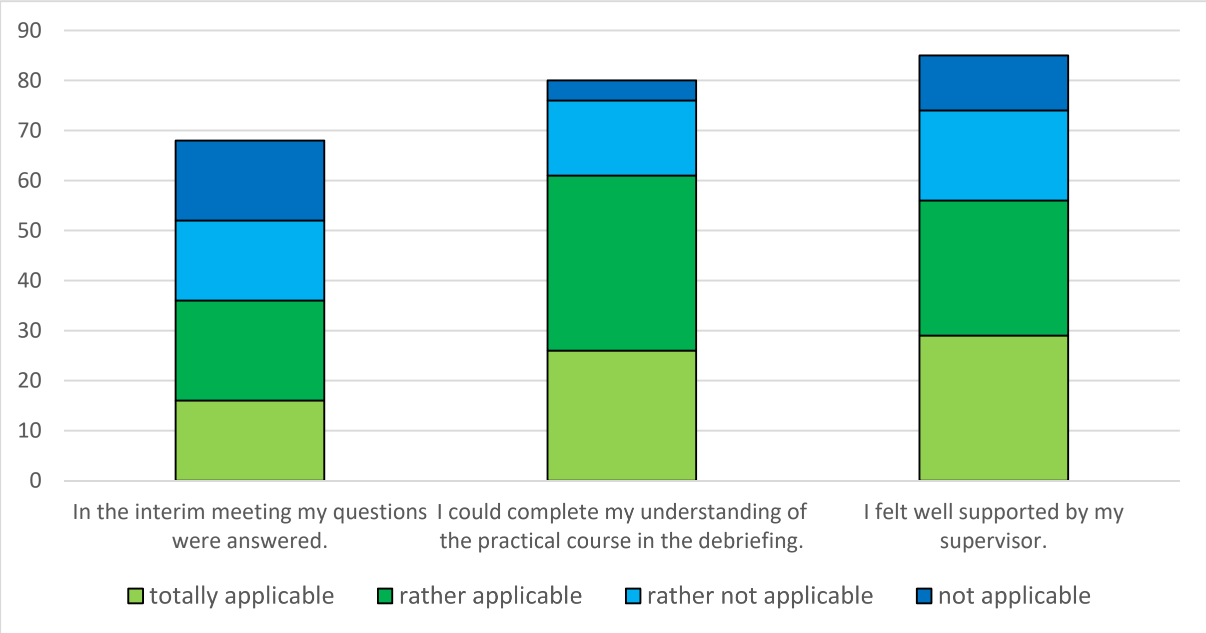

Figure 4: Supervision in interim and debriefing

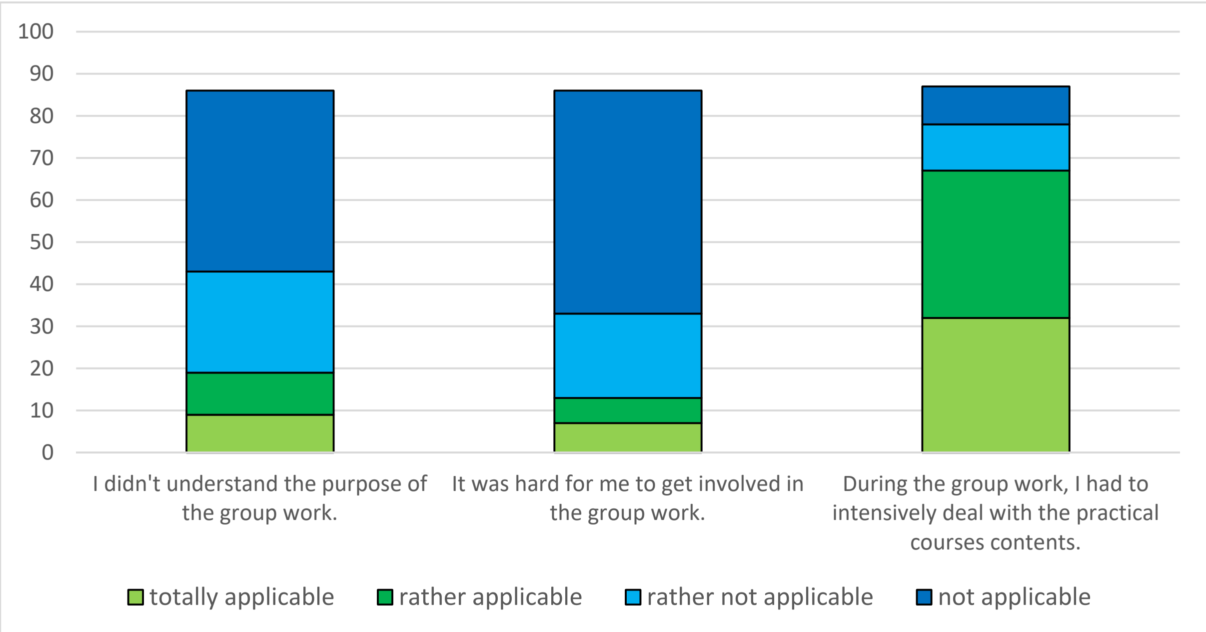

Figure 5: Students' experience with group work

Performance of the practical courses

When implementing the practical courses, it is important to consider how students accept the course. To achieve this, the content must be integrated into the lecture context and be of practical relevance to the students. This is reflected by the first two items shown in Figure 6 "I understood why the practical course is useful" and "In the practical course I was able to deepen my understanding of the lectures content." These statements are agreed to by 78% and 67% of the students, respectively. The result indicates that the students recognize the relevance of the practical courses content. The linking of the practical course to the lecture also seems to have been successful, but can still be strengthened. This can be achieved by making stronger references to the practical course in the lecture and by making more references to the lecture in the practical courses instructions.

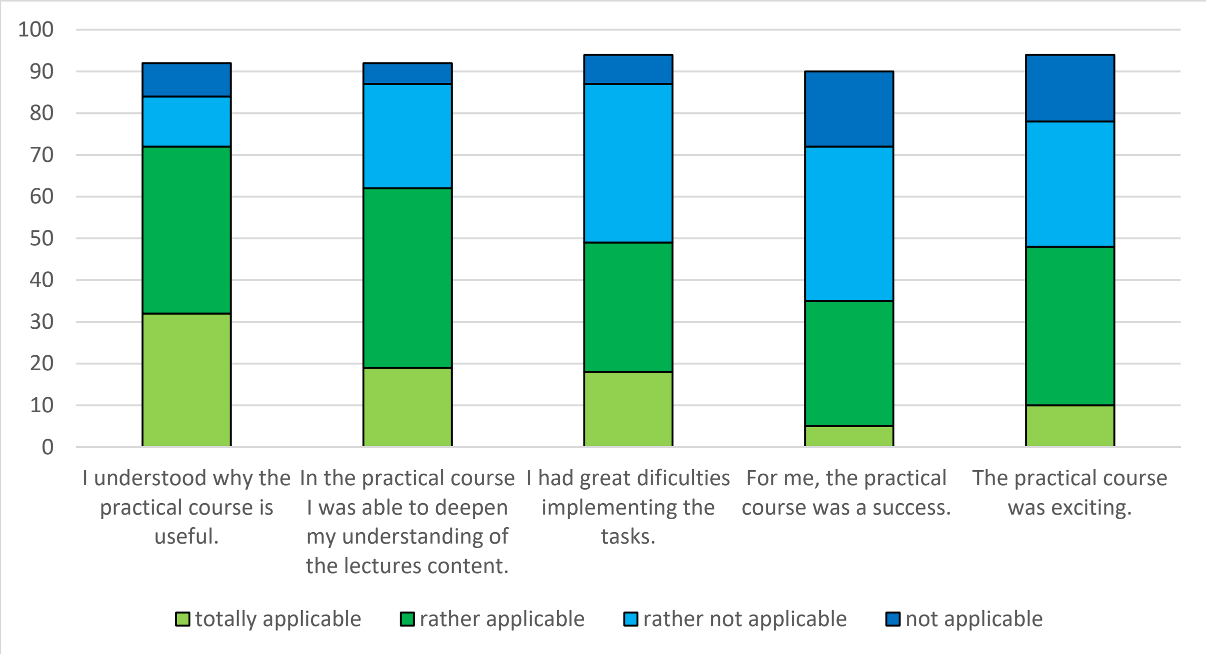

Figure 6: General evaluation of the practical course

The next item asks whether the students had difficulties in implementing the tasks. 52% of the students state that they had great difficulties. Some causes for this could be identified from the free text comments, which will be discussed in the following section.

While 51% of the students found the practical course exciting, only 39% of respondents rated it a success. It can be assumed that this assessment is related to the difficulties in executing the practical courses tasks.

Free comments

As a conclusion to the questionnaire, an open-ended question was posed that explicitly asked students to name problems: "What did you particularly like about the practical course and what didn't you like? What would you want to change?" A total of 37 % of the respondents used this opportunity and 120 comments were written. In addition to criticism, there was also positive feedback, but this will not be described further due to the small number. As explained in the 'Evaluation Procedure' section, the free texts were categorized and improvement items were formulated from the identified categories. Claims derived from the largest categories are listed below. The number of comments is noted in parentheses:

1. Reduce time spent in practical course (69)
2. Provide more stable measurement system (21)
3. Fix bugs in the code or communicate better (20)
4. Use digital protocols (12)
5. Answer questions during the interim meeting (6)
6. Answer questions also outside the interim meeting (4)

By far the most frequent comment refers to the excessive amount of time required for the practical course ("Implementation was far too time-consuming"). The students indicated an average processing time of 18 hours. This is indeed more than the twelve hours per course, allotted by the module description. However, it must be taken into account that the processing time of the practical courses varies and that the workload for the practical courses as a whole is still within the planned scope. Next semester, the workload should be communicated to the students at the beginning of the lecture so that they can plan their time accordingly.

The high time expenditure is additionally related to items 2 and 3 in the list of improvements. A major problem was the reproducibility of results due to the unstable measurement system: "In some cases, entire test series had to be recorded several times due to somewhat unreliable plug-in connections". Item 3 refers to the fact that during the practical course an error was discovered in the Arduino program provided, but this was not communicated to all students. This error caused massive deviations between the measured data and the theoretical comparison values, which is why the students invested a lot of time in troubleshooting. The error could already be corrected, which reduces the amount of work.

In the semester under review, the protocol was to be submitted in analog form on a trial basis. However, this was perceived by the students as "not up to date" and "unnecessary [additional] effort". Accordingly, a digital protocol will be implemented in the future.

Item 5 addresses a problem that has already been discussed in the section 'Supervision in midterm and debriefing'. Students state that their questions were not answered in the interim meeting. This should be solved by an adapted concept of the interim meeting in the winter semester 2022/2023.

This is followed by the request from item 6. The students would like to be able to ask questions outside of the consultation dates. However, this cannot be realized due to the large number of participants. However, this problem should still be taken into account. Before the next run of the practical courses, the challenge of supervising up to 400 students should be communicated transparently. In addition, guided preparation for the consultation is planned. This should enable students to identify difficulties in processing before the consultation, which will then be solved together in the face-to-face meetings.

6. Summary

A lot of insight could be gained even from the first evaluation. These insights will enable improvement of the practical courses and the design of the evaluation itself.

The students' assess their own declarative and procedural knowledge as very high. This can be attributed to various causes. On the one hand, only the central learning content of the practical course was surveyed. On the other hand, the timing of the survey has to be considered. Since the questionnaire was used at the end of the debriefing, a positive selection bias may have occurred. About a quarter of the enrolled students participated in the debriefing. Therefore, it is possible that the survey only captured the motivated and possibly higher performing students. Thus, the result of the evaluation cannot be considered representative for the students of the Measurement and Automation Technology module.

The results show, a correlation between the complexity of the knowledge as well as the effort required to achieve the knowledge and the students' self-assessment. The more complex and time-consuming the acquisition of knowledge, the fewer students indicate that they have this knowledge. However, it cannot be deduced from the survey whether the acquisition of knowledge is due to the design of the practical course or corresponds to the respondents' prior knowledge. Therefore, the set of items only indirectly allows conclusions to be drawn about the quality of the teaching-learning materials as well as the supervision. The results can be used as a starting point to record and assess the development of the practical courses across semesters. Thus, it can be measured whether the adjustments in the design of the practical course have a long-term influence on the self-assessment of the students.

Since more than half of the respondents state that their questions could not be clarified during the interim meeting, the concept should be revised. However, the group work phases were particularly well received. Both the guidance and the students' experience with this method received positive feedback.

It can be concluded from the evaluation that the students recognize the relevance of the practical course. The connection of the practical course to the lecture is also rated well, but can be further improved.

Almost half of the students had difficulties in implementing the practical courses tasks. Several reasons for this could be deduced from the free comments. One problem frequently encountered by the students was the reproducibility of results due to the unstable measurement system. In addition, an error in the Arduino code provided caused significant deviations between the measurement data and the values calculated. theoretically .

The open-ended question at the end of the questionnaire was used by 37 % of the respondents to give feedback on the practical course. This additionally revealed that the analog form of the protocol was rather rejected by the students and that they would prefer a digital version. Furthermore, it was pointed out in the free comments, that not all questions were answered in the interim meeting. Furthermore, there is a wish that additional questions can be asked and clarified outside of the consultation meetings.

Ultimately, the evaluation has shown how intricate the design of the course Praktika@home is. It is complex to formulate both the research interest as well as the corresponding items unambiguously and “to-the-point". During the evaluation it became clear that a great deal was asked, but the formulation of the items was sometimes too unspecific. As a result, the findings in these cases did not relate to the interest in knowledge.

The development of the evaluation alone has already triggered an intensive self-reflection of their course by the teachers. Many additional approaches for the further development of the practical course and the questionnaire could be gained from the evaluation of the first instance.

7. Outlook

One topic that was raised in both the closed questions and the open question concerns the answering of questions during the practical course. Here, on the one hand, there was criticism that questions were not answered during the interim meeting and, on the other hand, that there was no opportunity to ask questions outside of the consultation dates. Therefore, the supervision is to be adapted in the winter semester 2022/2023. In doing so, the documents for all practical courses will already be uploaded at the beginning of the semester. The dates for consultations and submissions will also be communicated at the start of the semester. In this way, students will be able to freely allocate their time and better plan work phases.

The structuring of the self-learning phases is to be supported by the use of logbooks (reading logs [7, 8]). If the logbooks are uploaded before the consultation, the students receive additional points. This is to allow students to think about the experiments in advance and formulate their questions. Supervisors can prepare for these questions and adjust the design of the consultation dates accordingly. This is also intended to increase the number of participants in the interim meeting.

From the free comments it became additionally clear that the students have no idea of the amount of work planned for the practical courses. It therefore suggests itself to integrate the practical courses more into the lecture. This would allow the workload for the practical courses to be put into the context of the entire module and be better understood by the students.

The design of the questionnaire should also be revised before the next use. For each item, it should be checked whether there is a relationship to the research interest "Are the teaching/learning materials provided and the supervision designed in such a way that they support the students in achieving the learning objectives?". Items that do not meet this requirement should be reworded or shortened.

In addition, the questionnaire should be tested before use by colleagues who were not involved in the development process to check if the items are understandable. Even during the evaluation of this first sample, problems or inconsistencies may already be noticed that can still be remedied.

Furthermore, a different evaluation time should be chosen. It has been shown not only that the number of participants varies greatly between semesters, but also that a group of students is systematically excluded from the survey. Students who do not participate in the final meeting have not yet had the opportunity to provide feedback on the evaluation. However, it would be of interest to understand why these students do not participate in the teaching-learning opportunities and how they would need to be designed to support students in their learning process.

It would be advisable to examine how the evaluation of teaching-learning opportunities differs when students indicate that they have subject-specific knowledge. This may provide information on how to better support lower-performing students.

A challenge with developing the questionnaire is the different perspectives of teachers and students. The teachers create the evaluation. In some cases, assumptions are made about student behaviors and challenges. To make the survey truly learner-centered, it would be beneficial to involve students in its development.

Acknowledgement

We thank the students of the Measurement and Automation Technology module who participated in the survey, as well as to all the instructors who supported and facilitated the evaluation.

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Evaluation of the effectiveness of teaching in the module Measurement and Automation Technology

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Abstract

Ausgelöst durch die Corona-Bedingungen wurde in den letzten Jahren viel in der Lehre verändert. Dabei stellt sich die Frage, welche Elemente der Lehre – digitale wie nicht digitale – für den Lernprozess der Studierenden tatsächlich förderlich sind. Um sich dieser Fragestellung anzunähern, wurde für das Modul Mess- und Automatisierungstechnik ein Evaluationskonzept entwickelt und im Sommersemester 2022 erstmals umgesetzt, mit dem Ziel, die studentische Perspektive auf diese Frage zu erfassen. Im folgenden Artikel werden das Konzept und Ergebnisse vorgestellt und kritisch diskutiert. Außerdem wird der Nutzen einer Evaluation konkreter Lehr-Lernelemente für die Weiterentwicklung der Lehre hervorgehoben. Dieser wird gesteigert, je häufiger eine Evaluation durchgeführt wird – in nachfolgenden Semestern, in anderen Modulen oder auch an anderen Universitäten. Ein klares Ergebnis dieser Evaluation ist die Bevorzugung von Präsenzveranstaltungen (auch in Ergänzung der Möglichkeit, online teilzunehmen) gegenüber reinen Online-Angeboten.

Triggered by the Corona conditions, much has changed in teaching in recent years. This raises the question of which elements of teaching - digital and non-digital - are actually conducive to the learning process of students. To approach this question, an evaluation concept was developed for the Measurement and Automation Technology module and implemented for the first time in the summer semester of 2022, with the aim of capturing the student perspective on this question. In the following article, the concept and results are presented and critically discussed. Furthermore, the benefit of an evaluation of concrete teaching-learning elements for the further development of teaching is emphasized. This is increased the more often an evaluation is carried out - in subsequent semesters, in other modules or even at other universities. A clear result of this evaluation is the preference for face-to-face courses (also in addition to the possibility to participate online) over purely online courses.

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This article was originally submitted in German.

1. Introduction

In the summer semester of 2022, the second part of the Measurement and Automation Technology module was evaluated with the aim of recording in detail the students' perspective on the effectiveness of teaching in the module. From this, relevant indications for the further development of teaching are to be gained. At this point it should be noted that the evaluation is not a substitute for the TU-wide course evaluation for the purpose of quality control, which is carried out at the TU Dresden by the Center for Quality Analysis. The objective of the evaluation presented here is different. It is described in more detail in the section 2 in more detail. In the section 3 the evaluation concept and the research design are described and critically discussed. An excerpt of the evaluation results is the subject of section 4. In the section 5 these are summarized and the gained knowledge is described, in the section 6 a conclusion for the teaching is drawn as well as an outlook on further surveys is given.

This article is primarily intended to address lecturers and persons involved in teaching in the field of engineering sciences who are also interested in obtaining impulses and indications for the further development of their own teaching concepts through evaluation. If similar evaluations are carried out in different modules, comparisons can be made or questions can be evaluated together. This would lead to a higher significance and to more far-reaching indications for the further development of teaching.

2. Motivation and objective

After several Corona semesters and repeated upheavals in teaching concepts triggered by the pandemic conditions, there has not been - as perhaps suspected - a weariness and reluctance to change teaching concepts. Instead, there are efforts to put further changes on a solid footing, to incorporate the findings from the Corona semesters into teaching, and to figure out the best possible variant that combines classroom formats with online or digital elements. In addition to the expertise of the teaching staff and their ongoing discourse on teaching, the focus here is on the students' perspective.

The question is how effective the individual elements from the teaching offering - digital and non-digital - actually are from the students' perspective. Are there elements that seem particularly useful to students? Further questions to be answered with the help of the evaluation are: Are there different assessments between German and non-German students? How often are teaching offers (lectures, exercises, laboratory practicals, lecture videos) used? Which format (in presence, hybrid, digital) is preferred by the students?

How these questions can be answered with the help of the evaluation carried out is shown and discussed in section 4 and discussed in the following section. The evaluation concept, which is presented in the following section, is fundamental for a targeted interpretation of the results.

3. Evaluation concept and study design

What is evaluated?

The subject of the evaluation is the module Measurement and Automation Technology, which includes a two-semester lecture, lab practicals and computational exercises (hereafter referred to as teaching-learning offerings). The individual elements (see study design), which are intended to support the learning process of the students in the teaching-learning offers, are examined with regard to their effectiveness. It is not possible to measure the effectiveness directly. It is ascertained via the assessment of the students. Although it is possible to derive statements about the achievement of learning objectives from the results of self-tests offered in the course of the semester and the exam results at the end of the module, these cannot be related to individual elements.

The aim of the teaching-learning offers is an increase in competence, i.e. knowledge, skills and abilities in the field of measurement and automation technology. **Learning processes** are understood according to the description in the study regulations [1]: They aim at an increase in competence in a specific technical area and include various processes that can be supported by different teaching-learning offers. Relevant are cognitive processes for the development of an understanding of the subject, application processes in which skills are developed and knowledge is deepened, and practice or training phases in which skills develop into abilities that are more automated. Of secondary importance when considering the effectiveness of teaching-learning opportunities, but nevertheless significant, is motivation, without which no learning process can be started and maintained.

What is the purpose of evaluation?

The aim of the evaluation is to find out which teaching-learning offers and elements are assessed by the students as helpful for their learning process in order to obtain indications for the further development of teaching concepts (insight interest). The aim is not so much to omit elements from teaching that were assessed as less helpful on the basis of evaluation results, but rather to determine the need for optimization in their implementation or to use more frequently those elements that were assessed as particularly helpful (development interest). In addition, it should be found out whether different groups of students (non-German, German, male, female) evaluate teaching-learning offers differently.

How is evaluation done?

The evaluation was carried out ex-post, i.e. at the end of the offer period, and consequently has a summative character. The evaluation is based on the following assumptions:

A learning process in the sense of gaining knowledge with subsequent consolidation through application and practice, which leads to an increase in competence, is optimally supported by motivating, knowledge-supporting elements as well as elements of application, consolidation and practice. Students can assess which elements motivate them to deal with content and which elements contribute how strongly to understanding, comprehending and consolidating contexts (it is neither a matter of ranking, nor of either/or). In doing so, an ex-post facto design allows for comparison between student groups.

In addition to the teaching-learning offers, whose effectiveness is to be recorded with the evaluation (intervention effects), other factors can significantly influence the learning process. These external confounding effects are included in the survey at the end of the teaching-learning offer period. Examples include: Learning with friends, talking with family, watching YouTube videos, etc. The effects that these factors produce are not part of the subject of the survey. This needs to be thought about in the survey.

In addition to the summative character, the survey has a formative character, since the results are to be used for the continuous further development of teaching. Further surveys allow a comparison across semesters and enable statements about the long-term development of teaching.

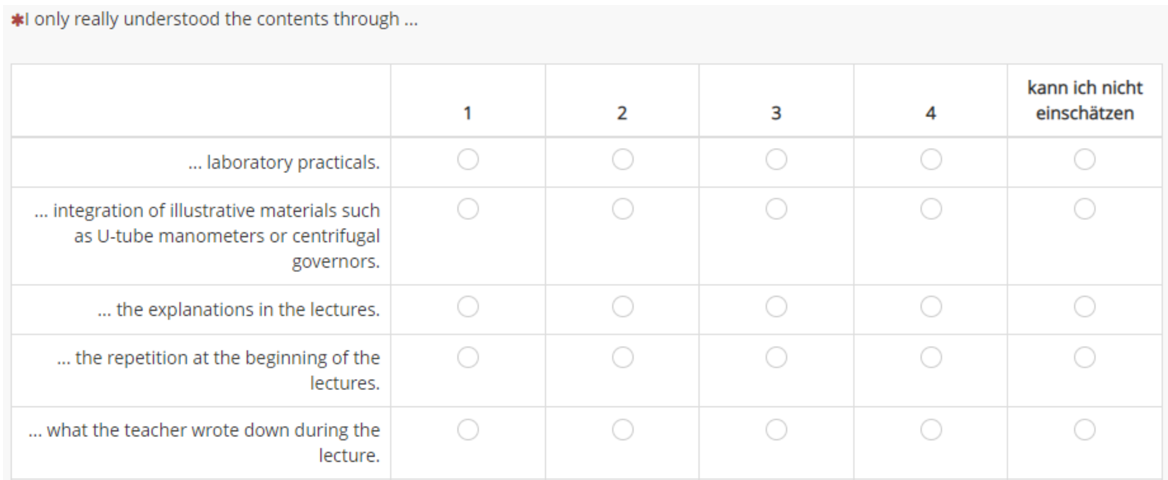
Study Design

The evaluation took place in a final survey in the last lecture of the summer semester 2022. All students present were asked to complete the online questionnaire in a time slot within the lecture. For this purpose, a QR code was generated that led directly to the survey. This approach made it possible to survey almost everyone in attendance. In addition, the link to the survey was sent to all students, so that people who did not attend the last lecture could also participate in the survey. The standardized questionnaire was created using the online survey application LimeSurvey, which is provided to the TU Dresden via the Saxony Education Portal [2]. The survey was anonymous, with recording of the date and timings to the individual question blocks.

The questionnaire contains primarily closed questions with a 4-point unipolar Likert scale ("1," "2," "3," "4," "I can't estimate"), whose lowest expression ("1") is specified as "disagree" and whose highest ("4") is specified as "agree completely." For the first question of the questionnaire, examples are given on the answer options. The questions are bundled into the following blocks:

- Block 1: The course offering on measurement and automation technology in the summer semester 2022: What helped you?
- Block 2: What did you use?
- Block 3: What do you prefer?
- Block 4: General information (socio-demographic data)

In **block 1,** the participants were asked about their assessment of the following elements: explanations in the lecture, interim queries using the learning platform Kahoot! [3], repetitions at the beginning of the lecture, integration of illustrative materials, what was written down by the teacher during the lecture, practical applications, own transcripts, X-chapter[1] , historical narratives, lecture videos, solving exercises, attending exercises, sample solutions to the exercises and the lectures and exercises as a whole, as well as lab practicals. No further differentiation of lab practicals into individual items was made, as there were separate surveys [4] for this purpose. An example of the items can be found in Figure 1.



*I only really understood the contents through ...

	1	2	3	4	kann ich nicht einschätzen
... laboratory practicals.					
... integration of illustrative materials such as U-tube manometers or centrifugal governors.					
... the explanations in the lectures.					
... the repetition at the beginning of the lectures.					
... what the teacher wrote down during the lecture.					

Figure 1: Sample items from the survey in the summer semester 2022 on teaching effectiveness.

Other item beginnings are:

- "I was able to understand the connections through...",
- "I was able to consolidate my acquired knowledge by...",
- "I was motivated to engage with the content by...",
- "In my learning process, it has moved me forward...".

In **block 2,** students were asked how many lectures, exercises, and meetings on the lab practicals they attended. The answers were given via numerical entries. Likewise, the self-study time per week was queried numerically in minutes, as well as used possibilities besides the teaching-learning offer, such as textbooks, Youtube videos, conversations with friends etc.

Which variants were preferred in the area of digital teaching was the subject of **block 3**: lecture in presence, screen recording, live transmission, hybrid implementation as well as the temporal integration of Kahoot! - at the beginning, in the middle or at the end of the lecture.

The following data were requested in **block 4**: degree sought, field of study, semester, gender and nationality (German, EU countries, non-EU countries). At the end of the questionnaire, comments, wishes and criticisms could be expressed in a free text field.

Critical discussion

No pre-post design

If the effectiveness of teaching-learning offers is to be recorded, it is advisable to measure the level of competence at the beginning and end of the offer period. A pre-test is not possible in the measurement and automation technology module. In addition, the comparison between the competence levels does not provide a differentiated view of individual elements. For these reasons, an ex-post survey was chosen to assess the effectiveness of individual elements as well as the teaching-learning offerings as a whole.

Distortions

Due to the amount of items in block 1 (26), there may be some fatigue in the assessment.

[1] Here students are asked to photograph measurement technology in everyday life, to question it and to send it to the teacher. In the so-called X-chapter in the lecture, the underlying measurement principle is explained.

However, since this was the first time the survey had been conducted, it was important to have as many items as possible assessed. In addition, isolated items were asked twice with different wording to check for random ticking.

Further biases are possible due to the measurement time in the last lecture. The assessment of the effectiveness of individual elements of an entire semester may well be difficult. It should also be considered that elements of the teaching-learning offer do not contribute directly and noticeably to understanding or consolidation, but possibly with a delay or unconsciously. These effects are not recorded in the survey, but are just as desirable as those that are directly and consciously perceptible.

External Confounding Effects

These effects have already been addressed. The survey was used to ascertain whether students used textbooks, YouTube videos, conversations with friends, fellow students and family to make better progress in the learning process. However, since all individuals use such resources to a greater or lesser extent, data sets cannot be excluded to rule out corresponding effects.

Also mentioned here are students' performance and willingness to perform, which can strongly influence the assessment of elements of teaching.

No representative sample

All students present at the last lecture were surveyed. It is possible that these students are more motivated to complete the module than the students who did not come to the last lecture. Other reasons for non-attendance could be illness or family commitments, or a preference for using the lecture videos. Thus, the group of respondents is not representative of the entirety of students in the Measurement and Automation Technology module.

4. Evaluation results

In the following, selected results from the survey are presented and critically discussed.

The participants

A total of 160 complete data sets were available for inclusion in the evaluation. Of these, 26 were female, one was diverse and 120 were male. 13 persons made no statement. The proportion of women is 16% and thus corresponds approximately to the proportion of women in the entire student group in the module in the summer semester 2022 (17%). The proportion of students from EU and non-EU countries is 17.5%. A total of 356 students participated in the written exam for the module Measurement and Automation Technology in the summer semester 2022.

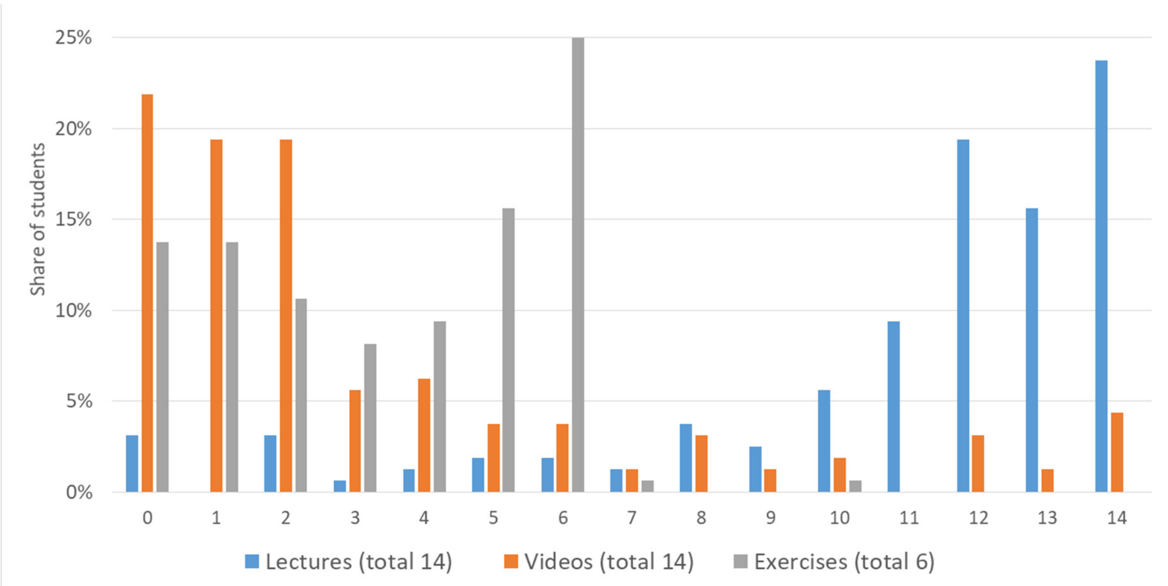


Figure 2: Number of offers used.

Thus, 45 % of the students could be surveyed. 85 % of the respondents are aiming for the diploma degree, the rest for the bachelor's degree, master's degree or the diploma postgraduate degree. Over 90 % of the respondents are studying mechanical engineering, with just under seven percent studying process and natural materials engineering. 76 % of the respondents are in their 6th semester at the time of the survey, the others in their 2nd (Diplom-Aufbau), 4th, 8th or 10th semester.

Use of offers

Students were asked how much of the 14 lectures, 14 lecture videos, and six exercises offered they used. The following graph (Figure 2) shows the results.

Nearly 90% of respondents used at least half of the lectures and about half used four or more exercises. Seven or more videos were used by just under 20% of respondents. The percentage of people who did not attend lectures was 3%. One fifth of the respondents did not attend any exercises.

Although only six exercises were offered, two individuals reported a number above six. It is possible that these individuals went to parallel exercises that were offered at staggered times. In future surveys, an upper limit should be set here, since the issue is whether all exercises were attended or fewer.

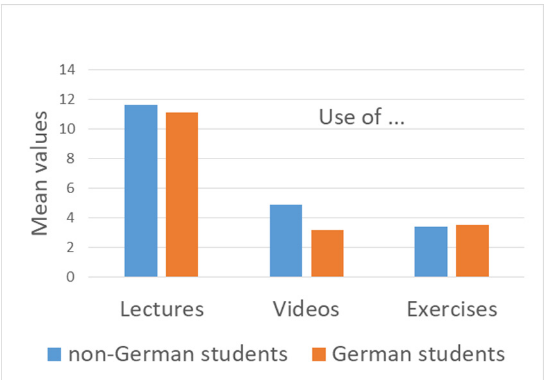


Figure 3: Comparison of usage means between non-German and German students.

A comparison between German and non-German students is interesting with regard to the use of teaching-learning offers. However, due to the small group size of the non-German students (28), the results are only of limited significance. For the comparison, the mean values of the usage frequencies of both groups were compared for lectures, videos and exercises (Figure 3). Lectures and exercises are used with similar frequency by both groups, but videos are used somewhat more frequently by non-German students. The reason for this could be the language barrier, which can be compensated for by the possibility of interrupting the videos or playing them more slowly.

The comparison of mean values of usage frequencieswas also drawn between women and men (Figure 4). Here, too, the group size of women (26 respondents) is too small to make any generally valid statements.

A significant difference in the usage behavior of the two groups is not evident for lectures, lecture videos, or exercises.

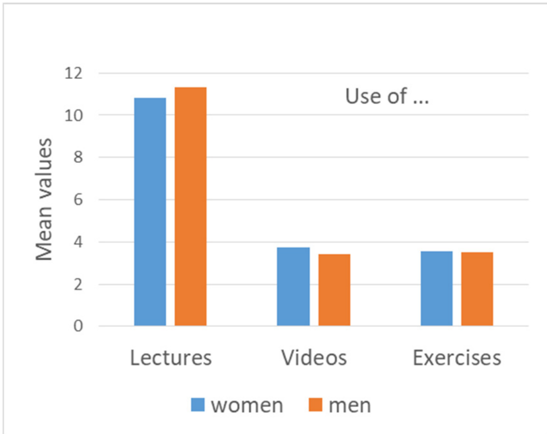


Figure 4: Comparison of mean usage values between women and men.

Assessment lectures, exercises, lab practicals

The students were asked how much they were advanced in their learning process by the lectures as a whole, the exercises as a whole and the lab practicals as a whole. This evaluation was asked chronologically after the evaluation of individual elements, so that it can be assumed that "exercises as a whole" was understood to mean not only the Exercise event, but also the exercise tasks and sample solutions.

Only the results of respondents who had attended at least half of the lectures and the exercises were used (Figure 5).

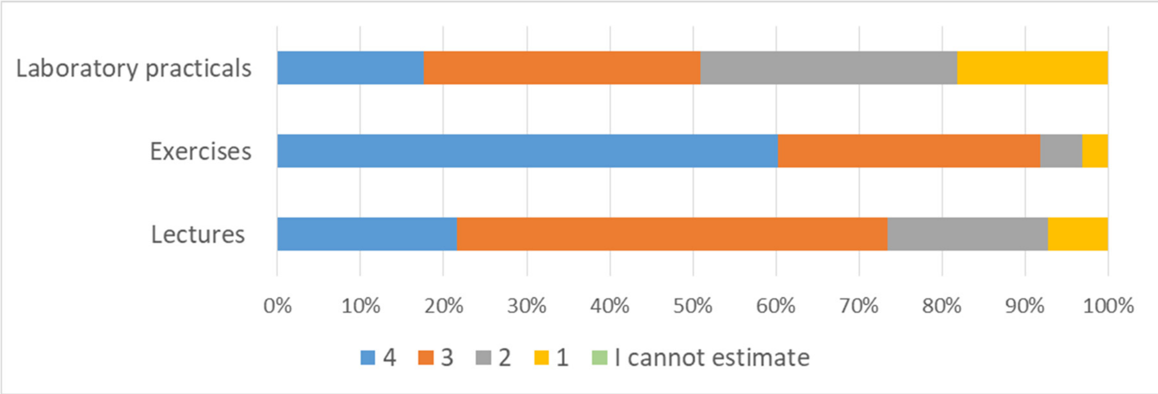


Figure 5: Overall assessment of teaching-learning opportunities.

More than 90% of the respondents rated the exercises positively (response categories "3" and "4"), just under three-quarters rated the lectures positively, and half of the respondents rated the lab practicals positively. The reason for the different evaluation between exercises and lectures can be found in the didactic function of both teaching-learning offers. While the lectures primarily present the content and the students largely acquire it by taking notes, exercises promote a more active engagement with the content by solving the exercises independently. It is quite understandable that the exercises are thus rated as more effective for one's own learning process than the lectures, even though the lectures provide the basis. The added value of doing things independently as opposed to just listening is likely to be even more apparent in the lab practicals, as these are even more action-oriented. Here, not only calculations have to be performed, but data has to be determined by experiments. However, the results show that the lab practicals were rated significantly lower. A very likely reason for this is the stage of development of the lab practicals. They were redesigned during the Corona pandemic and have yet to be optimized accordingly, while exercises and lectures have been adapted but are still based on concepts that have been tried and tested for years. For example, the coordination between lectures and lab practicals still needs to be improved. This explanatory approach is supported by comments in the free text field at the end of the questionnaire.

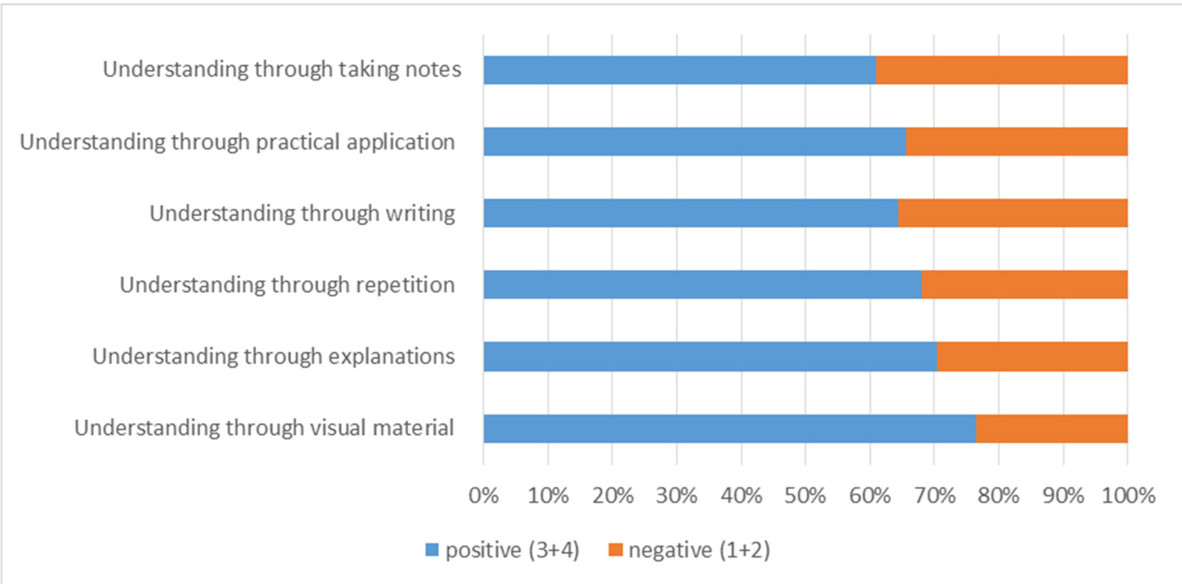


Figure 6: Evaluation of lecture elements.

Evaluation of the lecture elements

In question block 1, students were asked how effective the various elements, such as note-taking or writing to them by the teacher, were for their learning process. The following graph (Figure 6) shows results from students who attended at least half of the lectures. For the evaluation, the response categories "1" and "2" were combined under "negative" and "3" and "4" under "positive".

The elements were predominantly evaluated positively. Three quarters of the respondents rated visual aids as helpful for their own understanding (highest effectiveness). 60% of the respondents rated understanding through their own note-taking positively (lowest effectiveness). All other elements were in between.

When evaluating these results, it should be noted that these elements are only effective in combination and basically cannot be considered on their own. It is possible that the respondents found it difficult to differentiate between the effectiveness of individual elements. If we look at the correlations (calculation of the coefficients with the Excel function KORREL) between similar items, we get values between 0.3 and 0.5.

The correlation, for example, between "I only really understood the contents by including visual materials" and "I only really understood the contents through practical applications" is 0.33. The correlation between the teacher's note and the students' notes is 0.48. Consequently, there are correlations.

Furthermore, the participants were asked which elements of the lecture helped them to consolidate the material. In the Figure 7 shows the results for the elements repetition at the beginning of the lesson and intermediate questioning.

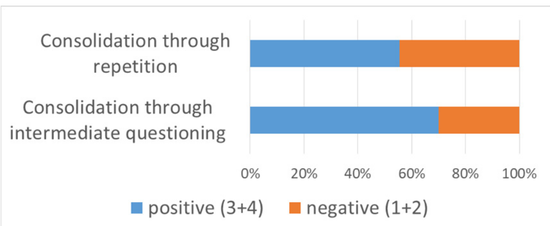


Figure 7: Evaluation of the elements repetition and intermediate query.

Both were predominantly evaluated positively, whereby the intermediate question scored better. This is possibly due to the fact that the intermediate question refers to the material that was discussed directly before. The review was done at the beginning of the lesson, the material was then a week ago. Thus, the repetition at the beginning of the lesson serves more for reactivation than for consolidation. This should be made more explicit in a subsequent survey.

An interesting aspect of the assessment of the lecture elements is a comparison between the groups of non-German and German students. For this purpose, the mean values of the groups for the individual elements were compared (Figure 8).

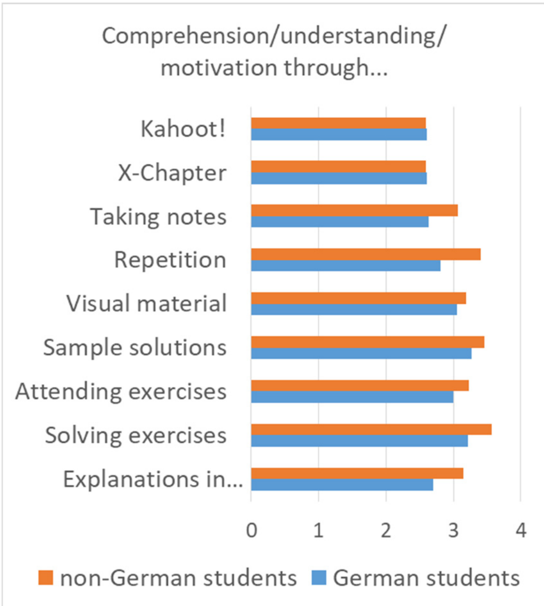


Figure 8: Comparison of lecture element ratings.

Except for the elements Kahoot! and X-chapter, the non-German students rated the elements 0.1 to 0.6 points better than the German students. This can be interpreted as a tendency to rate individual elements better. The small group size of the non-German students should be pointed out again as a limitation.

Exercise evaluation

Students were asked about the exercises and how helpful the elements were in helping them to understand the subject-specific connections. From Figure 9 it can be seen that solving exercises and the sample solutions to the exercises were positively evaluated by over 80% of the respondents, and attending the exercises by just under three quarters of the respondents. Possibly the reason for the different evaluation is the fluctuating quality of the exercises, depending on the person leading the exercises. This hypothesis is supported by the somewhat larger spread of answers than for the other elements.

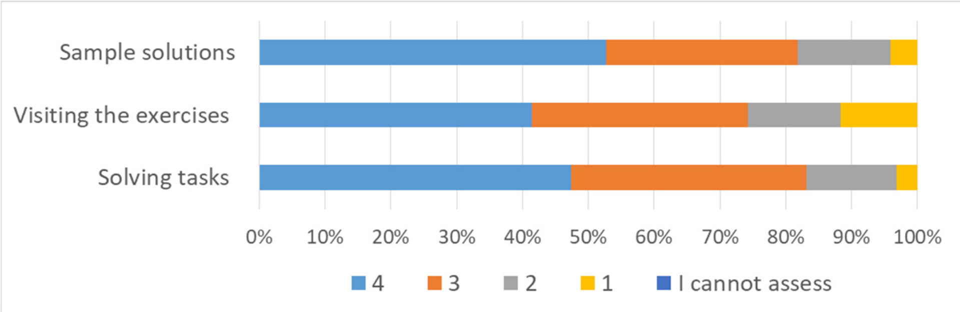


Figure 9: Comparison of exercise element ratings.

Preferred variants

The students were asked which variant of the implementation of the lecture they personally preferred. For each variant, they had the opportunity to select one of the following response categories: "yes," "no," and "I cannot assess." The results are shown in Figure 10.

Over 80% of respondents voted for a face-to-face lecture and likewise over 80% voted for the hybrid option, i.e. a face-to-face lecture with the option to participate online.

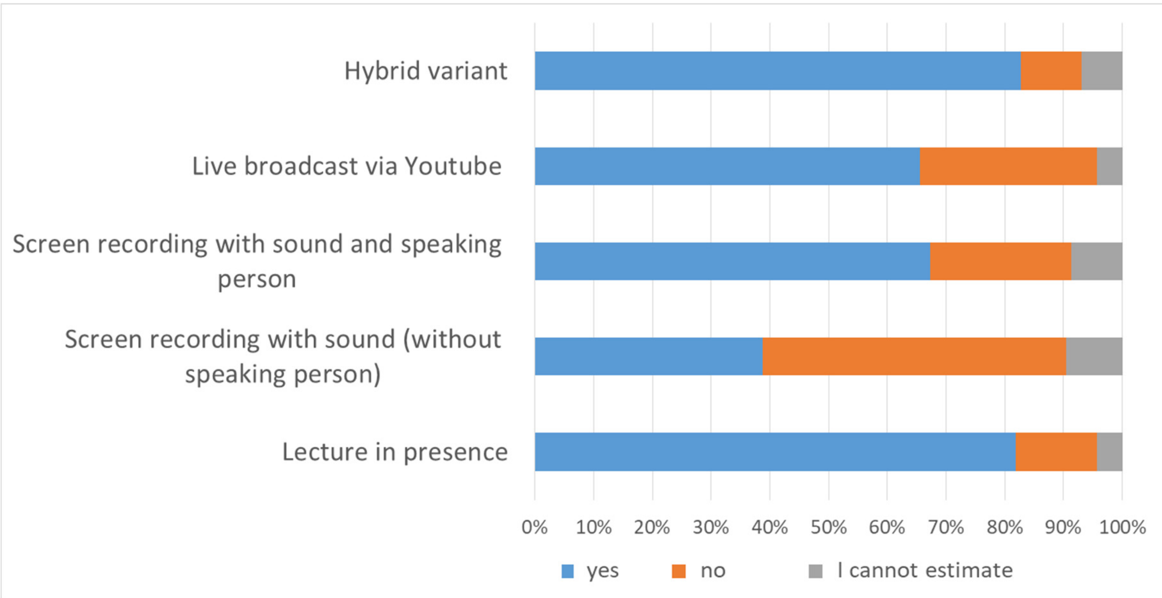


Figure 10: Preferred variant of the lecture.

The correlation of these two variants is less than 0.1, so there is no significant relationship between them. 65% of the respondents were in favor of live broadcasting via YouTube, screen recording with sound and speaking person by 67% of the respondents. The majority of respondents (61%) rejected screen recording with sound but without a person speaking. Consequently, there is a clear preference for face-to-face lectures.

Furthermore, students were asked which variant of the query with Kahoot! was preferred.

Students had the option to answer "yes", "no", "not at all", or "other" to each variant. The results in Figure 11 show that respondents clearly favor the mid-lecture query. The results "not at all" and "other" have been omitted from the figure (total of three people).

In question block 2, the students were asked about what other options they use to progress in the learning process in addition to the teaching-learning offer for the Measurement and Automation Technology module. The following graph (Figure 12) shows that conversations with fellow students as well as conversations among friends were used far more frequently than documents from other students, tutorials or textbooks. However, a comparison of the effectiveness of these elements compared to the teaching-learning offer for the module cannot be drawn with these results.

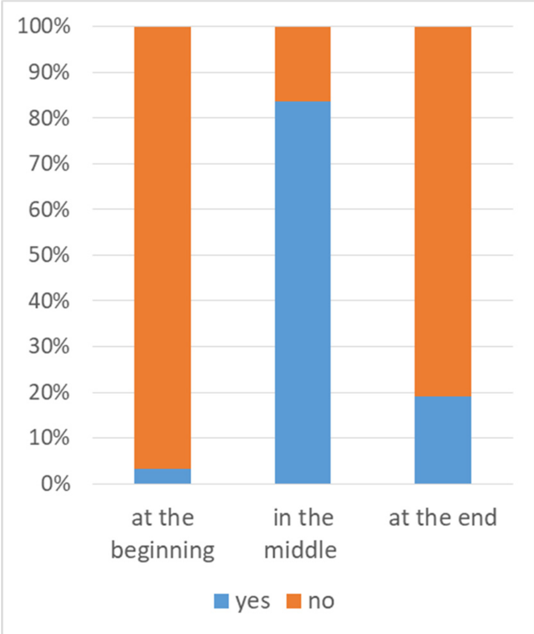


Figure 11: Preferred variant for intermediate query with Kahoot!

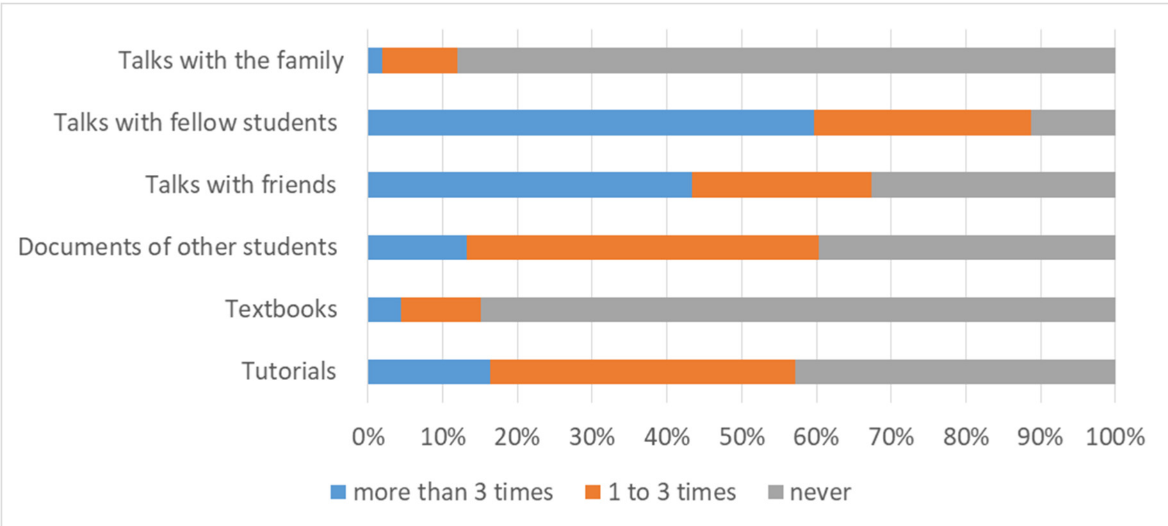


Figure 12: Use of other learning opportunities.

5. Summary and interpretation of results

Almost 90% of the respondents use at least half of the **lectures** and about half of the respondents use four or more exercises. 20% of the respondents did not attend any exercises. It can be concluded from this that the students consider attending the lectures to be useful, while attending the exercises seems to be less useful or helpful for some. However, in the overall assessment of the teaching-learning opportunities, the exercises score best. If one looks at the evaluation of individual elements in the exercises, it becomes clear that the exercise tasks and sample solutions are assessed as very effective, the attendance of the exercises as less effective. It can be concluded from this that the quality of the exercises can be improved in terms of their effectiveness on the learning process.

Even if the lectures perform less well than the exercises, this may not mean that they should be improved. The reason may also lie in their didactic function. The practical courses, on the other hand, should be adapted, which was already named by the lecturers before the survey and which is evidenced by the comments in the free text field.

The **videos** on the lectures were not considered effective and used by all. However, it was shown that they were used more frequently by the group of non-German students.

The solving of **exercises** and the sample solutions to the exercises were rated positively by over 80% of respondents. They thus achieved the highest result in the evaluation of teaching-learning offerings and elements. Solving tasks independently is consequently perceived as very effective by the students. The positive effect of exercises on the learning process could have been further supported by the sample solutions, in that they provided helpful hints when students were unable to progress in exercise tasks and thus prevented frustration. This could be explicated in a later study.

More than 80% of respondents voted for a **classroom lecture** and another 80% for the hybrid variant, i.e., a classroom lecture with the option to participate online. Accordingly, students clearly favor face-to-face lectures. Equally clear is the favorite of the intermediate survey in the middle of the lecture.

Review of the questionnaire

For this purpose, the following points were examined:

If it was stated that no lecture was attended and no video was watched (applies to one respondent), the answer category "I cannot assess" should have been selected for the assessments of the elements of the lecture. The verification showed that all answer categories were ticked. In order to avoid incorrect ticking, it would make sense to ask about the use of teaching-learning offers before assessing the individual elements and to skip the assessment of the lecture elements if lectures and videos are not used.

When indicating that lecture videos were not used, the following items were checked:

"I didn't really understand the content until I watched the lecture videos."

"I was able to understand the connections through the lecture videos."

For the first item, the answer categories "1" to "4" were used by 60% of respondents, and for the second item by 51%. This indicates that the answers were randomly selected. This problem can possibly be reduced by reducing the number of items and by clearer formulations that are immediately understood by the students.

Furthermore, the correlation between two items targeting the same content was investigated.

"I was able to understand the connections through the explanations in the lectures."

"I only really understood the content through the explanations in the lectures."

The comparison was made for the whole group, for the group of German students, and for the non-German students, with the following result:

Group:	**total**	**Non-German**	**german**
Correlation coefficient	0,65	0,78	0,59

The total value of 0.65 certainly indicates a correlation, but not to the extent that would be expected if the content were the same. This suggests that the items do not clearly reference content, at least for the group of German students. Thus, they seem to differentiate the two items more strongly in terms of content than the non-German students. Another explanation would be that they ticked a value rather randomly and thus would be less conscientious than the non-German students. In order to obtain clearer results here, the items would have to be formulated in such a way that they actually do not permit different interpretations.

6. Conclusion and outlook

An evaluation of teaching in the direction of the effectiveness of individual teaching-learning offers and elements is a good basis for the concrete further development of teaching. The evaluation presented here was conducted for the first time in the summer semester of 2022.

Initial findings could be drawn from it. However, reliable statements in the breadth of the survey can only be derived once it has been conducted several times and, if necessary, applied in other modules. In the following, a conclusion is drawn from the findings for the teaching concepts and subsequently an outlook on further evaluations is given.

Conclusion for the teaching concept of the module Measurement and Automation Technology

In order to increase the number of students attending **exercises**, it can be helpful to train the exercise instructors and thus improve and ensure the quality. The instructors should learn how to work in a more student-oriented manner, so that the exercises do not involve pure recitation and are more advisory in nature.

Furthermore, **lecture videos** should be provided to give the possibility to repeat lecture contents or to use them as a substitute for the lecture if attendance in presence is not possible.

In order to use the positive effect of exercises also in the **lecture**, smaller exercises could be integrated already there, which would have to be solved independently by the students. This would increase the activity of the students and interrupt the process of pure listening and taking notes - similar to the intermediate questioning. This would be a better way to maintain student attention. It can also make it easier to link lectures and exercises.

Events should be offered **in presence** if possible. Additional online participation can be very useful for persons with disabilities, but will not completely replace attendance in presence.

During the **evaluation** it became clear that the questionnaire for the next evaluation round should be adapted according to the following points:

- Clearly worded and easily distinguishable items,
- Fewer items,
- No assessment of teaching-learning opportunities that were not used,
- Clarification on individual elements, for example: How were sample solutions used?
- Possibly multiple interviews throughout the semester,
- Inclusion of results from self-tests offered during the semester.

Despite adjustments, items that have provided clear results should be retained. Even when further developing items, it is useful for comparability to use scales that can be transferred to each other. Thus, developmental trends in teaching can become visible by comparison with the evaluation already available. In addition, as already mentioned in the introduction, long-term efforts are being made to ensure that other modules in the Faculty of Mechanical Engineering at the TU Dresden and beyond (subject and university) are conducted in a similar form and that joint evaluations are carried out. On this basis, it will be possible to discuss the effectiveness of teaching in an interdisciplinary and well-founded manner - especially with regard to the digitization or partial digitization of courses.

Acknowledgement

Our thanks go to the students of the Measurement and Automation Technology module who participated in the survey as well as to all lecturers who supported and facilitated the evaluation. Dr. Adrian Lange should be mentioned here by name.

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The competence studio as an agile teaching format - Biomechanics project work up to the prototype

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Abstract

Um den Campus im Zeitalter von digitalen und hybriden Lehrveranstaltungen wieder attraktiv zu machen, wird ein agiles Lehrformat vorgestellt, das die kooperative Problembewältigung durch projektbasiertes Lernen und agiles Projektmanagement ins Zentrum stellt. Hierzu werden zunächst allgemein die Elemente agilen Projektmanagements vorgestellt und anschließend die Übertragung auf den Lehrkontext erläutert. Zur weiteren Verdeutlichung des Ablaufs und des Zusammenspiels der Gruppenmitglieder wird am konkreten Beispiel des Moduls *Kompetenzatelier: Biomechanik agil mit Scrum* die Durchführung beschrieben und das schrittweise Erstellen eines Demonstrators durch die Studierenden gezeigt. Abschließend wird die Evaluation des Kompetenzateliers zur Identifizierung von allgemeinen Stärken und Schwächen genutzt. Dabei wird besonders auf die agile Reaktion der Studierenden auf geplante und ungeplante „Störelemente" eingegangen. Das Kompetenzatelier bietet für Lehrende kleiner Studiengänge und Gruppen eine Anregung zur innovativen und kreativen Auseinandersetzung mit einem agilen Projektmanagement und fördert die Selbstmotivation zum Lernen durch eine unmittelbare praktische Anwendung.

To make the campus attractive again in the time of digital and hybrid teaching, an agile teaching format is presented that focuses on cooperative problem solving through project-based learning and agile project management. Therefore, the elements of agile project management are first presented in general and then transferred to the teaching context. For further clarification of the process and to show the cooperation of the group members, the actual example of the module Competence Atelier: Biomechanics agile with Scrum, is described including the step-by-step creation of a demonstrator by the students. Finally, the evaluation of the competence atelier is used to identify general strengths and weaknesses. In particular, the agile reaction of the students to planned and unplanned "disruptive elements" will be addressed. The competence atelier offers teachers of small courses and groups a stimulus for innovative and creative engagement with agile project management and supports self-motivated learning through immediate practical application.

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1. Introduction

The establishment of digital and hybrid courses is accompanied by the question of the necessity and value of face-to-face teaching. The experience of the Corona pandemic clearly showed that face-to-face teaching not only has decisive advantages for students' sense of belonging, but that practical teaching formats are also highly valued in the university context. The question arises as to how this added value of face-to-face teaching can be increased and made clear to students.

The teaching staff of the Chair of Biomaterials at Dresden University of Technology took on this task in order not to simply follow the path back to long-established teaching formats after remote teaching during the Corona pandemic. The focus was therefore primarily on the continuation of the newly established digital techniques and feedback formats, the use of elaborately created videos of the digital and hybrid semesters, and the integration of these elements into a new teaching concept.

During the Corona semesters, many digital and hybrid lecture and seminar formats as well as practical courses with digital communication tools and Lab@Home approaches were implemented in the teaching activities of the Chair of Biomaterials. These (experimental) lectures, seminars and practical courses took place as synchronous and asynchronous online as well as hybrid events [1,2]. The importance of practical training elements and the high significance of students learning together - under the guidance of the teachers - became particularly apparent in the course of this challenging time.

Three courses were redesigned to emphasize the values and importance of face-to-face teaching for students. The focus of these so-called "Competence Atelier" is the joint development of a prototype or a demonstrator in the form of a product to solve a real-life or work-related problem. The respective problem is oriented to the subject matter, which ranges from *biomechanics*, *quality assurance and statistics* to *sustainable materials*. The aim is to activate the full spectrum of methodological, subject matter, personal and social skills in the students.

The development of the *Competence Atelier: Biomechanics Agile with Scrum* for students in the 8th semester of the Materials Science study program was primarily based on the experience with the workshop *Biomechanics in Everyday Life* (2nd semester). This was further developed into a synchronous digital practical course with asynchronous activity phases during the time of the Corona pandemic [3]. Here, the focus was on promoting self-competence and methodological competence.

In the following chapter, agile project management, as established e.g. in the field of software development with the Scrum framework, is first explained. Subsequently, the transfer to a university teaching format is described. Since the process, the personal roles, and the teaching elements (artifacts) deviate from classic teaching formats such as lecture, seminar and lab course, the term competence atelier is used in the following.

Finally, there is a chapter on the specific implementation of the competence atelier using the example: Biomechanics agile with Scrum. The evaluation and student feedback on this example serve to assess the new teaching format.

2. Agile project management

Agile time and project management based on Scrum according to Ken Schwaber and Jeff Sutherland follows a strict but universal set of rules, which is not limited to the originally addressed software development [4]. Agile methods are characterized by an iterative development process. Instead of working through an extensive catalog of tasks in order to develop a final product, small iteration stages are implemented in demonstrators in order to obtain feedback from team members and clients at an early stage. This allows a quick and flexible - i.e. agile - response to changing requirements.

The use of agile project management methods in the context of a university course serves to convey specialized content in a practice-oriented manner using the widespread working methods of teams and work groups in many companies [5]. There are three central aspects, the roles, the events and the artifacts. Their correspondences in the teaching context are assigned in chapter 3.

In general, the organizational framework of Scrum defines the roles of a Product Owner, a Scrum Master and the Developers for a team of max. 10 people. A functional explanation is given in chapter 3, which describes the transfer to a lecturing context. The chronological sequence of a project according to Scrum is divided into so-called sprints, which in turn are subdivided into a sprint planning session, daily meetings (Daily Scrum), the actual work phase, a sprint review and a sprint retrospective. The interaction of the Scrum elements is schematically summarized in Fig. 1.

Individual increments or prototypes of a finished product are developed during the sprints, increasing the complexity of the product over time. The so-called artifacts are used for group organization and documentation. These include the product backlog as a prioritized list of increments to be worked on in order to generate a product with the most important requirements as quickly as possible.

The Product Backlog is always oriented towards the goal of the entire project, i.e. the wishes and requirements of the customers or finally the users. In the sense of agile project execution, this backlog is always refined and effort as well as risk estimates are made for the prioritization of the individual increments.

For each Sprint there is a Sprint Backlog, also a prioritized list of tasks that are processed until the respective "*Definition of Done*" is reached. During the Sprint, the Developers work through the individual work steps (Items).

The Product Increment already mentioned represents a delimited (partial) competence or individual functionality of the final product. This must be generated by the team within each Sprint and its functionality should be testable. Then the "*Definition of Done*" is fulfilled.

This initially abstract description of project execution with Scrum is transferred to the specific context of a university course in the following and the generalized teaching format "Competence Atelier" is derived from it.

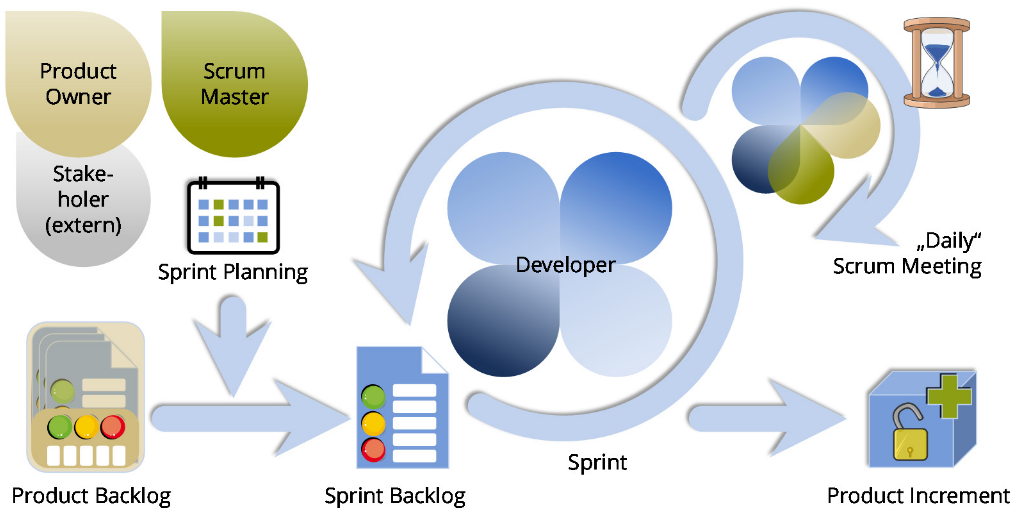

Fig. 1: Schematic representation of the project management work cycle according to Scrum

3. Agile with Scrum in University Teaching - The Competence Atelier

In the new course format of the Competence Ateliers, the focus is on cooperative problem solving and project processing. In order to enable students to work together as efficiently as possible, they are first introduced to agile project management (based on Scrum [4]Fig. 1). By directly applying the agile method, they internalize the roles (Scrum Master, Product Owner, Developer team), events and artifacts through their own experience.

The general Scrum rules were adapted to the constraints of university teaching (weekly rhythm, double lessons, group sizes, role assignment, etc.) (Tab. 1). With the planning described here, the Competence Atelier is feasible for courses with 4 semester hours per week of 45 min each (2 double lectures) and up to 12 students in one room. For up to 24 students, the Competence Atelier can be implemented with two rooms or one larger room. Since the lecturer is in a deputy function of the Scrum Master, she or he cannot participate in the "Daily" Scrums of two groups. Therefore, an offset of approx. 20 min (especially in the first Sprint) is advisable in this case.

Tab. 1: Semester schedule for a course with 4 semester hours per week of 45 min each (2 double lectures) with color coding of the 3 sprints. In contrast to the Scrum framework, the "Daily" does not take place daily but weekly, at the beginning of each appointment as an hybrid or face-to-face event.

Week	Duration / min	Content of the Competence Atelier	Learning units
1	90	Thematic introduction (in the current example: biomechanics)	Digital short videos, exercises, quizzes as 10-30 min self-learning units, permanently available and individually retrievable via Videocampus Saxony or Opal.
	90	Introductory event on the project management method Scrum, (group formation)	
2	30	Assignment of roles (in the groups)	
	60	Meeting with stakeholders or development assignment, define requirements profile	
	30	Creation of the Product Backlog	
	30+30	Planning Sprint **1**, creation of Sprint Backlog; Sprint 1	
3	15+75	"Daily"; Sprint 1	
	90	Sprint 1, Backlog Refinement	
4	15+75	"Daily"; Sprint 1 Review	
	15+75	"Daily"; Sprint 1 Retrospective and submission as a 1st protocol (until next appointment).	
5	15+75	"Daily"; planning **Sprint 2**, creating Sprint Backlog.	
	90	Sprint 2	
6		*(lecture-free)*	
7	15+75	"Daily"; Sprint 2	
	90	Sprint 2, Backlog Refinement	
8	15+75	"Daily"; Sprint 2	
	90	Sprint 2, Backlog Refinement	
9		*(lecture-free)*	
10	15+75	"Daily"; Sprint 2 Review	
	45	Sprint 2 Retrospective and submission as a 2nd protocol (until next appointment).	
11-14	Σ = 720	**Sprint 3** (according to procedure VL 5-10) with submission of the 3rd protocol (until 1 week before the exam).	
Exam time		"Daily"; Release: Group Exams	

This results in the descriptions of roles and artifacts in the teaching context summarized in the following:

Stakeholders (module supervisor or lecturer, external experts as guests if necessary)

- Customers, clients, users or patients who "bring along" a task or problem,
- Deliver the task, which is reformulated by the Product Owner into the product goal,
- Are represented by the Product Owner during the sprints,
- Evaluate the increments or the final product after each Sprint,
- Implementation in the form of **a)** user stories as short descriptions of individual features of the desired product or **b)** stakeholder statements as several 1-2 page problem descriptions of various (fictitious)

organizations and persons or **c)** stakeholder interviews in the form of expert discussions for problem description and product idea generation.

Product Owner (1 student per group)

- Has a vision of the final product after exchange with stakeholders,
- Responsible for the final properties as well as economy,
- Continuously develops the Product Backlog, determines priorities, values and risks of the individual increments and items,
- Explains the requirements and product features to the developer team.

Scrum Master (1 student per group supported by 1 lecturer)

- Responsible for compliance with Scrum rules and timeboxes,
- Helps to manage the Product Backlog/ Sprint Backlog transparently,
- Provides techniques for group management and constructive collaboration,
- Moderates "Daily" Scrums, Sprint Review, Sprint Retrospective,
- Documents project progress in a collection of protocols (submitted after each Sprint as part of the evaluation),
- Lecturer is responsible for more general aspects (access to labs/rooms, technology, equipment) and supports in finding roles (especially during 1st sprint).

Developer (groups <10 students)

- There are no fixed roles in the team,
- Design a plan for the Sprint and maintain the Sprint Backlog,
- Estimate the effort of each backlog item, define the "Definition of Done" for each increment and item together with the Product Owner,
- Deliver product functionalities with priorities desired by the Product Owner,
- Work on items individually or in small teams during sprints (on-site or self-study).

Product increment

- Delimited (partial) competence or individual functionality of the product,
- Must be manageable by the developer team in one Sprint,
- Functionality testable (Definition of Done).

Item

- Individual work step - to be implemented by a developer or small team,
- Should not last longer than 90 min,
- Result together in a product increment or form the basis for it,
- Also includes learning the basics (provided instructional videos, practice materials, expert interviews, etc.).

Product

- Consists of increments developed/implemented during the Sprints,
- Each increment can represent a product (with limited functionality) as a demonstrator or prototype,
- Further increments add functionalities according to prioritization *(Backlog)*.

Product Backlog

- Prioritized list of increments to be worked on as a long-term project plan,
- Effort and risk assessment,
- Managed by the Product Owner and continuously refined and improved during Backlog Refinement (1-2 per sprint) - also in collaboration with developers,
- Part of the evaluation: Delivery as an approx. 10-page summary after each Sprint (Tab. 1).

Sprint Backlog

- Managed by the developers,
- Ordered list of necessary work steps of the current Sprint, including the *"Definition of Done"*,
- Planning of processing a single item (should take < 90 min),
- Divided into "*ToDo*", "*In Progress"* and "*Done"* (the basis for *burn-down chart*).

Sprint

- 3-4 week interval (Tab. 1) for self-organized implementation of the *Backlog items*,
- At the beginning, the Sprint Backlog is developed during Sprint planning,
- At the end of each Sprint, a completed increment is delivered in the Sprint Review,
- Is completed by the Sprint Retrospective to improve team collaboration.

"Daily" Scrum (1x per week, max. 15 min)

- Prelude to each meeting, everyone must have their say - statements are not addressed (only to capture status),

- All persons answer 3 questions:

1) What happened since the last meeting?
2) What do I plan to do between now and the next meeting?
3) What is preventing me from achieving this goal?

4. Concept of the Competence Atelier using the example: *Biomechanics agile with Scrum*

According to the semester schedule (Tab. 1), an introduction of the students to the general topic of biomechanics and agile project management with Scrum took place in two hybrid lectures at first. The definitions of roles and artifacts were additionally repeated in further short teaching segments to give the students impulses for actions and tasks of individual group members. Owing to the participation of only 6 students, it was not necessary to form several groups. This was planned in advance from a group size of more than 11 students.

On the one hand, the biomechanics focus was ensured by already existing videos (24 videos of 20-80 min each, provided via Opal/Videocampus Sachsen [6,7]). This allowed the students to deal with the theoretical biomechanical basics at their own pace and according to their information needs for their project.

Stakeholder input was conveyed in the form of seven 1-2 page statements from various fictitious organizations and individuals (Figure 2).

The statements consisted, for example, of texts from a fictitious health insurance company that, as a client, would like to provide a product for patients to prevent aseptic loosening of hip endoprostheses. This input was complemented by a patient perspective on the rehabilitation process after implantation of an artificial hip joint. Furthermore, the perspectives of an implant manufacturer, a biomaterials researcher and a surgeon were provided as exemplary problem descriptions. The professor responsible for the module also sent a stakeholder statement to emphasize the importance of biomechanical principles for the project and the final demonstrator. From these statements, the students developed the product goal, which was phrased by the Product Owner as follows, "*Sensors wearable on the patient's body in everyday life to detect harmful hip positions to prevent implant loosening due to hip dislocation using direct feedback.*"

Based on this, the Product Backlog was derived and recorded as a task list for the iterative development of the demonstrators during the Sprints. As a written documentation platform for the Backlogs and the project/sprint progress, the students were provided with a Miro board via a free teaching license, which can be accessed independently of the operating system [8].

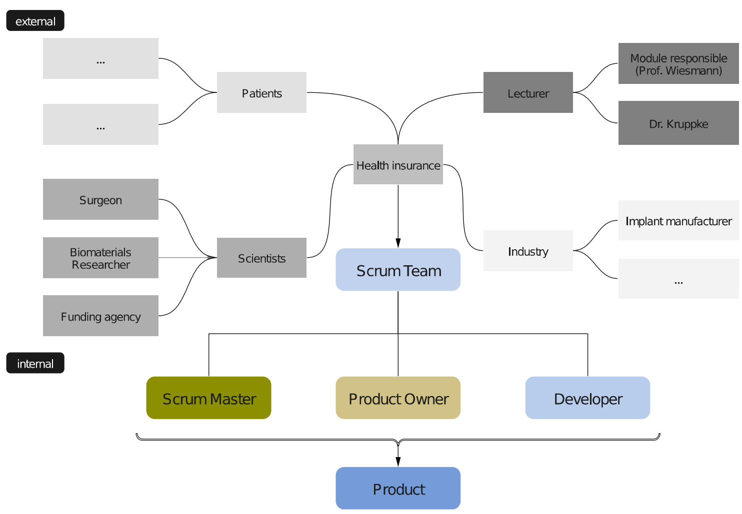

Fig. 2: Overview of exemplary stakeholders in "contact" with the Scrum team

Fig. 3 shows the schematic final state after one semester. The Miro-Board contains an overview of the students' appointments and notes in column 1. Column 2 shows the stakeholders and a template for the user stories, which was given at the beginning of the Competence Atelier. Furthermore, column 3 shows the product idea, the Product Backlog with prioritization and effort weighting, and the Definition of Done for individual increments. Column 4 contains the Sprint Backlog, a burn-down chart and a Kanban board for transparent assignment of the tasks to all team members, with the processing status marked as "To do", "In Progress" and "Done".

During the first Sprint, the students decided to record the biomechanics of the human motion using the motion sensors of cell phones (app phyphox ®[9,10]). Here, they focused on measuring the flexion angle between the thigh and the torso to identify harmful hip joint deflections in the case of artificial hip joints.

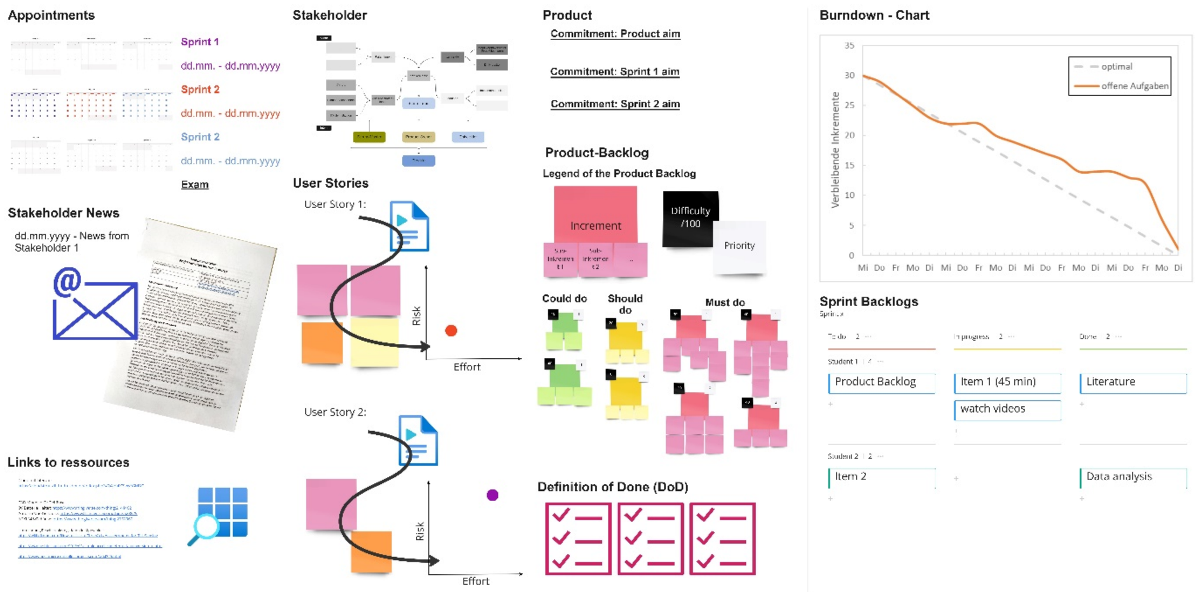

Fig. 3: The schematic Miro board of the Scrum team.

The increment (first demonstrator) was presented in the first Sprint Review, in which the angle measurement was demonstrated using two cell phones and the subsequent calculation of the damaging motion sequences. Subsequently, the requirement profile was sharpened for the 2nd Sprint.

The Scrum team showed its adaptability in the context of agile project processing when two new additive manufacturing devices (filament and resin-based 3D printer) including the materials for 3D printing were made available. In addition, students were able to use several Arduino microcontrollers with a variety of sensors and other electronic components.

Thus, the next Sprint Backlog included the implementation of an Arduino-based system with two sensors and production of the housings and a hip model to show the product's functionality using 3D printing (Fig. 4).

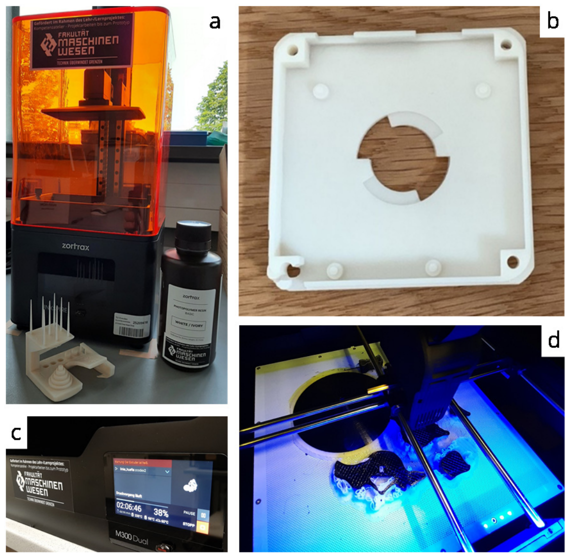

Fig. 4: UV LCD printer (a) and housing part for portable prototype (b), dual filament printer (c) and printing of a hip model as a presentation aid (d).

After each Sprint, the project progress was summarized in a protocol of max. 10 pages, which was created by the Scrum Master. The report summarizes the artifacts (Product Backlog and Sprint Backlog) and shows the Sprint progress as a burn-down chart. In addition, a retrospective view of the team's work is to be integrated into the protocol. Here, the measures (possibly necessary) developed during the sprint retrospective to improve the collaboration and performance of the developmer team are briefly discussed.

The final product *Hip.sense* was presented as a prototype (Fig. 5) and its functionality was proven during the final oral exam. It is a smart medical device which should help to reduce the number of aseptic loosenings of hip endoprostheses due to harmful movements after implantation.

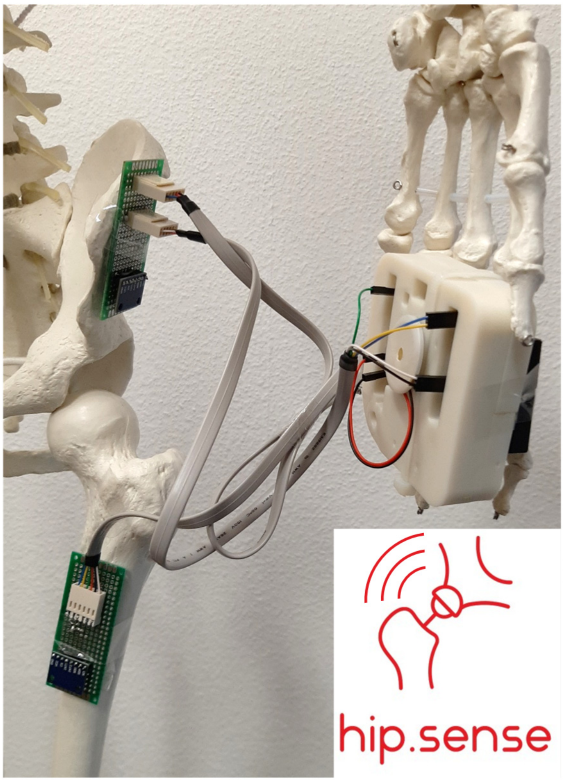

Fig. 5: Hip.sense prototype on a skeleton model with two accelerometers on thigh and hip and the Arduino controller with power supply and acoustic output.

Hip.sense detects the positions of the thigh in relation to the upper body and sounds an acoustic warning signal to avoid too much bending (when sitting down, tying shoes, etc.).

The prototype meets the following requirements:

- Affordable, readily available components,
- Expandable platform (other joints and movement pattern warnings),
- Portable power supply,
- Potential for miniaturization (e.g. fixing in special pockets on underwear),
- Customer-friendly demonstrator.

5. Evaluation and student feedback

The evaluation at the halfway point of the second Sprint revealed a predominantly positive assessment of the teaching concept, the introduction of agile project work, and the participating lecturers by the 6 students (Tab. 2).

Criticisms of the teaching format can be summarized as follows:

- Provide instructional videos as early as possible,
- Offer any available project resources (equipment, budget) early in the project,
- More stakeholder input and
- Perhaps communicate expectations more clearly at the beginning.

Among other things, these criticisms pick up on the additional stakeholder statements submitted after the 1st and 2nd sprints, which were explicitly intended as stimulating elements. Here, the advantage of agile project management became apparent, as the students had to react by adjusting their planning. As expected, these "disruptive elements" to kick off the agile restructuring led to criticism, but were integrated into the project in an exemplary manner.

The selected student comments suggest additional strengths and areas for improvement in the concept:

Student 1:

"*I find the creative concept of offering a project-based internship in addition to a compact, asynchronous course extremely good. The concept allows time flexibility and free focus by the students. All in all, this makes it one of the best and most innovative courses in the materials science program. Please continue to work on creative lecture concepts with integrated digital teaching for-*

mats to adapt university teaching to the realities of the current times! "

Student 2:

"Super lecture concept!"

Student 3:

"Pros:

- *Interesting concept with integration of compact asynchronous teaching content and practical group work (best teaching concept in my opinion)*
- *Time flexibility*
- *Access to 3D printers and microcontrollers*

Contra:

- *High effort in the practical part*
- *Introduction of the Scrum methodology and role reversal within the group should possibly still be reconsidered and adapted if necessary.*
- *Unclear how some user stories (material development, endoprostheses with looseness detection) will actually be implemented in practice"*

Student 4:

"More effort compared to other events. If the topic is good, it motivates to deal with it more deeply".

Tab. 2: Evaluation result (selection)

Statement	Complet ely true	Applies mostly	part/ part	applies little	Does not apply at all
Lecturer establish a link between theory and practice.	66.67 %	33.33 %	0 %	0 %	0 %
I find agile project management to be an enrichment in teaching.	50 %	33.33 %	16.67 %	0 %	0 %
I feel better prepared for the professional future with the methods of agile project management.	33.33 %	16.67 %	33.33 %	16.67 %	0 %
The practical elements are aligned with the course content.	16.67 %	83.33 %	0 %	0 %	0 %
The practical task leads to a deepening of the lecture contents and animates to deepen new topics.	33.33 %	50 %	16.67 %	0 %	0 %
I think the Competence Atelier is good.	33.33 %	66.67 %	0 %	0 %	0 %

6. "Lesson learned"

An essential component of the agile Competence Atelier is the step-by-step improvement of prototypes up to the finished product. After the individual work phases, the students should be able to present sprint prototypes and receive feedback on this from the course instructors (module leaders and teachers) and, if necessary, external stakeholders. This allows the students to subsequently revise their tasks and priorities and produce a new, improved prototype in the next Sprint.

With this concept it was possible to encourage students to work together and to get them newly excited about face-to-face teaching on campus. The following advantages and disadvantages were identified:

- Agile teaching format Competence Atelier allows adoption of proven digital elements (videos, Miro boards) and linking with face-to-face teaching,
- Project execution encourages students to work out specialist information independently (in the future, stronger incentives are planned through expert interviews),
- Scrum team works even if individual members fail - agile response by reassigning items,
- Meetings can be conducted hybrid (combined presence and online participation) and
- Incentives for development of technical content by all team members should be increased.

Teamwork and prototyping is only possible on campus and *hands-on* at the device. This is our contribution to demonstrate to both faculty and students the importance of face-to-face teaching.

7. Outlook

Thanks to the support of the teaching/learning project by the Faculty of Mechanical Sciences and Engineering at the TU Dresden, the methods of additive manufacturing and microcontroller programming could be made accessible to the students (almost) without restrictions. For demonstrator and prototype production, this will result in significantly expanded degrees of freedom in the future and the Competence Atelier is also excellently equipped for future runs. In future, the students will be able to try out very different and creative problem-solving approaches from the practice of applied biomechanics in each Sprint, but also from year to year.

The universal character was tested by the simultaneous introduction of this novel teaching format in the module *Competence Atelier: Quality Assurance and Statistics with Scrum* (also 8th semester). The flexible transferability is due to the project orientation of the Competence Ateliers and the focus on agile project and time management.

In the future, students will also be able to focus on new material developments in the field of biomaterials (degradable polymers) and the processing of sustainable materials (biodegradable composites, recycled polymers). Also, the microcontrollers on the Arduino platform can be flexibly used with a wide range of sensors. It is thus easy to determine characteristic values for biomechanical loads in everyday life directly as a basis for prototype production as part of a student project. In the specific case of biomechanics, the Competence Atelier as a teaching format can thus be adapted very flexibly to the circumstances of the department and the stakeholders and product ideas can be varied each year. Furthermore, the general design of the agile project execution in the Competence Atelier allows to adapt it to other modules and departments, to strengthen the importance of face-to-face teaching and independent project processing by students.

Acknowledgement

We would like to thank for the financial support of the teaching/learning project "Kompetenzatelier - Projektarbeiten bis zum Prototyp" from the funds of the Faculty of Mechanical Sciences and Engineering of the TU Dresden.

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10 years thermoE - A survey of the online-based support of the basic lecture thermodynamics

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Abstract

Thermodynamik ist ein zentrales Fach in der Ausbildung von Maschinenbauern sowohl im Grund- als auch im Fachstudium. Besonders im Grundstudium ergeben sich besondere Herausforderungen: Heterogenität der Vorkenntnisse der Studierenden, hohe Teilnehmerzahlen in der Vorlesung, rigide Modulvorschriften ohne Berücksichtigung von Praktika und begrenzte Anzahl von wissenschaftlichen Assistenten für die Betreuung. Vor diesem Hintergrund wurde seit 2012 eine online-basierte Begleitung der Vorlesung und der Übungen erarbeitet, die mit Stand heute neben der Unterstützung des Selbststudiums durch E-Assessment mit Feedback-Funktion auch virtuelle Praktikumsversuche, ein barrierefreies Vorlesungsskript sowie eine online-Klausur umfassen. Für Studierende, die dieses Angebot konsequent nutzen, ist ein signifikant besserer Abschluss der Klausur zu beobachten. Anhand ausgewählter Beispiele soll hier das mittlerweile auch in allen anderen Vorlesungen der Professur etablierte Vorgehen einer online-basierten und kompetenzorientierten Vorlesungsbegleitung gezeigt werden.

Thermodynamics as basic subject for mechanical engineers faces certain challenges due to the heterogeneity of students, a high number of lecture participants, a rigid syllabus without consideration of practical training as well as a limited number of teaching staff. Therefore, an online-based teaching tool has been developed since 2012, which comprises up to now a feedback-controlled e-assessment, virtual practical courses, a barrier-free lecture script and an online final test. A consequent use of the assessment during the semester by students resulted in improved marks in written exams and less student fail. Some selected examples are presented here, which are representative for the general approach of the chair to provide online-based and skill-oriented lectures using all digitally possible tools.

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1. Motivation

Technical thermodynamics is a central subject in the basic training of mechanical engineering and is currently located in the third semester of the mechanical engineering curriculum at the TU Dresden. At this early stage of the studies, most of the first-year students are still enrolled and possess very different previous knowledge. This heterogeneity of the mechanical engineering students is additionally increased by the participation of students from other study subjects, such as regenerative energy systems, process engineering and teaching (different subject combinations). This results in a large number of differently motivated students, who have to be supervised by a limited number of academic staff. In addition to lectures, this supervision includes weekly exercises and the examination at the end of the semester (which could not be offered online until 2021 due to a lack of legal foundations, although it would have been possible). Thus, there is an enormous supervision effort during the semester in the exercises and a very high time requirement for the control of the written exams, so that especially at the end of the semester almost all academic staff members are blocked for the control of the exams. Furthermore, in a module plan regulated by credit points (and thus the available semester hours) as well as by historically entrenched structures in the course of studies, no practical courses are provided for thermodynamics. If one compares this constellation for thermodynamics to other universities, including engineering universities, problems become manifest on several levels. Exercises, which mostly consist of calculational tasks, can no longer be collected and individually controlled on a weekly basis due to the high control effort in this constellation, which precludes goal-oriented supervision. Experiences from a topic-appropriate practical course cannot be incorporated into the understanding of lectures and exercises. The large number of weekly group exercises with an increased number of participants reinforces subjective differences, which are introduced into the exercises by individual instructors. This has been proven to hinder weaker students in their learning process, as they are often excluded from becoming active in the exercises. There was a need for action here, and since 2012 this has led to the creation of thermoE and other teaching projects at the chair.

2. Targets

The development of a computer-based learning system is, just like the analog so-called "classical" teaching, a dynamic process, which should permanently question itself, grow with the respective circumstances, thereby develop further and remain alive.
While at the beginning the creation of an online-based exam was in the foreground at the chair, a completely semester-accompanying e-assessment soon came to the fore. The background to this decision of neglecting online exams was the lack of administrative support, as online exam formats require legal frameworks that were outside the professors' own responsibility.
With the focus on a computer-based format for the exercises (and for the exam), the following technical questions arose. Is it possible to transform mathematically based questions into a digital format? How can self-study tasks and potential exam questions ensure a competency-based performance review in the exam? How can the heterogeneity of students be taken into account and thus enable an individual learning process? How can the schedule of the e-assessment tasks adopted to the semester structure without an immediate adjustment of the module description? In which way can the feedback from the e-assessmentbe reflected in the lecture and the tutorial? Can the missing practical course be replaced by the design of virtual experiments and thus enhance the learning effect?

Numerous projects have been dedicated to these and many other issues since 2012, which have contributed to the success of thermoE. However, it should also mentioned that this form of financial support, which essentially provided only student help staff (SHK) funds, is not a truly sustainable and lasting solution. Some presentations [1, 2, 3, 4] and publications have emerged from these projects [5, 6, 7, 8]. During the projects, interdisciplinary collaborations with different partners have contributed to the success. More information can be found on the website of the chair.

It is important to emphasize that the many years of work on thermoE did not focus on creating a substitute for face-to-face time lectures or seminars. The so-called freedom of learning at any time propagated by many sides is unfortunately, in my opinion, in a very simple way related to digital formats which are expected to solve all learning problems. It should be emphasized that the technical CONTENTS transported by digital formats is completely identical to classical analogue formats. In this respect, the new digital world does not represent any added value in terms of content, it transports content differently but not better! In addition, it should also mentioned that it was at all times possible to study at any time, regardless of location and time, simply by picking up a textbook. Since the majority of these are now also available digitally, there have been even no financial hurdles to self-determined learning for many years. Unfortunately, the one-sided propagation of digital formats by means of euphonious project titles, which must contain signal words such as "innovative," is due to the continued funding shortage for teaching at universities. Fine-sounding project titles secure short-term financial resources (mostly temporary staff at undergraduate level), but do not solve the fundamental problem. This problem also includes the fact that more and more institutional committees or staff units for quality control are being created, which in the end are not concerned at all with teaching and work with the students, are served from the general pool of positions and, despite individual positive approaches, do not contribute to an improvement in the teaching situation with their work.

3. thermoE - Competence-oriented E-assessment in thermodynamics

The semester-accompanying self-learning tool is now permanently integrated into the thematic sequence of lectures and exercises. Self-learning tasks, which cover the entire ONYX-Opal task spectrum, supplement lectures and exercises with both theoretical questions and calculational tasks. The quality of the computational examples has always been adapted to the current features of OPAL (use of maxima and consequential error consideration). The immediate response with “correct/wrong” allows an immediate self-control to the students and shall support their further self-studies by including references to literature or the script in the response to an incorrect answer.

In addition, all students may use the “contact button” to their instructors and thus questions can be dealt related to their individual problems in the next exercise. After several years, it appeared that a regular active assessment participation of the students during the whole semester, the number of failed exams decreased significantly. Details can be found here [1-8].

The success of the new teaching structure is illustrated in Figure 1. Shown are here the achieved quota for passing the exam for Technical Thermodynamics in the last winter semester 2021/2022. In contrast to the previous year 2020/2021 , this exam was again written in paper form, as the professorship would not have been able to provide the newly required remote camera monitoring of the online formats of several hundred students. For a comprehensible comparable evaluation of the effect of the e-assessments on the performance of students, a relative representation was chosen, as the number of students without and with bonus points (BP) differed. Therefore, the two data series (with/without BP) were normalized both to the total number of students in each group. It should be emphasized that the collection of bonus points is always on a voluntary basis. During the hybrid Corona winter semester 2021/2022, as in all lectures, access and thus the approach to students was massively limited, so that fewer students actually took up the offer. Since there was no feedback for non-participation, further reasons for the lower usage are not known. In the current WS 2022/2023, participation has visibly increased and can be explained by attendance.

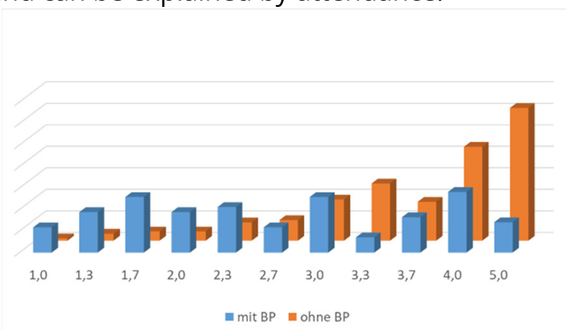

Fig. 1: Normalized representation of the grade distribution for the Technical Thermodynamics exam in 2021/2022. Blue: students with bonus points (BP), orange : students without bonus points.

4. thermoE - expansion through virtual practical experiments

Another focus by the chair was set recently to the creation of virtual practical experiments. This new part of the e-assessment is intended to compensate for the lack of real practical courses and emphasize the practical relevance of thermodynamic knowledge much more clearly than it would be possible via lecture and exercise examples. In addition to provide a basic knowledge for all students, such as the use of calorimetry (enthalpy of combustion) or the determination of heat capacities, the focus is also put on selected improved experiments such as adsorption, Maxwell distribution, isentropic coefficient, etc., which are intended to provide additional input for talented students. Those are also given the opportunity to carry out the real practical experiments in our labs [9]. This offer is mainly used by students of higher semesters. Undergraduate students are often not willing to take advantage of offers outside their prescribed curriculum. So far, only very interested and excellent students have taken advantage of the offer, and they often stay in the working group until they graduate and do their doctorate.

The main challenges for the implementation of virtual experiments were the limited availability of features in ONYX-Opal. Therefore, Python elements were applied preferably and are primarily used to create the new virtual practical experiments, thus ONYX-Opal is only used as a pre-for checking the theoretical background before starting the experiments. Details can be found here [9, 10].

Results for various applications were presented [11]. Currently, the real practical part of the course is supported by the acquisition of a new apparatus within the framework of a teaching project of the Faculty of Mechanical Engineering under the title: "Experience thermodynamics – take active part in innovative energy projects", for which a digital representation is also to be created.

5. thermoE - competence-oriented assessment and online exam

With the development of the various digital assessments, which primarily support the self-study, the focus was given to a competency-oriented content. Thus, different levels of learning (recognizing, evaluating, applying, ...) are addressed. With regard to thermodynamics, the correct recognition of systems, boundary conditions of a process as well as the choice of the appropriate balances for first and second laws are in the foreground. The pure mathematical skills for solving simple algebraic equations are assumed to be known and are not included in the technical evaluation of thermodynamics.

This general approach applies to both the assessment tasks accompanying the semester and the final online exam.

6. thermoE - Conclusion

The addition of electronic assessments to the portfolio of lectures and exercises of the Chair of Thermodynamics has led to an improved teaching-learning environment compared to the previous purely classical offerings. Classroom lecture content is now supplemented by electronic assessments and, thanks to a feedback function, provides more individual support, even for larger groups of students. The students' learning success is higher and the exam results - both classic and online format - are improved significantly. In addition, a more effective tool for communicating with students has been developed, and internal training of staff has been initiated at the same time. Additional offers, such as the combination of virtual and real practical courses, can also be used to interest future employees at an early stage or to make an offer to more talented students. During the Corona period, the existing electronic offerings enabled an immediate transition to the digital world.

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Digital, collaborative small group work in Active Plenary - a contradiction?

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Abstract

Der eingereichte Beitrag beschreibt eine neuartige Variante der Methode "Aktives Plenum" im Hinblick auf ihren Einsatz in digitalen Lern-Lehr-Aktivitäten im Rahmen eines computergestützten Praktikums, wobei dieser Ansatz mit einer Kleingruppenarbeit kombiniert wird. Neben der Beschreibung des inhaltlichen Ansatzes und des organisatorischen Ablaufs werden die Chancen und Grenzen des Unterrichtsformats aus der Perspektive von Lehrenden und Lernenden beschrieben.

The submitted paper describes a novel variant of the "active plenary" method with regard to its use in digital learning-teaching activities in the context of a computer-based internship, combining this approach with small group work. In addition to the description of the content-related approach and the organizational process, the opportunities and limitations of the teaching format are described from the perspective of teachers and learners.

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1. Didactic challenge

The practical course considered here is part of the course "**Simulationtechnik"** is set within the module "Berechnung von Leichtbaustrukturen" (MW-MB-LB-04) and is offered by the Institute of Lightweight Structures and Polymer Technology (ILK) in the summer semester. It is a compulsory module for students of lightweight structures in the diploma program and in the postgraduate program in mechanical engineering of the Technische Universität Dresden (TUD), whereby the postgraduate program in particular is mainly used by international students. In addition, students of industrial engineering can take simulation technology as a compulsory elective subject in their studies. This results in a very heterogeneous composition of the student group in terms of previous knowledge, semester and language competence. More detailed information about the general conditions of the course are described in [1].

While the teaching-learning activities were abruptly converted from analog to digital formats at the beginning of the corona pandemic, the gradual return to more face-to-face teaching offers the opportunity to use and further develop established concepts from both worlds and to link them with each other. For the practical course under consideration here, which can be carried out exclusively with the help of a computer, it is therefore appropriate to largely retain the digital formats, so that the practical course is embedded in the integrated teaching-learning concept [2] established at the ILK with the method of **flipped classroom.** The evaluation of the teaching evaluation of the previous semesters shows that in particular the active learning phase and the associated exchange between the students but also between the teacher and the students is conducive to learning success. In particular, the work in a further developed form of the **Active Plenum** [3] is positively emphasized, so that this format is increasingly used in the planning of the course.

2. Further development of the Active Plenum

The Active Plenary method is characterized by collaborative work on a task, with this format featuring a high degree of interaction between learners while simultaneously consolidating, deepening and applying familiar learning content. It is therefore extremely suitable for activating students within synchronous courses. This concept was originally developed for use in larger seminar or lecture rooms, with students forming *a group to* solve the task.

In the context of a digital synchronous course as a video conference, communication between students is inhibited. On the one hand, this is due to the fact that almost all students are not willing or able to activate their cameras despite corresponding instructions from the teacher, so that non-verbal communication is hardly possible. On the other hand, short and silent agreements between a few students are not possible because there is only one sound channel and the exchange via chat function is too slow. Therefore, in the context of digital teaching, the students are divided into several small groups, which results in a change in the flow of the method (see Fig. 1)

3. Procedure of the small group work

Even before the first learning unit, the mostly unknown teaching-learning situation is introduced to the students by means of a short video [4]. In **the first learning unit, in** which the active plenum is used, **this format is rehearsed with all students** as a real active plenum. The teacher first introduces the task and answers questions about it. Subsequently, one person from the plenum assumes the role of the moderator and the teacher assumes the role of the executor in the creation of the computer model. All other students contribute to the solution by giving instructions to the executor. The moderator coordinates the incoming instructions, the can be received both as word

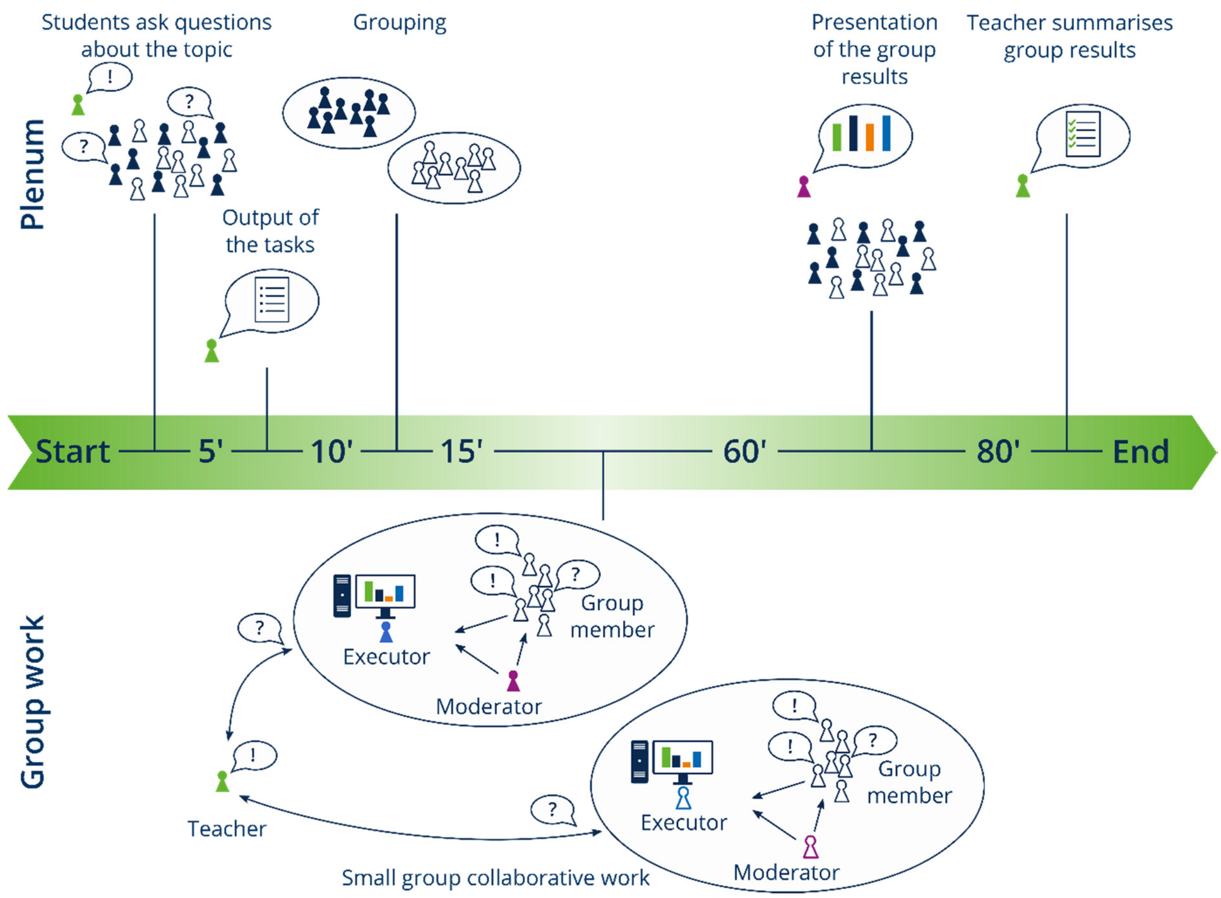

Fig. 1: Alternation between plenary and small group work within a

messages and as chat messages. The teacher strictly adheres to the instructions and also carries out non-target or incorrect solution steps, whereby queries are possible in case of ambiguities. Typically, wrong instructions are corrected directly by other students or revised by the group afterwards. The teacher should only intervene if the group work as a whole is in danger of failing. After the task has been successfully completed, the moderator or another person, possibly determined in advance, summarizes the most important steps in the solution and presents the overall solution.

In the further course of the learning unit, the teacher introduces a new but similar task and answers corresponding feedback or comprehension questions. Subsequently, the students are asked a question to divide them into groups, such as their favorite color, the answer to which is distributed as randomly as possible among the student body. The questions are given out using a survey tool integrated into the Zoom video conferencing system and the answers are collected. The instructor then summarizes the responses to create groups of approximately equal size with about four to eight members. This procedure is intended to ensure that the **groups** are **as well mixed as possible.**

Before the group work starts, the teacher makes sure that the work instruction is clearly formulated and understood by the students. In addition to the actual problem, the **work assignment** also includes a time limit and the indication to secure the results in the form of a downstream presentation in the plenary. The students then enter sub-rooms of the video conference, which are referred to as breakout sessions in Zoom.

During the group work, the teacher enters the respective sub-rooms from time to time and observes the group work. Although the teacher is available to answer questions, he or she should be very cautious in giving advice. Counter-questions that facilitate a change of perspective on the problem as well as hints on time management are more suitable. The distribution of roles within the group as well as the **organization of work is left to the group itself**. Typically, the role of the moderator is omitted in small group work, although the roles of executor and presenter are not always performed by the same person.

At the end of the allotted time, all students come together again in the plenary session. Selected representatives of the groups present the results of their work in a concise form and at the same time go into detail about the development of the solution steps. Following the short presentation or live demonstration of the model, the entire group is available for questions from the teacher or the other groups. It is up to the teacher to compare, summarize and classify the work results and the presentations of the groups. Furthermore, it is possible to collect the models of the groups and make them available to all students, for example by uploading them to the learning platform used.

4. Positive aspects of the teaching format

The fixed external structure of the active plenum on the one hand and the freedom of content on the other encourages the students to actively participate in the course. The partial "absence" of the teacher in the group work reduces inhibitions among the students. The small group size makes it difficult for individuals to "dive in" and the pressure to actively participate increases as the group size decreases. At the same time, any gaps in knowledge are communicated more openly than in the plenum or to the teacher, which leads to a faster filling of these gaps (**learning through teaching**).

In contrast to many other exercise and internship formats, this learning format not only allows students to evaluate their own learning progress by completing set tasks. Rather, the **comparison with the learning status of the group contributes to** an improved visibility of their own learning status.

The fact that the Active Plenum is gladly accepted by the students can be seen, among other things, in the number of participants. Similar to analog teaching formats, the attendance rate for this course is also decreasing. Of 90 students enrolled in the OPAL course, about 40 were present in the video conference at the introductory session for the internship. In the further course of the semester, the rate of participants in the consultations, which are also offered, drops to about ten students, whereas up to 20 people regularly participate in the active plenum format. The reasons for the rather low participation rate appear to be the unattractive timing of the course on Friday mornings, the parallel availability of online learning materials, and the increased stress level among students due to the activation.

Since the response of teaching evaluations in previous semesters was low, this course is evaluated in close cooperation with the Center for Interdisciplinary Learning and Teaching of the TUD (ZiLL) as part of the “Action Weeks Teaching Analysis Polls (TAP): Qualitative Teaching Evaluation for TUD Teachers". This evaluation is conducted by a ZiLL staff member without the presence of the instructor and takes place in the middle of the semester, so that students have a direct influence on the course going forward. Furthermore, the format of group discussion and evaluation seems far more appealing than filling out a questionnaire. Nevertheless, only nine students participated in the group discussion and only seven in the final evaluation of the most important points, so that the low response rate limits the significance of the evaluation results on the one hand. On the other hand, the possibilities of getting the majority of students to give constructive feedback appear to be exhausted, and further work can only be done with the statements made.

From the students' point of view, the most important points for the learning success were the joint elaboration in the Active Plenum (6 out of 7), the engaged teacher (6 out of 7) and the practical application tasks (4 out of 7). Thus, this teaching-learning activity appears to be **highly suitable for** the transfer of knowledge and skills in the field of simulation technology

5. Limits of the teaching format

As with many digital teaching-learning formats, there is a risk that participants will use the learning unit to record the content. On the one hand, the mere **recording of the content** in no way corresponds to the concern for increased activation of the learners, and on the other hand, this disturbs the protected space as well as the relationship of trust between students and teacher. This could also be a reason why almost no students, even in the small groups, activate their camera.

Although this format of working in small groups minimizes the risk of **individuals not participating in the group at all,** but assuming a supposed learning success due to the positive group outcome, this fact cannot be completely dismissed.

Another disadvantage of this format lies in the **technical equipment of** the students. Thus, for active participation, especially in the role of performer, moderator and presenter, it can be advantageous to operate two screens in parallel. From experience, most students use one screen and thus the readability is reduced during the screen transmission.

The proportion of international students in this subject is around one third, although the proportion in synchronous courses is significantly below average. On the one hand, **language barriers and the interactive learning culture** could be a deterrent; on the other hand, these students could also feel adequately provided with teaching material due to the online materials that are also provided.

As a key point of the TAP, it was noted that a lack of rounding or sample solution in the active plenaries inhibits learning success (5 out of 7), so in the future sample solutions will also be provided for the group work.

6. Conclusion

As part of the practical course on simulation technology, the active plenary method, which has been further developed for use in digital teaching, is examined as an interactive form of learning. After a short introduction by the teacher, the students work digitally and collaboratively in small groups and then present their work results to each other.

On the basis of an evaluation of ZiLL, an overall positive conclusion can be drawn regarding the use of this teaching format. In particular, the high level of activity during the work in small groups leads to a high level of motivation among the participants and to considerable work results. At the same time, the participants seem to have a strong desire to receive a sample solution authorized by the teacher.

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Digital Media versus Blackboard and Chalk — Online and Hybrid Teaching in Theoretical Physics

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Abstract

Die Wissensvermittlung in der Theoretischen Physik ist nicht an Demonstrationsexperimente und Versuchsaufbauten vor Ort gebunden. Dies bietet eine erhöhte Flexibilität beim Wechsel zwischen Präsenz- und Online-Lehre. Dennoch sind auch hier einige zentrale Punkte zu beachten. Zum einen sind oft eine schrittweise Entwicklung der Inhalte inklusive Erläuterungen der Dozierenden und Rückfragemöglichkeiten essentiell. Zum anderen müssen viele Rechentechniken und symbolische Schreibweisen erst erlernt und geübt werden. Eigenes Schreiben ist hierfür in der Regel unerlässlich. Beim traditionellen Tafelanschrieb und Mitschreiben in Präsenz werden diese Aspekte automatisch berücksichtigt. Beim Wechsel in die Online-Lehre bildeten wir dieses Format ab, indem wir auf synchrone Veranstaltungen setzten, in denen „live" vor- und mitgeschrieben wurde. Unser Vorgehen evaluierten wir in einer Online-Umfrage. Teilaspekte unserer Herangehensweise werden bei der Rückkehr in die Präsenzlehre weiterhin von den Studierenden bevorzugt, insbesondere eine digitale Ausführung des Live-Anschriebs. Dies unterstützt hybride Lehrformen, die gleichzeitig in Präsenz und online stattfinden, was sicherlich einen wesentlichen Aspekt der zukünftigen Entwicklung universitärer Lehre darstellt.

Knowledge transfer in theoretical physics is not tied to on-site demonstration experiments and experimental setups. This offers increased flexibility when switching between face-to-face and online teaching. Nevertheless, there are some key points to consider here as well. On the one hand, a step-by-step development of the content, including explanations by the lecturer and opportunities to ask questions, is often essential. On the other hand, many calculation techniques and symbolic notations must first be learned and practiced. Writing on one's own is usually indispensable for this purpose. With traditional blackboard writing and taking notes in presence, these aspects are automatically taken into account. When we switched to online teaching, we replicated this format by relying on synchronous events in which "live" writing and taking notes were implemented. We evaluated our approach in an online survey. Several aspects of our format were still preferred by the students when returning to face-to-face teaching, especially a digital version of live writing. This supports hybrid forms of teaching that take place simultaneously in presence on site and online, which is certainly an essential aspect of the future development of university teaching.

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1. Introduction

When studying physics, theoretical physics represents an essential pillar of education. Unlike experimental physics, which derives laws of nature from experimental observations and measurements, a mathematical description of reality is derived from a few mathematically formulated axioms using mathematical methods. Thereby, a quantitative predictive power arises. The quality of a theory is assessed by comparing the results to experimental measurement results.

This already reveals essential requirements and skills that must be taught and learned in the context of theoretical physics. For example, these are logical and step-by-step successive derivations of mathematical relationships and conclusions based on fundamental, mathematically formulated assumptions. At the same time, appropriate calculation techniques and the corresponding notation must be learned and practiced. A high degree of precision is required when performing corresponding calculations.

Our presentation refers to our teaching activities at Otto von Guericke University Magdeburg in the four-semester period from the winter semester 2020/2021 to the summer semester 2022. Our courses in this period were alternately taught in presence under appropriate hygiene regulations, via fully digital online teaching, as well as in a hybrid format in which teaching took place simultaneously in presence on site and online. These developments allow us to report here on a wide range of experience with different formats. At the end of the winter semester 2021/2022, we conducted an evaluation to get quantitative feedback from the students on the formats we used and their general impressions.

In the following, we refer to eight courses in the field of theoretical physics carried out by our department in the mentioned four semesters. Four of these courses are assigned to the bachelor program in physics [1] and four to the master program in physics [2] at Otto von Guericke University Magdeburg. In detail, these were the courses Theoretical Mechanics (in Magdeburg submodule 1 of the module Mechanics and Electrodynamics, Physics Bachelor [1], extending over two semesters), i.e. the study of the motion (and statics) of material bodies in space under the influence of known forces – twice; Theoretical Electrodynamics (in Magdeburg submodule 2 of the module Mechanics and Electrodynamics, Physics Bachelor [1], extending over two semesters), i.e. the teaching of the motion of electric charges in space as well as the interaction with and temporal change of electric and magnetic fields, including aspects of special relativity – twice; Hydrodynamics and Elasticity (in Magdeburg submodule of the double module Compulsory Elective Courses with corresponding specializations, Physics Master [2]), i.e. the study of the flow of fluids and the deformation of elastic solids – twice; Theory of Polymers (in Magdeburg submodule of the double module Compulsory Elective Courses with corresponding specializations, Physics Master [2]), in particular the statistical description of properties of single linear polymer molecules and polymer melts – once; Statistical Mechanics in Non-Equilibrium (in Magdeburg submodule of the double module Compulsory Elective Courses with corresponding specializations, Physics Master [2]), especially on the classical theory of linear response, on statistical methods in the framework of Langevin and Fokker-Planck equations, and on classical density functional theory – once. The temporal frame of these courses amounts to 6 hours per semester week (Bachelor courses) and 3 hours per semester week (Master courses), respectively. Two thirds of these hours are spent on lectures, one third on discussions of exercises. The admission to the module examinations is acquired through performance certificates (e.g. successful completion of exercises, written or oral tests). The module examinations for all these courses are oral.

2. Teaching before the pandemic

Before the developments associated with the Covid 19 pandemic, teaching in theoretical physics was largely carried out in the classical classroom format. As already mentioned at the beginning, in most cases traditional blackboard instruction was used. This form of teaching serves many of the requirements already mentioned in this context.

First, the teaching content is developed step by step through “live writing”. Causal chains and calculation steps that build on one another can be conveyed particularly well in this way. The writing activity of the lecturer automatically adjusts pace. In addition, with a sufficiently large board, the previous calculation steps remain present for longer times and are available in the further course of the lecture, so that reference can be made to them if, for example, intermediate steps in previous calculations are used at a later point. Oral explanations of the calculations by the lecturers are often perceived as essential, as is the possibility for the students to immediately ask questions.

An essential part of education in theoretical physics is to learn how to perform complex calculations independently. For this purpose, it is necessary not only to be able to understand calculations logically, but also to learn the calculation techniques themselves, including the symbolic notation used. These techniques usually have to be practiced by writing them by oneself. The transcript in face-to-face courses offers a first step into this direction. In fact, a clear majority of students in our courses usually grasps the opportunity to take notes. Already before the development of the Covid 19 pandemic, we made our lecture notes available online to students after the respective event date. This allows the transcript to be cross-checked for any ambiguities or possible typos. In addition, students who were unable to attend events in person can access the content.

Exercise assignments timed to the lecture content were available online and were also distributed as hard copies in the past. Depending on the course, solutions were submitted on paper and graded. In the exercise courses, the solutions to the exercises were presented and discussed on the blackboard by students or lecturers.

Depending on the course, different contributions had to be made to performance records in order to gain admission to the module examination. In particular, these were a certain proportion of successfully completed solutions of exercises, presentations of solutions in the exercise courses (depending on the course), and written performance tests in presence. In particular, calculation skills had to be demonstrated. The module examinations of all mentioned courses are to be carried out in oral form in Magdeburg. Here, mainly content-related knowledge and understanding are tested as well as knowledge of central formulas and very short calculations. These individual examinations in presence usually took place together with an assessor at a table, writing on a sheet of paper.

3. Switch to online teaching

Our course in the Physics Bachelor started in the winter semester 2020/2021 under appropriate hygienic measures in presence. The classic blackboard served as the medium for transferring knowledge. However, due to the development of the pandemic, a change to digital media and online teaching became necessary after a few weeks. Accordingly, our courses were held entirely online for the remainder of the winter semester 2020/2021 and the entire summer semester 2021.

For the reasons outlined above, we set ourselves the goal of replicating as far as possible the experience of writing on the blackboard in presence with the possibility of taking notes when switching to digital formats. We also intended to provide the possibility of asking questions in real time. Therefore, we chose the format of synchronous online live events. At Otto von Guericke University Magdeburg, Zoom video conferencing software was and is available for this purpose [3]. Other frequently used formats are, for example, the discussion of previously prepared and completed slides, lecture notes, and solutions to exercises in video conferences; the provision of pre-produced videos for independent asynchronous study, supplemented, if necessary, by additional synchronous question sessions; or the provision of scripts and solutions prepared for independent, self-reliant study with subsequent online discussions. All of these formats offer their own advantages. However, due to the subject-specific characteristics of teaching in theoretical physics as described above, we found the implementation as synchronous online live events with “live writing” to be the most suitable.

To realize such a digital format, we purchased active displays with pen input, in our case Wacom Cintiq 16 [4]. In the online lectures, we used simple graphics programs to create long blank pages that could be viewed by all participants in the video conference by means of Zoom ("screen sharing"). The script was written live on these pages. As on the blackboard in the lecture hall, the previous calculation steps were available in longer derivations and could be referred to by scrolling back. Color markings as a very simple but effective aid were also possible. Care was taken to give students sufficient time to note down the content before the written lines disappear by scrolling on. As an advantage compared to the use of the blackboard in the lecture hall, the documents can be saved at the end and are still available in later lectures, for example in case of queries, ambiguities or reference to earlier derivations. Intermediate questions by students were always possible and encouraged. In practice, there was often a lively dialogue that could hardly be distinguished from corresponding experiences in the lecture hall in presence, even though almost nobody of the students used a camera. The lecture notes were made available to the students online after the events. For this purpose, the central e-learning platform (Moodle) at Otto von Guericke University Magdeburg was used [5,6]. As a rule and outside of examination times, most students attended the online lectures.

The events for discussing the exercise tasks were conducted in the same format and differed only in that the digital whiteboard of the Zoom conference software was used directly for writing. Here, no continuous scrolling but page turning is implemented. Due to the clearly defined tasks, this is sufficient. Since only a few participants had the necessary technical equipment, the students did not present their calculations, in contrast to classroom teaching. This task was completely taken over by the exercise instructors. The possibility to ask questions directly about individual calculation steps, which is particularly important in the exercises, was still available and was used intensively. In general, the discussion of the exercises took place in the online plenum and not in Zoom breakout rooms.

In the courses for the Physics Bachelor, the performance certificates consisted of successfully completed exercises and written interim tests. The exercises were made available digitally via the e-learning platform. After a processing period of approximately one week, the solutions were uploaded by the students in digitized form, for example as a scan or photo. The e-learning platform also allowed digital commenting and evaluation of the uploaded solutions, whereby the comments and evaluations could be viewed by the students. The written midterm tests were also administered via the e-learning platform. At a specific time, the assignments were released, and the students then had a set amount of time (60 or 80 minutes, depending on the test) to complete the assignments at home. In addition, 20 minutes were allotted for digitizing and uploading the solutions. In this process, students were required to work independently and no aids were allowed. We emphasize here the high degree of honesty and sincerity among the students during this procedure. Except for a few unclear individual cases, we could not detect any obvious deviations from the specifications or attempts of cheating. Nevertheless, we will conduct the interim tests in presence again in the future, if possible. In the courses for the Master's degree in physics, the performance certificates consisted of oral tests, which were conducted similarly to the module examinations described below.

The module examinations for all listed courses take place orally in Magdeburg [7]. In digital formats, these oral examinations were also realized using the Zoom video conferencing software. For questions that could be answered orally, this posed no problem. For questions that required short written calculations or formulas as answers, they could be written on a piece of paper with a dark pen similar to corresponding face-to-face oral exams. They were then held up to the camera. We did not experience any problem during this procedure. Some students were already equipped with devices for digital input via pen and were of course allowed to use them.

4. Transition back via classroom teaching to subsequent hybrid teaching

The winter semester 2021/2022 started at Otto von Guericke University Magdeburg again with classroom teaching. This was maintained for a longer period of time. It was not until the pre-Christmas period and especially with the turn of the year that our courses were switched to hybrid formats. This meant that we continued to offer face-to-face courses. However, students could also participate digitally and decide freely.

The transition from face-to-face to hybrid teaching in the lecture was relatively unproblematic for us. Building on the equipment for online teaching, we carried out live writing in the lecture room using digital means. The input was achieved via input pens and active displays connected to a laptop for presentation via LCD projector. In other words, the previously tested online format of synchronous digital live writing was now implemented in the lecture room.

At the same time, the writing surface on the laptop was shared via Zoom video conferencing software as a synchronous online event. According to the students, the laptop microphone and camera provided sufficiently good sound and image quality. Students were free to decide whether they followed the lecture in presence in the event room or digitally as a synchronous online event, with identical content delivered via live transmission. Both variants were accepted by the students, sometimes in alternation. It is particularly positive to note that even in this hybrid variant, students continued to ask questions leading to discussions even across the boundaries of online and face-to-face participation.

For the submission of the exercise solutions and their correction, we continued to use the digital procedure via the e-learning platform [5]. The discussion of the exercises continued to take place in presence, whereby a sufficiently large lecture hall could be found. This made it possible for the participating students to present their solutions and to discuss them directly and ask questions. The solutions were also made available via the e-learning platform. We conducted the written interim tests simultaneously in presence and digitally via the e-learning platform according to the procedure described above, whereby the students were free to choose between the two variants. Both variants were used in roughly equal proportions. Our comments above on the honesty and sincerity of the students continued to apply. Correction and assessment were again carried out via the e-learning platform, for which we digitized the analog solutions submitted in presence.

5. Return to classroom teaching

In the summer semester of 2022, most of the courses at Otto von Guericke University Magdeburg were again held in presence under appropriate hygiene measures. This includes the courses we offered. We gained the central insight for us when we asked the students which format of presenting the contents they would prefer in the face-to-face courses. They could choose between digital input via a display using an input pen, laptop and LCD projection on the one hand, and, on the other hand, the classic blackboard format.

Surprisingly for us, the majority of the students surveyed were in favor of digital live writing via LCD projection in the classroom, as opposed to the classic, analog blackboard variant. The reasons given were, for example, better readability and better visibility of the higher projection surface from the back rows. However, the main point that seemed to be important to the students was that the lecturers in the projection variant continuously face the students throughout the writing process and do not turn their backs to them in the meantime when writing on the blackboard (see also the evaluation results below).

On the side of the lecturer, it should be noted that the digital version is significantly less physically demanding. However, the set-up and dismantling times before and after the lecture are noticeably longer (approximately 10 – 15 minutes each) when compared to writing on the blackboard. Overall, these findings have led us to switch to the digital variant via LCD projection in the lectures since then.

In this way, routines developed during online teaching are now likely to find their way into on-site classroom teaching in the longer term. A significant advantage of this approach is the continued uncomplicated possibility and flexibility to conduct the events in a hybrid fashion. Consequently, students are provided with the opportunity to participate even if they, for various reasons, are prevented from attending events in person. This offer is frequently accepted, whereby we perceive a preference of the majority of students for participation in presence.

6. Evaluation by the students

In order to obtain a more detailed assessment of the situation of the students and the teaching formats we provide, we conducted an online survey via e-learning platform at the end of the lecture period of the winter semester 2021/2022. The anonymized response included 17 participants. At least, some tendencies can be inferred from this response. Not every question had to be answered, which explains the fluctuating numbers in the results presented below. The evaluation compared different teaching formats, but also asked questions about, for example, learning success in online teaching, dealing with reduced social contacts, and the learning environment.

First, we compared different teaching formats, distinguishing between five types:

- Format 1: Face-to-face event with classic live writing on the blackboard. Remarks on this traditional format were included above.
- Format 2: Synchronous online event via digital live writing. This format corresponds to the digital variant that we use. Comments on this format were likewise included above. We refer to it as a synchronous event because students and lecturers meet simultaneously in a video conference and thus communicate in real time.
- Format 3: Synchronous online event using previously prepared media, for example, discussing PowerPoint slides or scrolling through a lecture script with simultaneous oral explanation by the lecturer. Even if individual digital notes are inserted, live transcription is not the focus here.
- Format 4: Asynchronous online event. In this case, the instructors prepare digital materials and make them available to the students online. The students are free to decide when exactly they want to access and work through the materials. Examples of this format are recorded videos of lectures with blackboard notes, recorded discussions of PowerPoint slides or lecture notes, i.e. formats that to a certain extent emulate synchronous events but can be accessed asynchronously and also repeatedly.
- Format 5: Self-reliant study of lecture material. With this format we refer to working independently (asynchronously) through traditional learning materials such as lecture notes, solutions of exercises or book chapters.

The central criterion for us in evaluating the listed formats was the learning success of the students. Therefore, we asked the students for their assessment of the different formats (formats 1, 3, 4 and 5 in the list above) relative to the synchronous online format with live writing (format 2) that we chose. On the one hand, we asked students about their subjectively perceived learning success, i.e. independent of actual feedback through credits achieved in performance tests or results in module exams, see Fig. 1. On the other hand, we asked them for an assessment of their learning success based on actually provided feedback, see Fig. 1 as well.

It is clearly evident here that the responding students rated their subjective learning success worse on average in our synchronous online format with live writing (format 2 in the list above) than in the traditional face-to-face event (format 1 in the list above), see Fig. 1(a). This statement is almost neutralized when students include actual feedback such as scores achieved and exam results into their response. In fact, on the instructor side, we did not find a drop in learning success among students on average during performance assessments and exams compared to our longer-term teaching and exam experience prior to the pandemic.

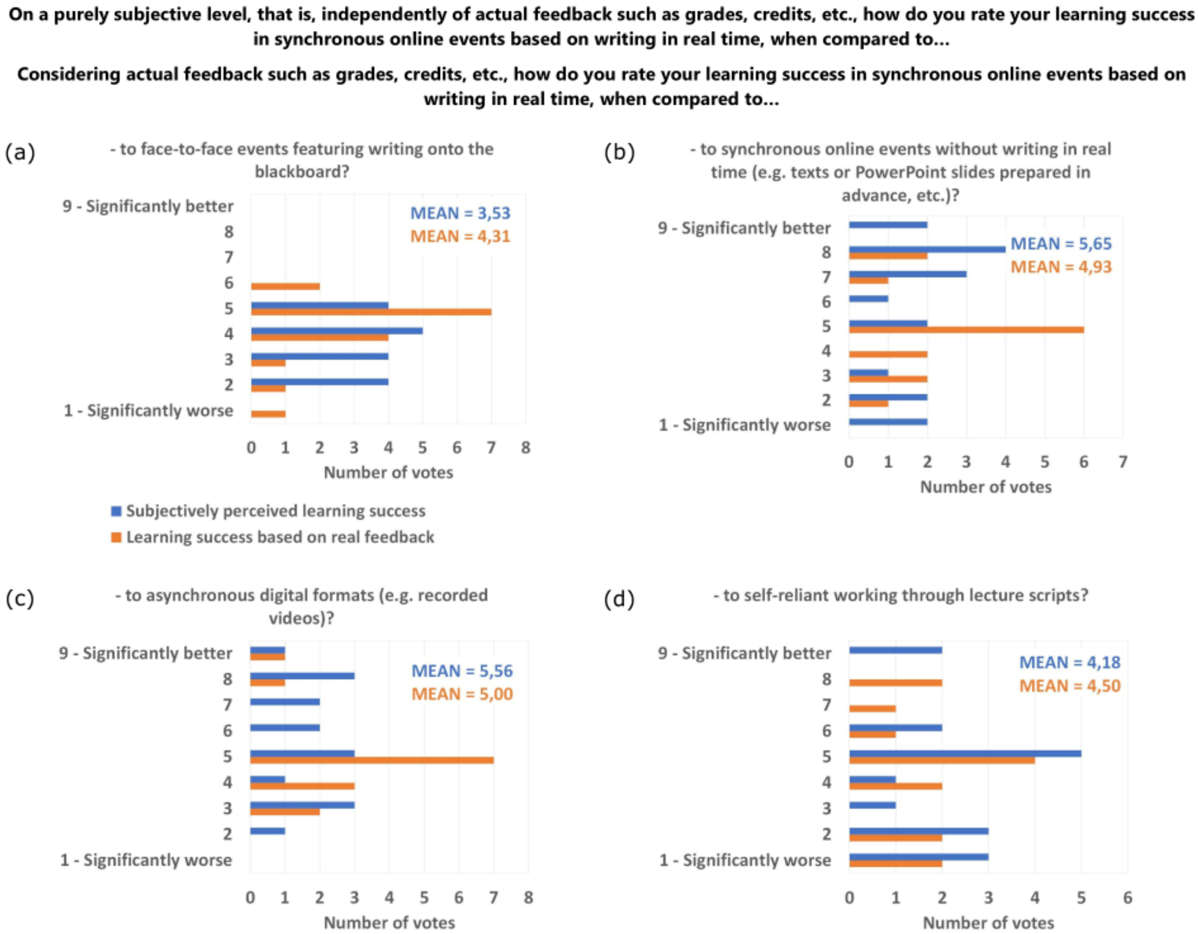

Fig. 1: Students' assessment of their perceived learning success in the synchronous online format with live writing offered by us relative to other teaching formats, namely (a) the classic face-to-face format with blackboard writing, (b) synchronous online formats without live writing but using slides, scripts and similar documents prepared beforehand, (c) asynchronous digital formats such as recorded videos, and (d) independent and self-reliant study of provided materials such as scripts or book chapters. The students' feedback was based on their subjective impression (blue) on the one hand and actual feedback such as exam results (orange) on the other hand.

The other synchronous and asynchronous online formats (formats 3 and 4 in the list above) were rated on average by the students as less successful in this respect compared to the format we chose, see Fig. 1(b) and (c). It is striking that working through the provided scripts independently and self-reliantly (format 5 in the list above) was perceived as comparatively more successful on average, see Fig. 1(d). However, this assessment is neutralized when the actual feedback that the students received on their performance is included. Overall, the survey results give the impression that the chosen combination of synchronous online course with live writing and additional online provision of lecture notes and solutions to exercises is a sensible variant in online teaching.

Since we assume that the students' (perceived) ability to concentrate on the contents is related to their subjective learning success, we surveyed them regarding their ability to focus during the different formats, see Fig. 2. The survey was conducted in absolute terms for the five formats mentioned above, not relative to our online format.

On average, the responding students felt the strongest ability to concentrate in face-to-face courses with blackboard writing, followed by the synchronous online format with live writing that we selected. Interestingly, the teaching format of the synchronous online event with previously prepared materials without live writing (frequently used in other courses) received the worst average rating with regard to the ability to concentrate. Asynchronous online courses and working through scripts on one's own were rated better on average with regard to the ability to concentrate than synchronous online courses based on materials prepared beforehand.

Another indication that several students link face-to-face formats with increased ability of concentrating is the rate of in-person attendance during contributions to written performance assessments. Thus, about 50 % of the students repeatedly participated in presence although an alternative (non-supervised) online variant was offered. Specifically, the students referred to their increased focus.

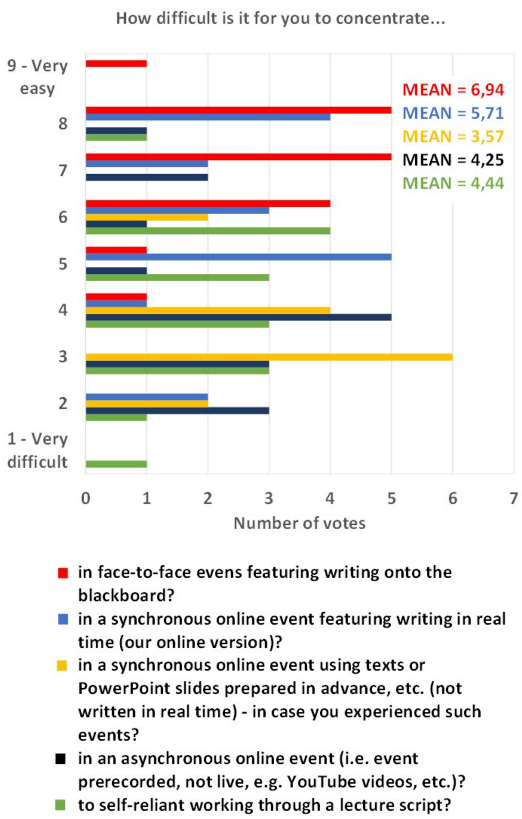

Fig. 2: Students' assessment of their ability to concentrate and focus in the different teaching formats.

In connection with the ability to concentrate during online courses, it was still important for us to find out to what extent it was at all possible for students to find an appropriate environment for following digital courses when taking into account their personal living situation.

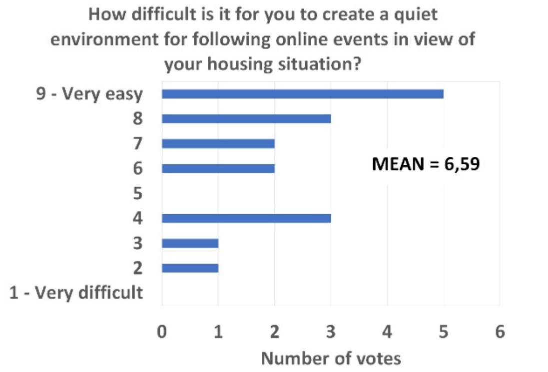

Fig. 3: Feedback from students regarding their ability to create a quiet learning environment with respect to their living situations.

As can be seen from Fig. 3, a significant proportion of students cannot easily establish a quiet environment in their current living situation. This problem is probably difficult to solve by adapting online teaching formats and argues strongly for at least hybrid formats in which at least some of the students can participate by being present on site.

Above we already mentioned that we consider the possibility for students to ask direct questions during lectures to be an extremely important component. Therefore, we wanted to find out whether the students experience an increased amount of inhibition to ask questions in events of online teaching. Here, the majority of students stated that they felt more inhibitions in this respect in the synchronous online formats than in face-to-face courses, see Fig. 4.

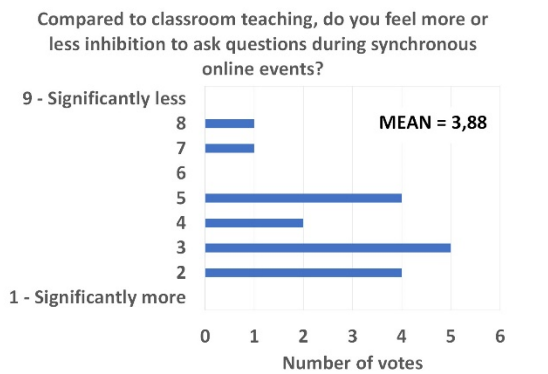

Fig. 4: Personal inhibition to ask questions during our digital format when compared relatively to face-to-face teaching on site.

Furthermore, it is not surprising that most students during online teaching miss the direct social contact with their fellow students, see Fig. 5.

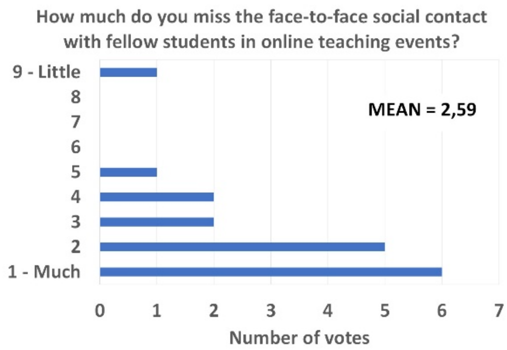

Fig. 5: Feedback on subjective perception of lack of social contact with fellow students during online teaching.

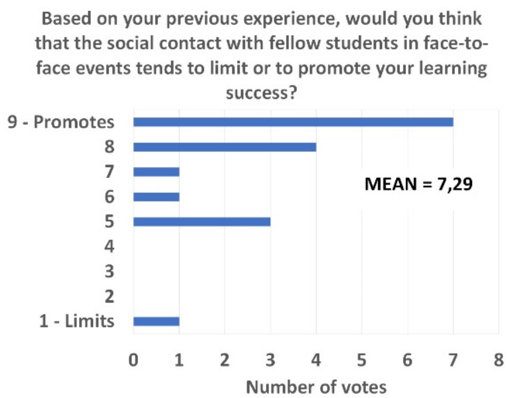

Fig. 6: Students' assessment of the impact of social contact with fellow students in face-to-face on-site events on their learning success.

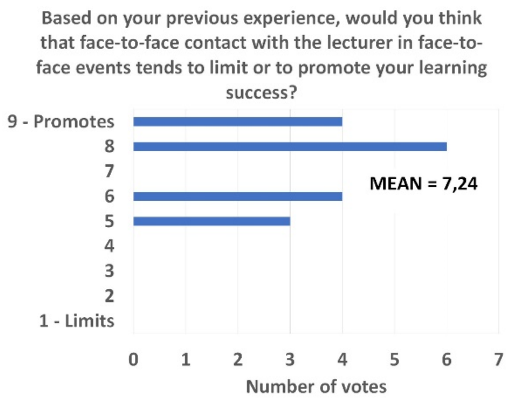

Fig. 7: Students' assessment of the impact of face-to-face contact with lecturers on their learning success.

It is interesting to note that the students assess this missing component to be partly responsible for their on average subjectively perceived reduced learning success in online formats, see Fig. 6. The lack of face-to-face contact with lecturers also reduces learning success according to the students' assessment, see Fig. 7.

Overall, we wanted to find out how students evaluate the synchronous online formats based on live writing that we offer, when compared to traditional face-to-face formats with blackboard writing. We expected a clear difference between lectures on the one hand and events on the solutions of the exercises on the other hand, as the latter usually more substantially rely on in-person discussions.

In fact, the majority of the students prefer face-to-face formats on-site for the exercise courses, see Fig. 8. In contrast to that, concerning the lectures, while taking all aspects into account, the students on average consider the synchronous online format with live writing as basically equivalent to the traditional face-to-face format, see also Fig. 8. We consider the latter to be a success of our implementation of online teaching in this area of theoretical physics. At the same time, it opens up corresponding possibilities for the design of future teaching formats.

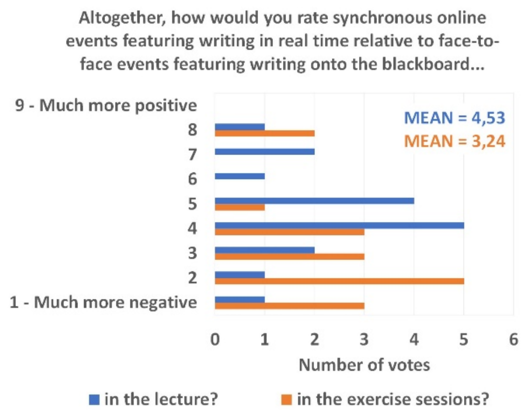

Fig. 8: Taking all aspects into account, comparison by students of digital online teaching via live writing with ordinary face-to-face teaching via blackboard writing, distinguishing between lecture and exercise courses.

Finally, the question arose for us as to whether elements of online teaching should also be adopted in the future after returning to face-to-face teaching or in hybrid teaching formats. As already mentioned above, the majority of students were in favor of live digital writing via LCD projection when compared to traditional blackboard writing during face-to-face teaching. Figure 9 shows the corresponding results of the survey.

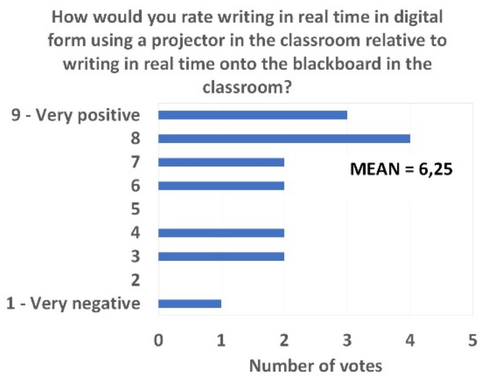

Fig. 9: Student evaluation of live digital writing in combination with LCD projection during face-to-face on-site teaching relative to typical live writing on the blackboard.

The reasons provided were the easy integration of digital elements such as images or web pages as well as the permanent access to the contents already discussed in case of later questions, in addition to the better readability and visibility already mentioned above as well as the uninterrupted facing of the lecturers to the students.

7. Our own assessment

Students are at the center of teaching. Their perspective has been described in detail in the previous section. Nevertheless, we would like to briefly summarize our own impressions as well.

We have already mentioned that setting up and dismantling the technical equipment in addition to starting and stopping the video conferences in the on-site teaching rooms takes around 10 to 15 minutes of time before and after each event in the case of digital live writing, in contrast to classic blackboard teaching. If successive courses are scheduled tightly, this can lead to conflicts. In particular, concluding discussions of a few minutes after the end of each event, which otherwise often develop, then suffer. Yet, there is a little bit more time available during the courses compared to blackboard writing, because there is no need to wipe the board.

From our point of view, there is another, possibly essential aspect that may have contributed to the very positive development of our courses as described above. While the courses were taking place in presence on site for at least a few weeks at the beginning of each winter semester, almost all students and lecturers were able to get to know each other in person. It seems plausible to us that communication barriers in the online mode were lowered in this way, which contributed to the lively exchange even during purely online teaching. In particular, students were not required to use their cameras during online events. A lack of initial face-to-face contact would probably have led to a very anonymous atmosphere as a result. This aspect should be further explored in the future, if necessary. It might generally be useful to hold at least one initial face-to-face event at the beginning of each semester, even in the case of purely online teaching.

We were not surprised that students perceived face-to-face formats in the exercise sessions as more important than in the lectures. On the side of the lecturers, the lack of possibility to directly visually recognize the reactions of the students was more noticeable when the cameras were switched off. As a result, in-depth questions and discussions arose less frequently in the online exercise events than during teaching on site. The online submission of the solutions to the exercises mostly worked smoothly, although corrections via the e-learning platform required some more time when compared to paper submissions. Overall, we did not notice any substantial reduction in students' performance when working on the exercise assignments compared to face-to-face formats. The same is true for other contributions to written performance tests. The necessary archiving of corresponding contributions in digital formats is comparatively easy. In fact, we plan to maintain the digital procedures for the submission and assessment of completed exercise assignments. We will continue to make lecture notes and solutions to exercises available online via the e-learning platform.

The most important new finding for us from the evaluations is that the majority of students also prefer digital live writing with LCD projection to blackboard writing in the face-to-face courses on site. We would have expected this to be different. Actually, we had assumed that our writing on the blackboard would be more appealing, which was evaluated differently by students on several occasions on average. Therefore, at least in the lectures, we plan to use the format of digital writing in combination with LCD projection more extensively in the future, as far as the technical and temporal possibilities allow. In the exercises, this format is less practicable when different students present their solutions during each event.

Overall, we are pleased that despite the given circumstances associated with the Covid 19 pandemic, we were able to offer students digital online and hybrid formats that received a positive response. It was worthwhile to try to consider the situation and necessities from the students' point of view at the beginning of the transition to online teaching and to draw resulting conclusions by implementing the chosen format. In general, our impression is that the success of studies in online formats depends even more on the motivation and personal responsibility of the students. The fact that most of them successfully met these requirements was clearly evident, for example, from the aforementioned sincerity in unsupervised parts of the written performance assessments. We are therefore very pleased that, on average, the performance of the students in our courses, as far as we can judge, was not affected by the given circumstances of the Covid 19 pandemic.

8. Lessons Learned

We assumed that a step-by-step development of the contents including explanations by the lecturers with possibilities for immediate queries, combined with the motivation to write down the formulas and calculations, are integral parts of teaching in theoretical physics, at least in the context of the courses we conducted. Overall, we see these assumptions confirmed. The positive feedback from students leads us to conclude that mapping such an approach to digital teaching also establishes a useful and successful teaching format in theoretical physics. Therefore, we will continue to give preference during digital teaching to synchronous online formats with live digital writing via video conferencing.

The most surprising finding for us is that the majority of students also prefers digital live writing via active display by input pen, laptop and LCD projection to traditional blackboard writing in face-to-face formats on site. This is significant because it facilitates the transition to different hybrid formats, for example, face-to-face lectures in the lecture hall combined with synchronous online transmissions via video conferencing. Such formats are likely to gain growing importance in the future, also because they increase flexibility on the students' side and may be better able to accommodate individual situations. It is possible that even in purely online formats, initial meetings in presence may have a positive influence on the further course.

In online events dedicated to discussing solutions of exercises, synchronous formats with live digital writing via video conference were preferred as well. Here, however, the implementation as face-to-face on-site events seems more urgent than in pure lectures.

Overall, we as lecturers may place great trust in the motivation, willingness to perform and sincerity of the students. In our case, this became particularly clear from their conduct during the unsupervised written performance tests.

Acknowledgement

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Lessons Learned from Implementing an Inverted Classroom Model

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Abstract

Für ein erfolgreiches Gelingen des Inverted Classroom-Konzepts ist die eigenständige Vorbereitung der Studierenden auf die Präsenzveranstaltung zwingend erforderlich. Damit die Studierenden für das Selbstlernen im Voraus motiviert sind, muss ein Mehrwert durch die Vorbereitung für sie entstehen. Dazu muss eine erfolgreiche Verzahnung der Selbstlerninhalte und der vertiefenden Praxisinhalte innerhalb der Präsenzveranstaltung erfolgen, damit die selbstgelernten Inhalte mit Beispielen verknüpft werden können und somit zu einem nachhaltigen Lernerfolg führen. In diesem Beitrag wird diese Herausforderung anhand einer beispielhaften Umsetzung eines Inverted Classroom-Konzepts für die Vorlesung „Produktionsmanagement und –logistik" an der Leibniz Universität Hannover verdeutlicht. Im Rahmen der Pilotierung des Konzepts wurde festgestellt, dass eine vollständige Digitalisierung der Lerninhalte zu keinem Mehrwert für den Lernerfolg führt. Somit wurden die Erfahrungen aus der Pilotierung analysiert und das Konzept entsprechend angepasst. Die Anpassungen ermöglichten eine auf die selbstgelernten Inhalte aufbauende Präsenzveranstaltung und führten somit zu einer erfolgreichen Verzahnung von Selbstlernphase und Vorlesung im Rahmen eines Inverted Classrooms.

For the inverted classroom concept to be successful, it is imperative that students prepare themselves for the classroom event. In order for the students to be motivated for self-learning in advance, an added value must arise for them through the preparation. To achieve this, the self-learning content and the in-depth practical content must be successfully interlinked within the classroom event so that the self-learned content can be linked to examples and thus lead to sustainable learning success. This paper illustrates this challenge by means of an exemplary implementation of an inverted classroom concept for the lecture "Production Management and Logistics" at Leibniz University of Hanover. During the piloting of the concept, it was found that a complete digitization of the learning content does not lead to any added value for the learning success. Thus, the experiences from the piloting were analyzed and the concept was adapted accordingly. The adaptations made it possible to build on the self-learned content in the classroom and thus successfully interlockthe self-learning phase and the lecture as part of an inverted classroom.

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This article was originally submitted in German.

1. The Inverted Classroom Concept

The approach of the inverted classroom model (also called flipped classroom) pursues a reversal of the classic lecture format. Here, students are supposed to acquire knowledge independently in advance of the classroom lecture in order to be able to use the classroom event more effectively and with active tasks [1]. In addition to the more intensive use of face-to-face time, this type of knowledge transfer also offers the advantage that students can learn more self-determined and at their own pace due to the availability of the learning content [2]. The independent preparation of the students for the face-to-face course is a central component of the concept and absolutely necessary for the successful implementation of the inverted concept. Increasing the student motivation required for this, is the biggest challenge in the inverted classroom model [3]. To implement such a model, it is first necessary to prepare and make available the previously analog learning content for the self-learning phase. This requires a switch from data sheets and exercises in print form to digitized learning materials. Today's learning management systems offer a wide range of options for this, such as learning videos with interactive elements or computer-supported methods such as learning paths [4].

The Institute of Production Systems and Logistics decided to take advantage of this concept for the lecture "Production Management and Logistics". To this end, a digital inverted classroom was to be implemented as part of a funded project. The project was made possible by a funding program to improve teaching at the Faculty of Mechanical Engineering at Leibniz University of Hanover. With the help of the funding, the previous lecture content could be transformed into digital learning content and the concept could be piloted during the semester. As part of the piloting, two of the eleven learning modules were implemented in an inverted format in order to first gain experience with the concept and to enable an evaluation by the students. The evaluation as well as the experiences of the teaching staff during the piloting were enormously valuable for rethinking the concept and thus for the complete transformation of the course. The concept of the pilot modules, the experiences through the implementation as well as the subsequent adaptations of the concept are described in this paper.

2. Approaching with pilot modules

The lecture "Production Management and Logistics" has long been an integral part of the curriculum for various mechanical engineering courses and has around 200 participants per semester. The current structure of the course is a weekly 90-minute lecture. This is supplemented by 45-minute exercises in which practical example problems are worked through. As an elective module, the lecture can be taken by both Bachelor and Master students from different disciplines. Thus, the challenge arises that the students have different levels of knowledge and thus the individual learning speed can differ greatly due to possible lack of prior knowledge. Therefore, it was planned in the concept to make all contents available through videos and learning texts in order to enable independent learning in self-study. This released capacity in the lecture session, which was intended to deepen the content and to provide an outlook on practical examples and later fields of application. Lectures on current research projects at the institute were also integrated for this purpose. Furthermore, the students were actively involved by means of live-questions and live-calculations of in-depth tasks. During the test phase, one of the two classroom sessions on the respective pilot modules was held digitally (via BigBlueButton) and the other was held in the lecture hall. Both formats are possible for an implementation of the face-to-face event. However, the format should be suitable for the planned content and activities such as group work or surveys.

During the implementation of the pilot modules, the digital execution of the face-to-face event could not prevail: Originally planned group work phases could not be carried out in a target-oriented manner, as a large part of the participants left the digital learning space when the work phase started. The reason for the lack of participation in the group work was presumable a lack of preparation on the part of the students as well as the low inhibition of leaving the digital event. Lessons learned from this is that such group work and the preparations required for it should be announced in advance. Likewise, the inhibition threshold for participation in group work appears to be lower in the context of face-to-face versus digital events.

The pilot modules were transformed into digital learning units and made available on a learning management platform (Ilias). In the process, the entire content of the previous lecture script was transferred into interactive learning videos as well as learning texts with partially interactive illustrations. For a better division for the acquisition of the contents, the entire lecture module was divided into smaller knowledge units. A module thus consisted of 3-5 knowledge units, whereby the knowledge units were oriented to the contents and thus the scope could be different. To assess the learning effort, the knowledge units were weighted with so-called effort points. A learning video for a knowledge unit was accordingly 15-30 minutes long. The associated learning text overlapped completely with the learning video in terms of content in order to ensure barrier-free learning on the one hand and to allow individual learning preferences on the other. At the end of an entire module, a final module test could be taken.

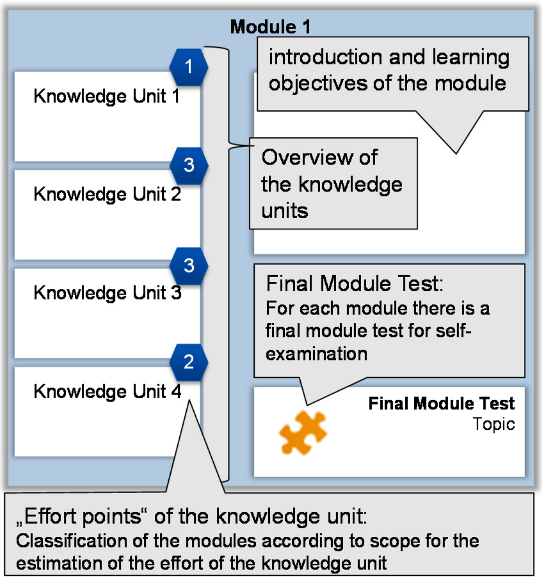

Fig. 1: Structure of a module

The design and question format was similar to the later online exam, so that students could already get used to the exam format. The design and structure of the modules were also to be uniform and visible for each module as an initial screen in the learning management platform. This initial screen showed an overview of all the module's content and was intended to serve as a guide for students to work through the learning content. The structure of this initial screen for a module is shown schematically in Figure 1.

3. Evaluation and experiences from the pilot modules

The pilot modules were evaluated by the students in active surveys and by the teaching staff themselves. The feedback from the students was very mixed. In addition to much positive feedback, there was also strong negative criticism. Of the participants in the evaluation, more than half rated the concept as good, 15% of them even as very good. Some students stated that they were not comfortable with self-learning in advance (18%), 2% of the respondents even found the learning materials difficult to understand. 22% of the students honestly stated that they had not looked at any learning content at all until the face-to-face event. Figure 2 shows the results of the evaluation graphically.

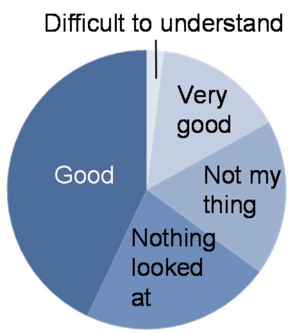

Fig. 2: Results of the student evaluation (Question: How was the self-learning in the Inverted Classroom format?

In addition to the general assessment as a closed question, further feedback could be given in open questions during the evaluation. There were many positive voices for the interactive videos as well as the availability of all learning content in digital format. The main negative feedback was that some students described the concept as "distance learning" and questioned the usefulness and function of the face-to-face course. In addition to the students' evaluation results, the success of the pilot modules could also be verified by means of the recorded learning times in the learning management system. This recording unfortunately showed that only a fraction of the students spent enough time on the learning platform in advance of the face-to-face lecture to fully view all learning content. A large proportion of students spent only very small amounts of time on the learning platform, or the time spent increased immensely during exam preparation. These experiences made it clear that the implemented concept as an inverted classroom had failed in this form. Due to the lack of processing of the learning content, the students were not adequately prepared for the face-to-face event, so that they could only comprehend the in-depth studies with difficulty, as they lacked the necessary basics. The following reasons were identified for the low processing rate:

On the one hand, the learning workload was significantly increased, as the learning videos per module alone were in some cases over 90 minutes in total length. In addition, students had to add their own learning and preparation time, the time for the classroom sessions, and the completion of the final module test. On the other hand, it was not clear to the students how they should prepare for the face-to-face event and on which foundations it would be based.

Another learning effect resulted from the learning videos. Recording the videos involved an enormous amount of work, since on the one hand a complex technical set had to be set up due to the high quality requirements. On the other hand, the recording itself took a long time, as special attention had to be paid to the expressions and explanations. This special attention is very important for the learning videos, because in contrast to the live lecture, no follow-up questions are possible in case of misunderstandings, but the students can watch the video again at any time, so that ambiguities and misleading formulations in the audio track of the learning videos must always be avoided. In retrospect, it was determined that the pilot modules focused exclusively on the transfer of previous learning content into videos and less on the review of learning content in terms of scope or supplementation. The result of the video recordings was thus a complete recording of the previous lecture content, so that the goal of interlocking self-study and classroom instruction was not successfully achieved. The complete digital availability of the lecture leads to major problems for the face-to-face lecture in the lecture hall. Neither a simple repetition of the digital content nor an additional consolidation is useful for the content transfer [4]. Repetition would make part of it obsolete, so presumably many students either go to the course unprepared or do not attend it at all. A too intensive consolidation brings the danger that the main goal of the learning module is neglected and thus reduces the learning effect.

Consequently, the experiences from the implementation of the pilot modules have shown that a mere transfer of the previous content into digital formats does not lead to a functioning inverted classroom. Instead, it should be examined exactly which of the contents should be learned in advance of the lecture as preparatory basics in self-study. In this way, the self-study content can be taken up in the lecture and brought into an overall context with the new content from the lecture. If these overall connections become clear in the classroom lecture and the students thus experience a learning effect, they are also motivated to prepare the content. The following chapter describes how the existing concept can be adapted for this kind of interlocking of self-learning content and classroom lectures.

4. Concept adaptation by interlocking self-study and classroom events

The experiences from the implemented pilot modules show that a revision of the concept is necessary. Instead of a complete transfer of the lecture into digital learning units, only basic parts are to be shifted to self-study. Thus, the lecture in the lecture hall remains for the most part, but can integrate an active involvement of the students due to the freed up time as well as deepen it with practical examples. The digital learning platform, which was set up for the two pilot modules, will not be set up in this form for the other modules, but will only show the self-learning content. The division of the modules into smaller knowledge units will also not be implemented further. In the original concept, this division had the goal of better dividing the content and the required learning effort time for the entire module. Since in the new concept the entire module content is no longer available digitally for self-learning, this division no longer serves the purpose. However, there will still be a similar overview per module as shown in Figure 1. Instead of the knowledge units, the content to be acquired in the self-learning phase will be shown in this overview page. The presentation of the module learning objectives as a central element will remain. These should serve both in advance as a preview of the upcoming content, as well as in the follow-up as a control of what has been learned for orientation. The future sequence within the framework of the inverted classroom concept is shown in Figure 3.

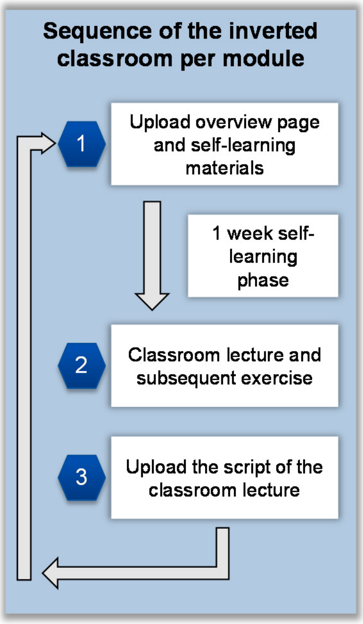

Fig. 3: Sequence of the Inverted Classroom

One week before the lecture of the respective module, the overview page with the learning objectives of the module as well as the self-learning content as "homework" to prepare for the lecture is published. Within the lecture the self-learning contents are deepened by examples or exercises and new contents are explained and both are put into an overall context. Without preparation of the basics, the understanding of the overall context can be achieved only with difficulty and it will not be possible to perform the exercise tasks. The shown script will be uploaded on the learning platform only after the lecture, because during the lecture questions will be asked in the auditorium, whose solutions can be seen in the following pages. The questions refer to the self-learning content to be prepared. In addition to oral questions, internet-based tools for answering the questions on students' mobile devices will also be included. At the end of the lecture, the self-learning content of the following module will be announced and the overview page as a guide for self-learning will be made available on the learning platform. Following the lecture, the respective final module test is activated so that students can test their learning success.

Interactive learning videos will continue to be part of the self-learning materials. However, these deal with models and tools that are to be applied at several points and thus partly serve as preparation several times. Instead of digital learning materials, an existing textbook will be used as lecture-accompanying literature. This lecture-accompanying book describes the Hanoverian supply chain model, on which the lecture is oriented [5]. For the self-learning phase in preparation for the lecture, explicit pages are designated in advance that explain basic content required for understanding the more advanced content in the lecture. Another advantage of the textbook accompanying the lecture is that students can also independently review the content discussed in the lecture. Thus, in the adapted concept, the self-learning phase consists of both some book pages and short general learning videos on the most important tools required for production management. Both the textbook and the learning videos thus bridge the gap between self-study and classroom instruction. Overall, the amount of preparation is significantly reduced and requires about one to two hours of effort, so it should be easily doable within a week. The self-study phase in advance and the basic knowledge acquired in the process enables a shortened lecture, so that full 90 minutes will no longer be required in the future. The time freed up can thus be used for more in-depth study and practical examples. Furthermore, group work phases will be used to carry out smaller exercises during the lecture. More extensive exercises will be calculated in the exercise hour following the lecture. The concept adaptations required for the implementation of the inverted classroom model for the course "Production Management and Logistics" are illustrated in Figure 4.

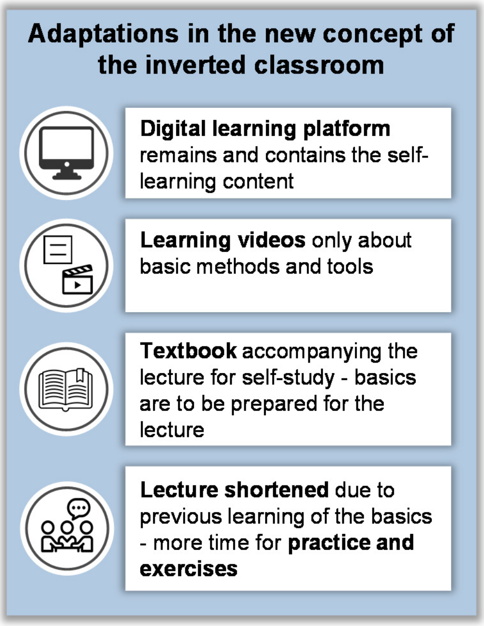

Fig. 4: Overview of the adjustments

The described adaptations ensure that the classroom lecture builds on the content learned in advance by the students themselves and that there is no mere repetition of this content. In addition, the in-depth lectures should particularly emphasize the necessity of self-learning through examples and exercises in order to increase the students' motivation for this. If this succeeds, the concept of the inverted classroom model is successfully implemented and enables both effective learning and learning at one's own pace through the lecture-accompanying book.

5. Conclusion and outlook

When new concepts are introduced as part of improvement measures for teaching, it is generally recommended to first test the implementation with pilot modules. Due to the extensive piloting of the original concept, weaknesses and errors could be uncovered. The teaching concept presented here could be tested, evaluated and purposefully transformed into an improved course through the procedure described. The concept adjustments were implemented in the current semester and the feedback so far has been very positive. This is reflected in particular by the active participation in the exercises on the self-acquired basics. A renewed evaluation of the concept is still pending and will be conducted at the end of the semester.

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Blended Learning with Jupyter Notebooks

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Abstract

Seit 2021 findet jeweils in der vorlesungsfreien Zeit im Frühjahr der fakultative Blockkurs „Python in der Physik“ als Blended Learning Programmierkurs mit Wissensvermittlung im Inverted Classroom basierend auf Jupyter Notebooks mit interaktiven Elementen sowie im gleichen Umfang Arbeit an konkreten physikalischen Aufgaben in Kleingruppen im PC-Pool in Präsenz und unter Anleitung durch Tutoren statt. Im Beitrag werden die organisatorisch-technische Umsetzung sowie die gewonnenen Erkenntnisse aus dieser Veranstaltungsform präsentiert.

Since 2021, the optional block course "Python in Physics" has been held during the spring semester break as a blended learning programming course with knowledge transfer via inverted Classroom based on Jupyter notebooks with interactive elements and to the same extent work on concrete physical tasks in small groups in the PC pool in presence and under guidance by tutors. The article presents the organizational and technical implementation as well as the insights gained from this type of event.

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This article was originally submitted in German.

1. Course conception

Up to and including the winter semester 2019, the bachelor's program in physics at the TU Dresden included a one-semester course in programming with two semester hours per week each of lecture and exercise in the PC pool. As part of the revision of the study regulations, the course was to be converted into a two-week optional block course during the lecture-free period between the winter and summer semesters. This gave rise to a fundamental revision of the methodology of the course:

- Knowledge transfer in self-learning units in the inverted classroom based on Jupyter notebooks with interactive elements instead of face-to-face lectures
- Work on concrete physical tasks in small groups in the PC pool under the guidance of tutors

In the self-study units, knowledge is acquired through multimedia online material in individual work [1] instead of in the traditional lecture format. The presence phase in the programming exercises in the PC pool is additionally used to clarify questions that have arisen during preparation. Thus, this combination of teaching-learning scenarios corresponds to the inverted classroom model [2],[3]. Together with the actual programming activity in presence in the PC pool, a form of integrated learning (blended learning, [4],[5]) is created as a combination of online and presence phases. The scope of the self-learning units and the programming tasks was chosen so that both forms require approximately the same amount of time.

Python [6] is used as the programming language, since on the one hand the entry barriers for programming beginners are particularly low, and on the other hand all purposes relevant to physics are covered by a large number of scientific modules. Jupyter Notebooks [7], which are based on Python, can be used anywhere as a web application and, in addition to the interactive execution of program code, offer the possibility of displaying equations, visualizations and references as well as formatted text. They therefore form an ideal tool for unifying programs, their results, and their description and documentation, as well as for performing data analysis in real time.

Students always find the same work interface, whether in the PC pool or on their private end device. This does not require any software installation. The notebooks are delivered in the web browser via a Jupyterhub [8], which was set up as a virtual server in the TU Dresden Enterprise Cloud.

In the corresponding course of the learning management system OPAL used at the TU Dresden, the participants will find links that automate the individual login to the Jupyterhub with the OPAL access data. The links are realized via the OPAL LTI tool (Learning Tool Interoperability) [9]. When using the corresponding link, an initially identical but individually editable and storable Jupyter notebook is delivered to each course participant by the Gitlab version control system [10] of the Department of Mathematics and Natural Sciences of the TU Dresden.

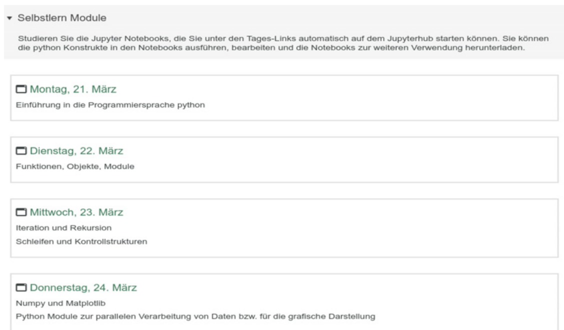

Fig. 1: Selection of Jupyter notebooks in the OPAL course.

In the notebook, program code can be written in input cells and executed directly. Students have the opportunity to independently check the correctness of the input.

In addition to the daily self-study units with approx. 1.5 hours of processing time, ninety-minute exercises supervised by tutors are also carried out daily in small groups (maximum twelve participants) in PC pools. There, two to three students come together to solve a programming problem together.

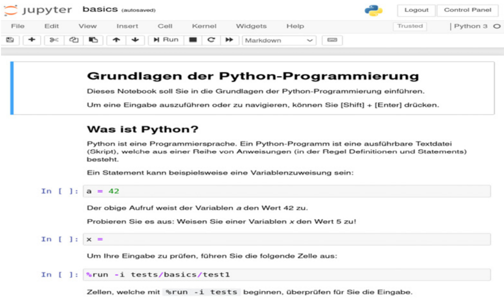

Fig. 2: Documentation and code cells in the Jupyter Notebook.

Fig. 3: Concept of the programming course.

Due to the wide range of prior knowledge of the participants, the course was divided into two independent strands, each consisting of self-study units and adapted exercises. Students with no prior knowledge of programming acquired the basics of the Python programming language in the first week and learned the modules for graphics output and numerical calculations on data arrays in the second week. They applied the acquired skills in the exercises to typical problems in the analysis of physics lab courses, e.g. linear fitting, random numbers and statistics, and Monte Carlo methods.

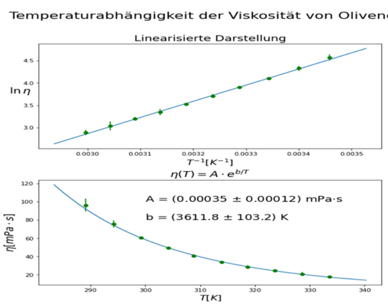

Fig. 4: Sample solution of the linear fitting task for programming beginners

The focus of the advanced group was on scientific data processing, understanding (through own implementation) elementary numerical methods for differentiation, integration, determination of zeroes of functions and solution of ordinary differential equations as well as getting acquainted with the standard modules for working on these problems.

Fig. 5: Numerical zero search task for participants with previous knowledge (part 1).

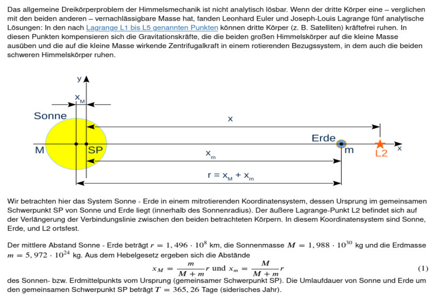

Fig. 6: Numerical zero search task for participants with previous knowledge (part 2).

2. Technical implementation

The self-learning units and exercises consist of individual notebook fragments that are assembled into the final notebook using a simple graphical interface for the Jupyter extension nbmerge [11].

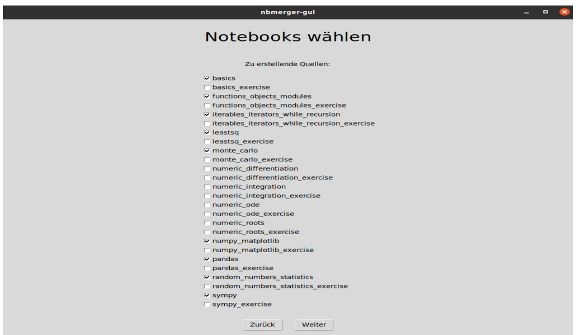

Fig. 7: Selection of notebooks for compilation using nbmerger-gui.

This approach allows a fast and flexible exchange of content blocks of the notebooks.

Fig. 8: Assembling notebook fragments for a self-learning unit using nbmerger-gui.

The connection between the Git repository with the prepared notebooks and the students' notebook instances on the Jupyterhub is established using the Jupyter extension nbgitpuller [12] in the OPAL LTI tool.
Since the version of the LTI tool used in OPAL so far does not provide for a return channel, a file upload for edited notebooks has been set up (though not used in the course, since no assessment of the exercises is done).
The entire implementation of the project based on the content of the programming course until 2019 was funded by the Multimedia Fund of TU Dresden in the period 2019/20.

3. Lessons learned

As of March 2022, 68 students from the target group of approximately one hundred -Bachelor of Physics, 1st semester- have participated in at least nine of the ten face-to-face exercises. The optional nature of the course and the absence of performance pressure, compared to the compulsory course until 2019 where credit points had to be earned in the exercises to pass the module, resulted in a much more lively, cooperative and productive character of the exercises. Practice-oriented exercise assignments established a connection to the major subject. The cooperation in small teams of two to three persons on a problem promoted the gain of knowledge.

On the last two days of the course, an anonymous online survey for the evaluation of the course was released to the participants. This contained 24 single or multiple choice questions about the course, which were based on the questions of the usual teaching evaluation for semester course events (supplemented by some technical questions about the concrete implementation). Forty-eight of the 68 participants took the survey.

Jupyter notebooks were considered to be a valuable tool due to their interactive character. The course component of the self-study units, designed as an inverted classroom, combined with individual tests with response was very positively received.

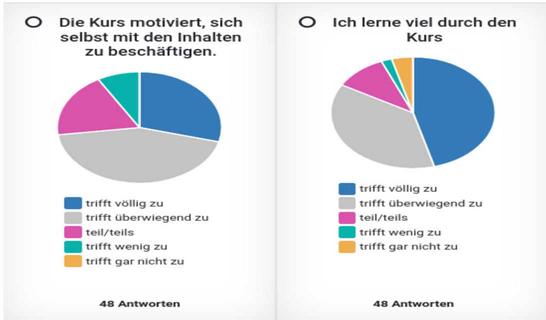

Fig. 9: Evaluation of the programming course.

The increased use of Python in experiment evaluation in the physics lab course, as well as the use of this programming language in more advanced courses (e.g., computational physics, numerics, and computer simulations in soft condensed matter), results in the practical relevance of the programming course.

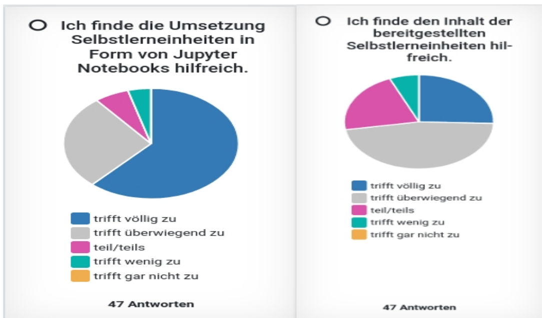

Fig. 10: Evaluation: Jupyter notebooks as work tools.

Fig. 11 compares the identical evaluation questions for both course types (blue - winter semester 2019/20 (compulsory course with classical face-to-face lecture and assessed exercises); red - block course 2022 (optional during the lecture-free period with self-learning units (inverted classroom) and supervised face-to-face exercises)).
While the requirements or the severity of the material as well as the amount of material were assessed as optimal in each case, there

are differences in some of the questions to be evaluated on the grading scale of 1 to 5. For example, although the content of both types of courses was nearly identical, the blended learning course 2022 was rated as better aligned with students' prior knowledge. Significant positive differences for the blended learning format occurred for the statements "I learn a lot through the course." (1.81 +- 0.14) vs. (2.77 +- 0.13) and "Overall, I am satisfied with the course." (1.77 +- 0.11) vs. (2.25 +- 0.14).

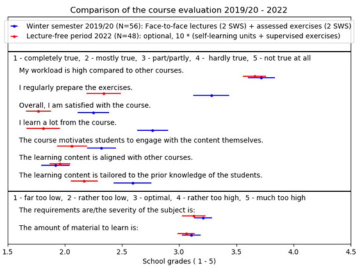

Fig. 11: Comparison of course evaluations: Blue - winter semester 2019/20 (compulsory course with classic face-to-face lecture and graded exercises, 56 survey participants); Red - block course 2022 (optional during the lecture-free period with self-learning units (inverted classroom) and supervised face-to-face exercises, 48 survey participants). Mean values and standard deviations of the questions evaluated according to school grades (1-5) are shown.

The result is particularly surprising for the statement "I regularly prepare the exercises." (2.34 +- 0.15) vs. (3.28 +- 0.16), since in the case of the worse result in the winter semester 2019/20, the exercises had to be handed in and assessed. When assessing the evaluation results, however, it should be taken into account that the cohort winter semester 2019/20 included all students of a compulsory course, while in the comparison with the blended learning course 2022, the participants came voluntarily during the semester break and can therefore be assumed to have a higher motivation on average.
The course was awarded the TU Dresden 2021 teaching prize at the suggestion of the students of the Physics Faculty.

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Saxonian Joint Project D2C2 "Implementing Participatory and Discipline-Specific Approaches to Digitalization at the University: Competencies Connected"

Didactic Insights into (partially) Digitalized Workshops and Laboratories

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Abstract

Das Projekt „D2C2 – Digitalisierung in Disziplinen Partizipativ Umsetzen :: Competencies Connected" setzt sich zum Ziel, aus den Erfahrungen der Covid-19-Pandemie zu lernen und Digitalisierung in der Lehre evidenzbasiert weiterzuentwickeln. Zehn sächsische Hochschulen sowie die BA Sachsen widmen sich zentralen Herausforderungen (teil-)digitalisierter Lehre. In diesem Rahmen fokussiert die TU Dresden gemeinsam mit der HTW Dresden die Lehre in (teil-)digitalisierten Laboren und Werkstätten. Ziel ist es, die Bedarfe sächsischer Studierender und Lehrender aufzugreifen und letztere aktiv dabei zu unterstützen, ihre Lehre in Laboren und Werkstätten weiterzuentwickeln. Dieser Artikel widmet sich einigen theoretischen Grundlagen der Didaktik in (teil-)digitalisierten Werkstätten und Labore mit Fokus auf dem Lehrveranstaltungsformat Praktikum. Es erfolgt eine Differenzierung der verschiedenen Ebenen der Digitalisierung, die im Werkstatt- oder Laborpraktikum und bei dessen didaktischer Umsetzung bedacht werden sollten. Veranschaulicht werden die verschiedenen Ebenen durch Verweise auf good practice Beispiele.

The project "D2C2 – Implementing Participatory and Discipline-Specific Approaches to Digitalization at the University: Competencies Connected" takes the experiences of the Covid-19 pandemic and aims to enhance digitalization efforts in teaching based on evidence. Ten Saxonian universities, joined by BA Sachsen, are addressing the central challenges of (partially) digitalized teaching. In this context, TU Dresden and HTW Dresden are focusing on teaching in (partially) digitalized workshops and laboratories. The goal is to address the needs of students and teachers and to actively support the latter in further developing their teaching in workshops and laboratories. This article is dedicated to some theoretical, didactical basics of how to teach laboratory courses in STEM subjects (German: "Praktikum"). It describes the different levels of digitalization that should be considered in laboratory courses and their didactic implementations. The paper sheds light on these different levels by referencing some good practice examples.

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1. D2C2: Workshops and Laboratories

During the Covid 19 pandemic, teaching in workshops and laboratories either had to be moved entirely into the digital space within a very short period of time, or partially digitalized opportunities for participation had to be created. As a consequence, a multitude of technical as well as didactic questions and problems arose.

The Saxonian joint project D2C2 is dedicated to address central challenges of (partially) digitalized teaching. Within the framework of this project, TU Dresden and HTW Dresden are focusing on teaching in (partially) digitalized laboratories and workshops. Through intensive research as well as broad networking with other universities, we try to enable a versatile exchange of expertise and experiences. The goal is to address the needs of Saxonian students and teachers and to actively support the latter in further developing their teaching in laboratories and workshops. In doing so, we aim to offer a didactically sound, high-quality and future-oriented education to students that takes aspects of sustainability and resource efficiency into account.

Connecting practice and theory is a special characteristic of workshops and laboratories, which in turn makes it necessary to pay close attention to specific didactic considerations. The general learning objectives in laboratories and workshops are extensive and versatile. Exploratory action is to be encouraged in order to gain a conceptual understanding of the subject matter. Hands-on experiences are offered in an experimental setting; students train how to collect data, communicate, and discuss results. Action-oriented skills, creative thinking, and working responsibly in teams are also among the learning objectives in workshop and laboratory [1]. Even beyond pandemic-related developments, work spaces within and outside the university are increasingly digitalized. There is thus pressure on those who teach to modernize courses that take place in laboratories and workshops [2]. Digitalized workflows in workshops and laboratories have long ceased to be a rarity. For example, the term remote laboratory (i.e., remote lab; [3]) has been used for about 30 years to characterize real laboratory setups that are automated and made available via communication technologies [4]. Technological advancements as well as changing job profiles in the professional world require universities to rethink their practices. As a consequence, efforts to digitalize teaching in this area have become increasingly important in recent years.

Various networks and projects at German universities have emerged in connection with digitalized labs, including the research projects Open Digital Lab for You (DigiLab4U), Cross-Lab, Dist-Lab, MINT-VR-Labs and SHELLS. In addition to these, there are numerous individual projects at universities or individual institutes, complemented by digital offerings from business and industry, e.g., Labster and LabsLand, two commercial internet platforms. All these examples share that they are primarily dedicated to technical challenges of virtual laboratory settings. Didactic aspects are mostly of secondary nature. Therefore, our project sets out to identify didactic challenges and requirements. Together with teachers and students, we aim to develop sustainable solutions of how to best teach courses in (partially) digitalized workshops and laboratories.

2. The Laboratory Course “Praktikum“

Demands placed on digitalization are becoming increasingly subject-specific, making it necessary to develop subject-specific solutions from a didactic perspective. As a crucial component of STEM studies, workshop and laboratory courses are traditionally related to STEM. These traditional teaching formats differ greatly from various forms of workshop and laboratory work practiced in other fields, e.g. in social work, nursing, and the arts and design. Because of its fundamental importance for STEM education, this article is devoted specifically to a teaching format in the STEM field which is known as “Praktikum” among German universities

Contrary to their name, workshop and laboratory practical courses do not necessarily require the physical space of the workshop or laboratory. Rather, they involve a specific continuum of activities in the sense of workshop and laboratory work. Examples include practical courses in science, e.g. in analytical chemistry and molecular biology, practical courses in engineering (e.g. in automotive engineering and electrical metrology), in mathematics (e.g. in numerics and stochastics), and in information technology (e.g.in computer graphics and robot programming).

By the term ”Praktikum” we refer to a practical course in STEM education at universities that is part of the official curriculum. It serves students to acquire or deepen theoretical knowledge while also acquiring practical skills, often also psychomotor skills. Students apply subject-specific theoretical knowledge in a practical way. They handle materials and substances, instruments and equipment or data and information. Work processes and procedures as well as scientific practices, including a critical examination of their own work, ought to be learned and applied to different situations. Conditions pertaining to time and place as well as teaching frameworks vary greatly and are specific to each course, offering students different degrees of independent work time and guidance. Alternative terms for “Praktikum” are laboratory or labcourse, experimental course or practical laboratory exercise.

Subject-specific technical infrastructure and equipment determine the distinction from other courses, such as lectures and seminars. The “Praktikum” is further characterized by students' independent work with this equipment. It may include, for example, chemical laboratory equipment, mechanical tools, electronic machines, and specialized hardware and software in the IT field. The students' practical work ranges from measuring and analyzing to experimenting, manipulating, synthesizing, constructing, repairing, controlling, and programming. Such a practical course can last from a few hours (as a single unit) to many hours (block module). Sometimes students work under extensive guidance, sometimes they do so entirely independently.

In a laboratory, the lecturers often do not teach merely by themselves but are supported by employees such as laboratory engineers, technical assistants, student assistants, and doctoral students. In this article, we refer to all of these people as teachers.

The course “Praktikum” consists of three successive phases: Preparation, consolidation, and follow-up. The practical activities of the students happen primarily during the consolidation phase. There are often two examination periods: A preliminary examination or “Antestat” takes place before the consolidation phase begins. A final exam or “Abtestat” is conducted in the follow-up phase.

3. Reasons for Digitalization

The digitalization of practical laboratory courses is usually associated with remote experiments, working in virtual reality spaces, and digital data acquisition. However, this is only part of the possibilities that this topic area encompasses. Digitalization already starts with the use of digital communication channels or teaching materials.

The reasons for and motivations behind digitalizing internships vary (see back, Info Box 1). They range from enabling remote learning to helping students learn how to handle novel technologies relevant to their field of practice. On a purely organizational level, efficiency can be increased and barriers, in terms of time and location, can be reduced for all participants. On a didactic level, the digitalization of internships makes it possible to expand or modify teaching content and thus increase the practical relevance with regard to Industry 4.0. In their 2019 study “Engineers for Industry 4.0,” the IMPULS Foundation offers an overview of current requirements for engineers [5]. The study emphasizes that universities must significantly adapt and modernize the learning goals in engineering subjects – a difficult task since university structures are not very flexible and often lag behind current developments. However, skills in computer science, data science, and data security have become indispensable to any engineering study program. In the natural science, similar dynamics, albeit to a lesser extent, can be observed. Moreover, digital teaching tools are also used for illustration purposes and can thus increase students' learning success, for example by using various means of digital simulation. We suggest that several reasons play into teachers' decisions to digitalize practical courses outside of emergency remote teaching. Just as there are different motivations behind digitalization efforts, digitalization can be realized in numerous ways. However, the specific reasons are decisive for what exactly (level of digitalization) and to what extent (degree of digitalization) changes should be implemented. For example, suppose spatial flexibility is desired in a course. In that case, changes to the ways in which teachers and students interact as well as their working environment and equipment should be considered. There are possibilities to either fully or partially digitalize courses. One lesson we learned in recent years is that digitalization in labs or workshops is sometimes quickly rejected, partly because it is associated with a holistic shift of labs and workshops into the digital sphere. The various levels and degrees of digitalization are not always sufficiently specified, so misunderstandings may occur. In the following section, we present various levels of digitalization and provide references to some "good practice" examples from Germany and abroad.

4. Levels of Digitalization

In practical lab courses, students interact with teachers in a variety of ways. They also interact with other students, with their working environment as a learning space, infrastructure or equipment, and with working materials. Furthermore, students encounter processes such as technical procedures or chemical reactions, which they influence through their practical work. The same applies to information and data that they receive, generate, or process themselves. On the one hand, the aspects mentioned reflect the complexity of the course. On the other hand, they indicate the variety of potential possibilities of digitalization. In this context, we describe four levels of digitalization (see Info Box 2). From a didactic point of view, there are specific challenges to be considered for each level. For this reason, a distinction and identification of the respective level are fundamental if teaching practices in workshops and laboratories are to be investigated and further developed.

Work Environment

Traditionally, the term work environment is understood to mean the physical space of the workshop or laboratory. In the context of the "Praktikum," however, the work environment also describes the subject-specific physical infrastructure and equipment that students use. Students must be able to find their way around the work environment and handle the relevant equipment, machines, and aids safely. If digitalization takes place entirely or partially at this level, the challenge arises of getting to know and handling this changed environment. For example, if a real experiment is converted into a remote experiment, students potentially need different prior knowledge and skills than in the real laboratory. These may include some basic knowledge in data processing and programming or competencies in independent problem analysis, since the experiment may have to be conducted independently at home. Often, groups are heterogenous and students do not share the same knowledge. Instructors face the challenge of identifying what new skills are needed by students and how they can be acquired. Thus, we recommend conducting a survey before or at the beginning of a term, in which students are asked to assess their previous skills. Pfeiffer and Uckelmann, [6] address changing requirements, such as those that arise when working with IoT (Internet of Things), in the information logistics practical course with a modified LabTC approach. In the initial elaboration phase, students can independently work through various learning resources in the learning management system to prepare for the subsequent laboratory experiment. Technical basics, in this case how RFID systems work, are also taught as part of this preparation. Asynchronously conducted units such as these provide a gateway into and subsequent orientation of the on-site working environment.

Processes

In practical lab courses, students learn to initiate, control, manipulate and monitor chemical reactions and technical processes. If these activities are no longer performed traditionally (analog) but digitally, the challenge arises to illustrate processes to students adequately, e.g. a chemical reaction that is controlled and observed remotely rather than directly on site. For an effective illustration, sometimes simply screening video may not be sufficient. Substances and reaction steps may have to be specially characterized by signals such as sound, optical effects, or even magnification and modeling. Staining of the real substances is also an option if they are difficult to distinguish, as is done, for example, in Ines Aubel's biotechnology remote lab in the CrossLab project [7].

Data

In practical lab courses, data from measurements, tests, and experiments are collected, documented, and processed. Traditionally, students read and transfer measures and other data from analog devices and create a handwritten protocol, e.g. by drawing a measured value diagram with a pencil and ruler. The process seems antiquated, but makes the underlying principle comprehensible to students. If data is no longer processed analogously and purely manually, but is automatically collected and processed digitally, the processes involved must be broken down transparently. Furthermore, students must be able to work with appropriate data software. For example, the Department of Physics and Electrical Engineering at the University of Bremen publishes a digital data sheet titled "Hints for Practical Training and Evaluation of Measurement Results" [8] to enhance students' understanding of data handling. Nowadays, data in laboratories is more frequently stored with the help of electronic protocols and lab books. Sebastian Schöning provides a list of possible digital solutions as well as important selection criteria on the website of the Fraunhofer Institute under the topic Electronic Laboratory Notebooks [9].

Interpersonal Communication

This level describes the interaction of (a) teachers and students with each other for the purpose of training and (b) students with each other in the context of group work. According to this classification, two unique features occur in practical lab courses:

(a) The supervision of students by teachers in practical lab courses is often done individually and thus intensive. Training in these courses is characterized by direct feedback (locally and temporally synchronized) at the students' workplace. The interaction often occurs on the spot. It includes, for example, brief verbal instructions on how to proceed with work, comprehensive explanations of theoretical background and safety measures, as well as manual demonstrations and assistance with current work steps. The individual feedback supports students in overcoming obstacles, so that they can successfully complete a practical learning unit in the specified time. If the communication between teachers and students takes place only digitally, e.g. by video conference, the local and often also temporal proximity to the students' practical work is missing. Teachers must find a way to compensate for the difference in location and time. An example of this is the so-called Lab@Home format. Students carry out the practical work at home, e.g. with the help of mobile experimental equipment. Teachers are not on site, but accompany the students' work from a distance, using digital communication channels, e.g. online chats, forums, or video conferences. In this context, it has proven helpful to prepare students for the practical unit by offering examinations or self-assessments, testing the knowledge they later require. Preliminary discussions of practice-specific knowledge, if necessary, can also be helpful. Good examples of this are the LabBuddy project at the University of Leiden [10] and the adaptation of the so-called "Flipped Lab Concept" in the chemistry internship [11] by Dirk Burdinski at the Technical University of Cologne. As preparation, Burdinski offers instructional videos that accurately depict the practical activity. In order to integrate timely and individual feedback, he defines precise time frames that schedule when students perform their work and at what time they receive feedback via video conference. This strategy is also successfully applied in the digitalized physics practical course at the University of Paderborn [12].

(b) The second unique characteristic of practical lab courses on the level of interpersonal communication is students' interaction with each other. They mostly work in teams, i.e. in groups of two or more students. On the one hand, working in teams is a necessity due to limited resources and capacities. On the other hand, teamwork is also often deliberately chosen to train students' collaboration and communication skills. Traditionally, group work takes place directly and synchronously in the workplace of the workshop or laboratory. If this synchronicity is no longer given and the students have to organize their collaboration with the help of digital communication channels, new steps need to be integrated into the work process. Students are asked to coordinate their working conditions in terms of time and place individually. They have to navigate a digital space that is characterized by shared documents and/or remote experiments, and the mutual illustration of practical work steps via digital communication channels. In her blog entry for the Hochschulforum Digitalisierung, Elisabeth Mayweg describes how digital formats of collaborative learning can be successfully used at the university [13]. Among other things, gamification is one way to make optimal use of virtual lab environments in the context of teamwork. Here, playful, even competitive elements and processes are used to increase students' learning success. The Gaming Lab of the Bremen Institute for Production and Logistics GmbH [14] deals specifically with this topic. The MINT-VR-Labs project at Berlin University of Applied Sciences should also be mentioned in this context. In this project, virtual laboratories are created to train students in scientific laboratory experiments [15]. These experiments contain playful components, which create a potential for gamified teamwork and, in turn, show that digitalization can not only be a challenge, but also an enrichment.

5. Didactic Challenges

As the previous sections indicate, digitalization in workshops and practical lab courses is characterized by a complexity that should not be underestimated. In order to better grasp individual challenges, the project D2C2 currently conducts a series of surveys. Based on an analysis of the current situation and further networking, training opportunities are to be developed for teachers that meet their needs. Our research sheds light on achievements and experiences that teachers and students have gained in recent years. We want to share these unique insights in a structured form with other teachers and students. In doing so, we must adequately address ongoing challenges whenever we want to implement new ideas. Although these surveys are still ongoing, we would like to provide a brief insight into a quick survey we conducted during the 4th Lessons Learned conference at TU Dresden in July 2022. Immediately following a project presentation, we asked teachers present at the conference what they view as the biggest challenge in implementing digitalized laboratory courses. Based on the 21 responses we received, we formed five clusters. These clusters provide a first impression of the various challenges that must be faced (see Fig. 1). It is important to note that the results of this small survey cannot and should not be read as representative. The value of such a quick survey lies, among other things, in the specific formulations that participants choose when asked right off the bat. On a discursive level, these answers provide useful insights whenever they are read closely and analyzed in more detail. Firstly though, let us state the basic parameters of the survey: the survey took place unannounced and participation was voluntary. We conducted the survey anonymously, in written form, with both a digital and analog submission form available to participants.

Six of the given answers point to challenges in effectively guiding students. Supervision is made more difficult by high numbers of students and by aspirations of some to involve all students equally. These difficulties are echoed by answers that mention technical problems, which also account for a high proportion. In part, the equal inclusion of all students is made impossible because not all students own adequate technical equipment or experience technical problems. At the same time, the demands on students and teachers are increasing. Among other things, haptic elements are often missing from digital settings, thus presenting a lack of practical relevance. In some cases, however, the focus is shifting to other skills, e.g. the handling of software. The given answers reveal that responsibility for deficits is often placed on the individual students, e.g. "many students cannot handle MS Excel." In their answers, participants did not refer to external structures, e.g. "as school, students were not taught how to use MS-Excel" or "the university does not offer classes that introduce software programs." A similar tension is inherent in the word "motivation," which was mentioned several times by participants. Students are said to lack motivation and active participation in class. Since motivation is not a measurable entity, partici-

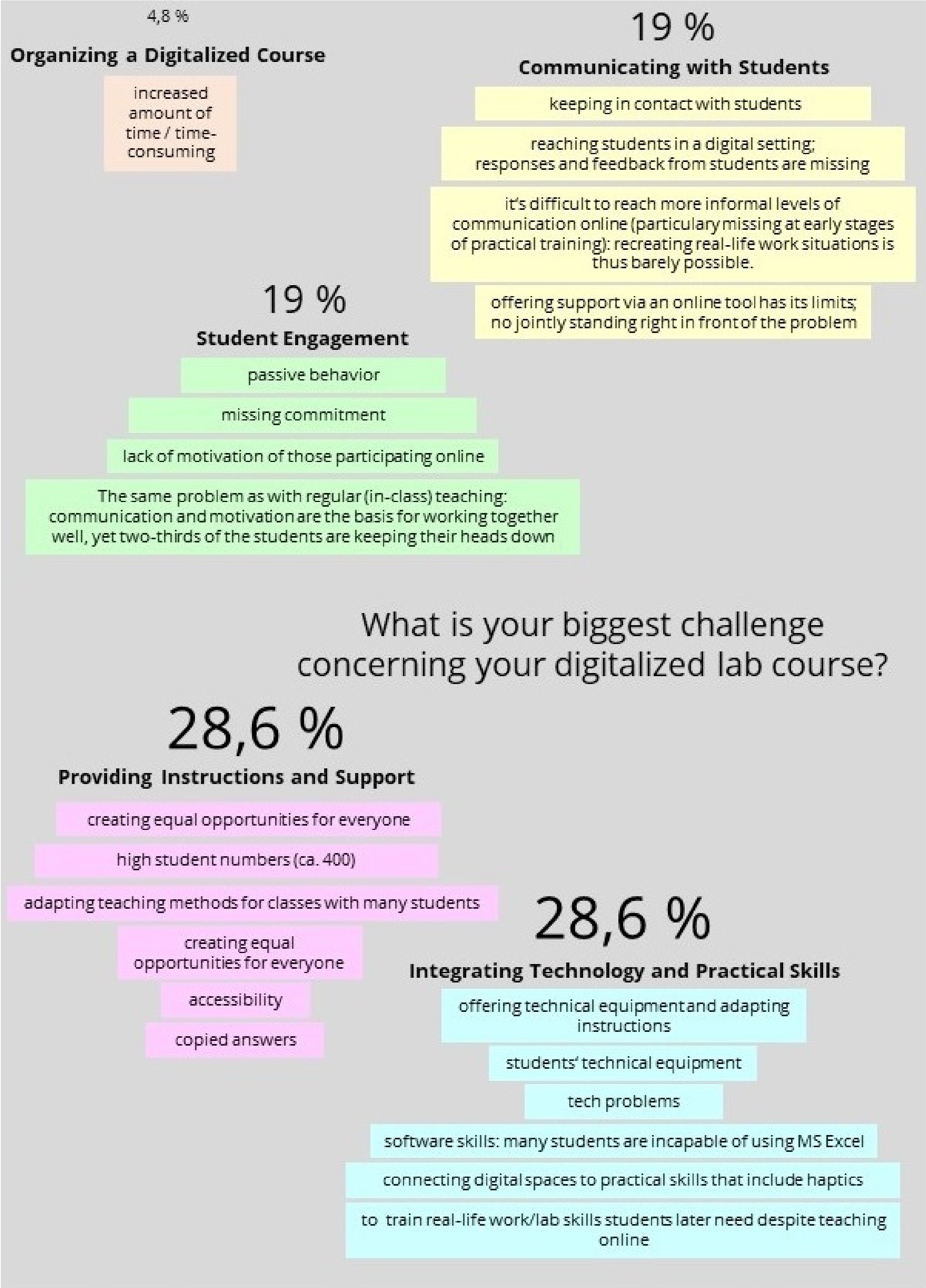

Figure 1: Results of a quick survey conducted at "Lessons Learned" conference (14th and 15th July 2022). Participants were asked, "What is your biggest challenge concerning your digitalized lab course?" Answers were provided in written form, either online (via "invote") or analogous (using file cards). In total 21 answers were handed in. The original answers are pictured in the colored boxes above; for a better overview, they were categorized subjectively. Percentage quotations show ratio of a respective category in regard to the quantity of all answers.
The survey was performed anonymously, randomly, and voluntarily. Results are not representative and do not reflect any scientific findings.

Info Box 1: Potential Reasons for Digitalization in Lab Courses

Organizational Issues

Increasing Efficiency

- Conserving resources, like time and financial means
- Automatization and optimization of processes, e.g. by using data networks or digital tools for control, organization, documentation, communication etc.

Removing Barriers

- Flexible time management for students regarding usage of lab equipment and learning material, e.g. for working or parenting students
- Location flexibility: remote teaching is possible, e.g. during a pandemic or to improve inclusivity
- Possibility to join students and teachers at other institutions and work together remotely, e.g. international collaboration
- Informatization: Creating and using digital information, e.g. learning analytics
- Improving working conditions of teachers, laboratory staff, and students, e.g. by replacing analogous with digital instruments, machines, and equipment

Didactical Issues

Improving Teaching Quality

- Increasing learning success & illustrating learning contexts, e.g. using virtual simulation
- Creating additional opportunity for exercise, trail and error and repletion of experiments to gain more insight into the learning matter
- Increase in activity during the self-instruction phase, e.g. through instruction videos or interactive screen experiments, in addition to written learning materials
- Extend variety of didactical methods, e.g. gamification as playful competition
- Addition or improvement of examination methods

Expanding Course Content

- Helping students to grasp recent methods and handling of (partially) digitalized equipment, machines, instruments, hardware as well as modern software
- Creating the possibility to work and learn remotely with laboratory facilities, machines, equipment, hardware, and software that cannot be provided locally, e.g. remote control experiments
- Training of competencies concerning the handling of digital or digitalized objects and applications in the fields of technology and communication

Increasing Practical Relevance

- Teaching methods that are relevant in regard to industry and research (in regard to 4IR, Fourth Industrial Revolution)
- Creating extensive connections of theory and practice as well as enabling more profound insight into industry and research by using digital broadcast

pants interpret and classify their students' behavior rather subjectively. It cannot be determined whether the students are, in fact, unmotivated or whether structural reasons underlie this appearance. It is all the more revealing that several instructors have chosen the term/phrase "(lack of) motivation." The answers illustrate a tendency towards student-related problem analysis. At the same time, structural problems are rarely addressed. To be clear, we do not wish to judge any of the given answers. Instead, we want to draw attention to ways in which students are discursively situated within debates about teaching. As

Info Box 2: Areas of Digitalization in Lab Courses

Laboratory environment

- Hardware digitalization:
    - digital addition to analog equipment
    - replacement of analog equipment by digital equipment
- Connecting hardware within a network
    - digital network and interaction of physical and virtual objects
        - local control (e.g. Internet of Things / IoT)
        - remote control (e.g. remote lab)
- Lab@Home:
    - students receive mobile experimentation kits (e.g. Arduino Engineering Kit)
    - students experiment with the help of home supplies (e.g. www.biotopia.net)
    - students experiment with the help of mobile digital devices like sensors of smartphones and mobile apps (e.g. MATLAB mobile, phyphox - Physical Phone Experiments)
- digital simulation:
    - of physical lab environment as (partially) virtual environment in 2D or 3D
        - local simulation (e.g. VR, AR, local simulation on screen)
        - online simulation (e.g. online simulation on screen)

Processes and Procedures

- digital documentation and illustration of processes, e.g. chemical reaction
    - audio-visual presentation only (e.g. video documentation)
    - interactive presentation (e.g. interactive screen experiments, branching scenarios, ultra concurrent remote lab)
- digital modelizing of physical objects
- digital simulation of physical processes
- digital allusion of physical processes

Data

- digital data in- and output
- digital data documentation
- digital data processing and data processing automation
- digital data transfer
- finding and using the digital data of others (e.g. from online database)

Interpersonal communication

- digitalized or digitally created learning material
- digital communication tools:
    - synchronous communication (e.g. video conference)
    - asynchronous communication (e.g. email)
    - digital organization tools
    - digital collaboration tools
- digitally supported work in groups (e.g. LabBuddy concept, multi-camera conference system)
- digital examination (e.g. online test)
- digital survey of student feedback and learning analytics

long as problems are located within the students, changes on a structural level will not take place. However, survey participants also pointed to some structural problems in their answers. Some answers emphasize that it is due to the restrictions of online tools that difficulties arise in creating informal communication in digital settings.

Some answers cannot be assigned to only one level of digitalization (cf. info box 2). Answers that address an “increased amount of time,” “lack of student commitment,” and “technical problems,” touch upon several levels (such as working environment and interpersonal communication). More detailed research would be required to determine the interaction of these different levels. It becomes clear, however, that some of the challenges mentioned are located at different levels of digitalization and must be addressed as such. Only if we distinguish different degrees and levels of digitalization can we successfully enhance digitalization in laboratory courses and meet the needs of a diverse student body. Such a distinction must take place right from the start and be part of any didactic considerations while teaching a practical lab course. More generally speaking, a gradual process that defines individual didactic challenges, considers them separately from one another and meets them step by step will be necessary to enhance digitalization in lab courses.

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Moving Beyond Mobility: Lessons Learned from a Project-Based Virtual International, Intercultural, and Interdisciplinary Collaboration

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Abstract

Der Beitrag beschäftigt sich mit dem Projekt "Collaborative International, Intercultural & Interdisciplinary Learning (COIIIL)" zwischen der Technische Universität Dresden (GER), Stellenbosch University (ZAF), Shiraz University (IRN) und Bucknell University (USA). Das Projekt bietet Einblicke in die Entwicklung von Mobilität als einzige oder primäre Form der Internationalisierung in Hochschulen und Universitäten. Der Beitrag stellt Good Practices der Zusammenarbeit innerhalb und zwischen den Institutionen dar und zeigt, wie eine interdisziplinäre Community of Practice für die digitale Internationalisierung der beteiligten Einrichtungen aufgebaut wurde. Es werden systematisch die aus dieser Zusammenarbeit gewonnen Erkenntnisse erörtert und weitere allgemeine Maßnahmen skizziert, die zu einer positiven Entwicklung der internationalen Zusammenarbeit im Hochschulbereich beitragen. Abschließend werden Schlussfolgerungen in Bezug auf die Hochschulpraxis und die Ausrichtung zukünftiger Forschung gezogen.

The paper focuses on the project "Collaborative International, Intercultural & Interdisciplinary Learning (COIIIL)" of the partner institutions Technische Universität Dresden (GER), Stellenbosch University (ZAF), Shiraz University (IRN), and Bucknell University (USA). The project offers crucial insights into moving beyond mobility as the sole or primary mode of internationalization toward an international campus. The paper presents good intra- and inter-institutional collaboration practices and demonstrates how an interdisciplinary community of practice for digital internationalization was established between the partners. It systematically discusses the 'lessons learned' from this collaboration and outlines further general measures contributing to the positive development of international cooperation in academia. Finally, conclusions are drawn regarding the practical implications and direction for future research.

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1. Introduction: Project Background

The ability to work collaboratively in international virtual teams is a crucial skill in the 21st century [1]. In this respect, the TUD COIIIL (Collaborative International, Intercultural & Interdisciplinary Learning) project was created as part of the International Virtual Academic Collaboration (IVAC, 2021) funding program, one of the three DAAD programs designed to strengthen and expand the international virtual collaboration of German universities [3]. IVAC pursued the goals of making study programs at German universities and their foreign collaborating counterparts more flexible while providing students and academic staff with expanded access to international higher education. IVAC also promoted the application of digital tools and concepts in cooperation between the partnering higher education institutions Technische Universität Dresden (Germany), Stellenbosch University (South Africa), Shiraz University (Iran), and Bucknell University (USA).

The project TUDCOIIIL offers crucial insights into moving beyond mobility as the sole or primary mode of internationalization toward a truly international campus. However, the project goes beyond pure teaching cooperation and addresses all fields of action of the internationalization strategy at a decentralized and central level. Additionally, the project's objectives are also linked to the goals of the TU Dresden's e-learning strategy and pursuing goals of the national Excellence Initiative.

Building on the previous intra- and inter-institutional collaboration, an interdisciplinary and intercultural community of practice for internationalization@home [2] and digital internationalization [4] was established during the funding period. This community of practice regularly exchanged information on all critical aspects of the topic, and documents, discussed challenges and opportunities, collected experiences and good practices, and shared expertise between the partner universities in the proposal procedures and at the project-based conferences. In addition, special digital exchange formats fostered mutual comprehension and learning in the following three tracks:

1. Academic topics and Virtual Collaborative Learning (VCL) framework;
2. Didactics of interdisciplinary, international, and virtual teaching;
3. Internationalization and development of intercultural competencies.

Academic topics and VCL framework: Virtual Collaborative Learning (VCL) has been used as a teaching format at the Chair of Business Information Systems, particularly Information Management, at the TU Dresden for over 20 years, in addition to traditional face-to-face learning processes and to transfer group learning processes into the virtual space. Small interdisciplinary and mostly international mixed groups of students work on complex, real-world problems based on specially prepared didactic case studies within 4-8 weeks in the VCL project. Figure 1 shows the general sequence of a VCL module.

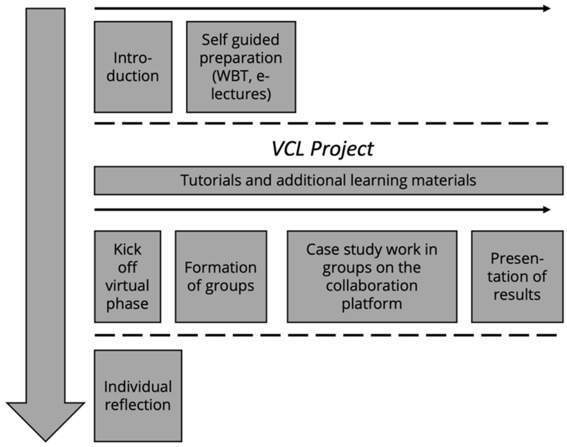

Figure 1: Sequence of VCL modules [5]

The group work in VCL modules is characterized by a high degree of self-organization and responsibility for the results and the adoption of various roles. During their group work, participants are supervised by specially qualified student e-tutors. The e-tutors are an integral part of the group and act as contact persons for all questions without being involved in solving the task. The groups' communication and documentation are carried out via customized collaboration platforms. Microsoft Teams™ is widely accepted and used as a standard collaboration software in VCL modules.

The VCL framework contributes to developing learners' 21st-century skills through the project format, collaboration, and specially prepared case studies. In particular, the focus is on enhancing virtual collaboration skills, a key competence for networked teamwork in professional life. The VCL framework offers teachers scientifically well-researched and extensively field-tested design patterns with numerous best practices for designing and developing virtual group work [5]. Teachers and e-tutors can access learner data in VCL settings regarding social learning analytics. This is enabled by analyzing the various tools and functions in the MS Teams™ environment, as shown in Figure 2.

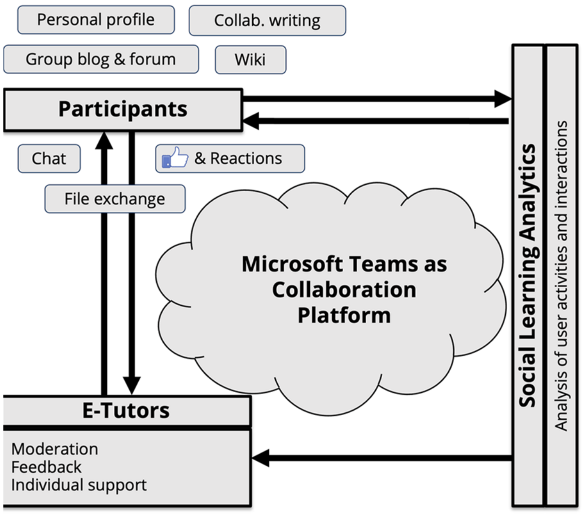

Figure 2: Social Learning Analytics on MS Teams™

This track incorporated findings from a collaboration between students at Shiraz University and TU Dresden, as well as findings from the framework transfer to students and teachers at Bucknell University.

Didactics of interdisciplinary, international, and virtual teaching: In track 2, the experiences of successful or unsuccessful interdisciplinary and intercultural cooperation were collected. These insights helped to identify and analyze best practices and systematically document them. The focus of the consideration was also the expansion of the international orientation of TU Dresden in terms of e-learning and internationalization activities.

Internationalization and development of Intercultural competencies: This activity built on Stellenbosch University's and TU Dresden's expertise in fostering intercultural understanding, supporting global learning outcomes in academic and co-curricular programs, and creating learning opportunities for students and staff from diverse backgrounds through internationalization initiatives.

Based on this, joint offers were planned and theoretically substantiated. Developing and establishing new formats is always built on previous experience to systematically tackle existing and new challenges. For example, this showed how difficult it could be to overcome different academic calendars – even in a digital context – for joint courses.

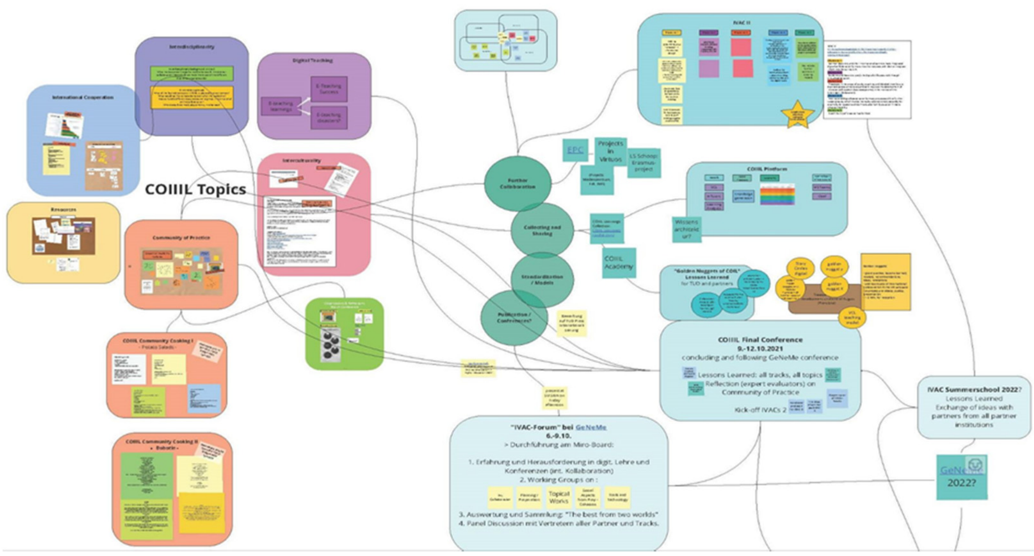

Figure 3: Screenshot of the central Miro Board™

(Digital) Collaboration: In the three tracks, the expert groups developed their own virtual, hybrid, and physical meeting culture in MS Teams™ and on Miro Board™ and fostered exchange within the group and with further experts in their respective fields. A discussion of ideas and experience was furthermore upheld between the three groups and culminated in a conference/ workshop at the end of the project phase to reflect on learnings, develop further joint projects and decide on the next expected steps. Figure 3 shows the Miro Board™, which was used as the central collaboration platform for exchanging, planning, co-creating, and documenting ideas and results.

The present paper systematically discusses the 'lessons learned' from this collaboration and outlines further general measures contributing to the positive development of international academic cooperation. Finally, conclusions are drawn regarding the practical implications and direction for future research on international university projects.

2. Lessons learned

All partners have not only developed their international exposure in teaching in the past semesters but also learned that international digital cooperation bears a considerable potential to increase the quality and intensity of partnerships – whether within one's own institution or internationally. The following reflections include the experiences of academic staff and students on teaching and learning and lessons learned from capacity-building activities that help increase digital collaboration and expand international higher education partnerships simultaneously.

It is evident that the intensity, timing, and depth of any cooperation changes in the digital realm and, as we learned, can easily be improved. This goes beyond creating or keeping teaching options within a crisis such as the recent pandemic: Internationality, interdisciplinarity, and interculturality do not only carry on as intended, but new opportunities can be created by and converge in digital collaboration processes and virtual spaces.

There are certainly also lessons to be learned on intercultural pitfalls in digital collaborations and on general limitations of these formats that keep us from reaching some goals or at least make them challenging to achieve.

It is crucial to consider varying degrees of participants' digital readiness and address them at the beginning to improve them through training during the overall process. Furthermore, the peculiarities of the virtual space and its effects, such as participants missing certain social clues, need to be cushioned by appropriate activities to get to know each other, especially at the beginning of the collaboration. Careful coordination of the activities is required to find the right balance and the proper activities fitting the composition of the consortium in terms of demographic, educational, and cultural backgrounds.

A concrete dissemination plan should be included to ensure broad visibility and thus enable external participation from the beginning. Furthermore, to ensure the sustainable application of the project's results, knowledge preservation and easily accessible resources even after the project's lifetime are of paramount importance. Lastly, regular quality assurance processes should be implemented independently from the project management to ensure we are doing what we intend to do.

Our reflection will draw on three key insights from the project:

1. Didactics of Virtual Teaching Collaboration
2. Internationalization
3. Evaluation of the Communities of Practice

Didactics of Virtual Teaching Collaboration: The project was firmly based on international collaboration, which was perceived as beneficial for all. Since it fostered multiple opportunities to increase cooperation between the different universities, the participating partners stated that the project helped them to overcome the crisis.

The transfer to the new context showed that the already existing didactic design patterns promote the transfer of VCL principles to new contexts. During this transfer and the subsequent analysis, however, it also became apparent that crucial aspects of the patterns were outdated and that it was necessary to extend them. Therefore, the patterns were revised, and the new knowledge was integrated.

The didactic design highlighted the importance of an intense preparation phase. It is necessary to prepare all partners for the exchange, e.g., by using digital tools and inclusion during the proposal preparation. The project also showed that international exchange and collaboration need time to evolve. Too many different topics and activities can hinder this development in a short time. Reflections bear crucial potential for further development and should be given time accordingly. Also, the development of collaborative courses is a process that requires intense time and resources. The project's progress clearly showed that more and more synergies could be found as time passed.

From a didactical point of view, the virtual collaboration showed the importance of possibilities for virtual social gatherings for all participants. The tool Gather.town™, used for this purpose, was praised for its social connection features, while MS Teams™ was just understood as a 'work platform' (see figure 4). The spatial chat tool and its communication possibilities had a motivating effect on virtual collaboration, which should be considered in future settings. The project also showed the importance of integrating additional practical components. Virtual collaboration is more than talking, listening, and writing. More practical activities should be included in future projects.

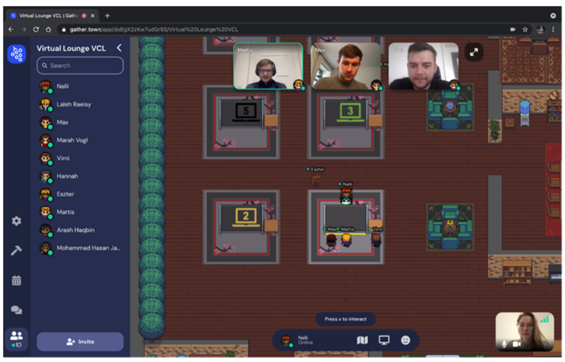

Figure 4: Networking session with students via Gather.town™ (permissions granted) [6]

The project also showed that social learning analytics are integral to analyzing socialized learning in a collaborative, intercultural, and interdisciplinary environment. The various possible analytics based on the dataset of MS 365TM were processed and iteratively refined. The visualization of analyzed user data helped the e-tutors to effectively accompany the collaborative work. Furthermore, data were used to inform the participants about their collaborative performance. In addition, text mining methods were combined with linguistic evaluation approaches to identify much-discussed main topics, emerging controversies, conflicts, and the general group atmosphere. The analysis results helped e-tutors react quickly to conflicts and provided daily overviews of the group atmosphere.

Internationalization: With the COIIIL framework, we could not only bridge the apparent gap in various ways but quite literally move beyond mobility:

During the pandemic, going virtual has helped maintain our collaboration with global partners. In many cases, it has led to working closely on a much more regular basis – even without physical meetings – than annual partner meetings did before, not to forget the time, money, and CO_2 saved by not visiting as much.

Digital internationalization also provided us with a wide range of international and intercultural learning, which does not apply only to students. Through virtual means, we were able to support international experience for diverse members of our universities, overcoming barriers we have been working on for years. Working across status groups and institutions was much more accessible. Our project's initiatives merged three perspectives: teaching, internationalization, and pedagogy. All objectives assume collaborating eye to eye, creating an inclusive and participatory process across traditional hierarchies, bottom-up rather than top-down. This, in turn, led to a broader range of results, more opportunities, and creativity.

However, our experience shows that creating this kind of partnership needs concentrated effort from the beginning, involving all sides in the application process and financial planning, rather than moving to a shared digital whiteboard once the project officially 'starts,' which will significantly contribute to developing common ownership of the project. Furthermore, maintaining a lively community of practice is not an addition but at the heart of the project since it creates an alliance across distances. An online community also shows real and perceived borders, such as questions of national data protection or the prohibition of using specific digital tools and platforms, which can always threaten internationality and creativity.

Using virtual internationalization sustainably and strategically can afford us a whole new outlook and create the type of visibility and transparency and thus tackle some of the longstanding challenges of internationalization, such as questions of decentralized or even mainstreamed internationalization and the resulting future role and responsibilities of (central) International Offices at universities. Looking at this question through the lens of digital internationalization, rather than asking where it should start and end, we might consider the potential of a central unit collecting, sharing, and growing information and programs as well as creating knowledge transfer and thus contributing to a better understanding and support of an institution's internationalization, bringing together bottom-up initiatives with top-down strategic developments. Lastly, professional coordination of digital initiatives from the proposal process onwards may create opportunities that would not be viable considering traditional resources of time and finances.

Evaluation of the Communities of Practice: The communities of practice were evaluated in a series of formative and summative assessment procedures [7]. As presented in figure 5, the methodology comprised several instruments of data collection: participant observation in the COIIIL project space, a short survey during the project meetings, three focus group discussions with project representatives from the main participating universities (TU Dresden, Stellenbosch University, and Shiraz University), and four semi-structured individual interviews with participants who held different positions within the VCL module (instructors, e-tutors, and participants). The data were consequently subjected to qualitative content analysis. Based on the findings, the evaluators provided feedback on the overall progress of the project and the VCLs as its distinct part. It concerned (a) the needs and requirements of different target groups in the project, (b) the connection between the different tracks, (c) modes of communication and interaction within the project, and (d) discussion about the stakeholders' different perspectives on interculturality.

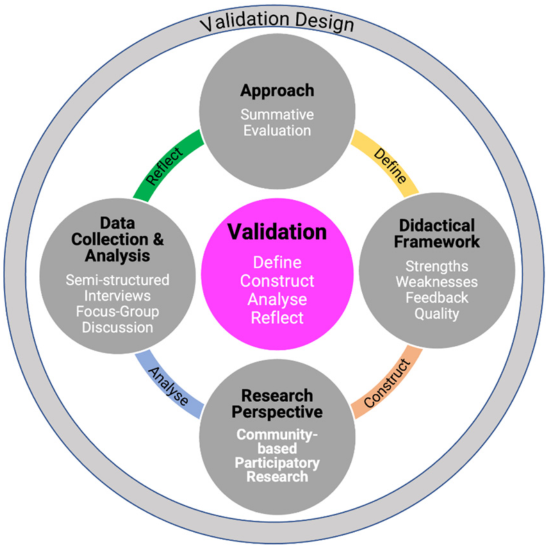

Figure 5: Validation framework for evaluating communities of practice (CC BY 4.0) [7]

The evaluation highlighted the following findings. First, the virtual collaboration enabled a colloquial exchange and helped the participants to develop intercultural communication competencies. However, the participants also experienced numerous challenges, e.g., in dealing with different role expectations and academic hierarchies. As a basic condition and requirement for such projects, it needs to be ensured that all participants have equal access to the learning community, infrastructure, and resources.

Second, online collaboration was understood as a 'cost- and time-effective' way for simultaneous conversation and instant exchange of ideas on digital platforms (MS Teams™, Miro Board™, Gather.town™). Yet a decision for or against a digital tool is not a purely technical question. Its conscious selection and purposeful use are of vital importance since it supports the development of communities of practice in particular: e.g., Gather.town™ "to create closer relationship to the members in general, the community members" and MS Teams™ "to be used for work" and beneficial for group discussion (group discussion). Every decision about digital tools is also related to possible experiences of inclusion or exclusion covered by the umbrella term 'digital divide,' which reflects the potential inequalities ensuing from demographic, social, economic, and cultural factors as well as personal attributes (e.g., 'digital natives' vs. 'digital immigrants' as an age-related distinction in terms of tech-savviness and media literacy). This issue also ties in with the recognition that the use of computer-mediated communication and digital tools in teaching and learning is anything but culture-neutral (just as the design and the specific features these tools contain are also culture-specific) and subliminal power-related biases that result from there have been one further critical finding.

Third, international collaboration was commonly experienced as enriching and 'future-oriented'. Participants expressed their awe at the tangible prospects of cooperating across national borders and between different geographical areas: "to see it actually work [at] that level [was illuminating]" (group discussion). The pitfalls of internationality (understood as distinct from 'national cultures') included the necessity to account for different time zones, to synchronize the academic calendars (foremost in the VCL modules), and to reconcile divergent global agendas (especially concerning the 'Global North' vs. 'Global South' issue).

Fourth, the participants also emphasized the interdisciplinary aspects of collaboration. Despite the challenges of differing discipline-specific terminologies, methodologies, and perspectives (e.g., regarding 'interculturality' as one of the common concerns), the project had largely contributed to the participant's professional and personal growth due to the cross-disciplinary peer exchange and the broadening of outlook it entailed.

Fifth, the participants also benefited from the project in terms of intercultural learning. For one thing, the intercultural aspects involved such classical issues as 'country-specific' time regimes or preferred patterns of communication (e.g., a preference for oral rather than written exchange or spontaneous rather than pre-scheduled meetings). In this regard, the participants cited several widespread stereotypes (e.g., "German punctuality" or the alleged "aloofness" of people from Western cultures), which they, however, often revised in the light of their recent practical experiences. For another thing, intercultural differences likewise stemmed from other domains, such as organizational cultures: while the "startup mentality" dictated, for instance, the use of cell phone messages/ voicemail, this stood in stark opposition to the sentiment of "academic propriety," which regarded it as an inappropriate display of urgency and favored emails as a legitimate communication instrument in professional contexts. Furthermore, 'culture' was also frequently related to language issues: the interviewees critically addressed differing levels of linguistic proficiency and sometimes different local accents in English as the lingua franca.

On the whole, these findings show that an effort needs to be made to involve all partners already at an early stage of the project, e.g., in the preparation of the proposal, agreement on the digital platform(s)/ channels of communication, or in the identification of common goals and expectations, thus enabling them to optimally use the (relatively short) time during the project itself: "the only pity for me is that the project is so short because it feels to me that we are picking up momentum now [and] we were able to identify very interestingly, important synergies" (group discussion). Furthermore, future projects would also benefit from cross-institutional and cross-disciplinary blueprints for virtual collaboration, e.g., "models, official models and verified models that can be used by many people around the world" (group discussion).

Additionally, some conclusions could also be drawn regarding the implementation of virtual collaborative learning (VCLs) into study programs: (1) It is important to develop and optimize the selection criteria in terms of language skills and personal motivation; (2) Sufficient time and resources need to be allocated for multi-level team building to foster interpersonal communication; (3) Regarding their foremost binational orientation, VCLs will benefit much from the integration of explicit and implicit intercultural/ area study elements in the course structure (e.g., cultural events/ presentations, reflection on/ discussion of culturally biased communication patterns); (4) Since e-tutors play an important role in the entire collaborative project, their actual role needs to distribute individual responsibilities both to them and to the participating students at all times. Specific preparation of e-tutors for their assignment in VCL courses includes fostering their autonomy and creativity in task-solving and supporting ethical decision-making.

3. Conclusions: Moving beyond mobility

In this concluding part of the paper, we discuss and suggest a few best practices, conditions, and requirements for successfully implementing such international projects within and between universities. We consider different levels of implementation: methods and approaches for creating a community of practice, theoretical and academic development, practical recommendations, and future research perspectives.

Creating a community of practice: For successful project-based collaboration in an international consortium, it is important to make strategic decisions early on so that all partners can consciously and committedly support the project's goals. For this purpose, a jointly prepared Mission & Vision Statement should present the consortium's goals and objectives understandably and clearly. Furthermore, it is advisable to discuss and co-create the statement with the entire project consortium and obtain feedback to achieve clarity about the jointly aspired goals from the beginning. Also, in the project's initial phase, regular meetings, e.g., in the format of jour fixes. These meetings are vital for academic sustainability and the possible development of new projects building on the previous one and should take place beyond the project's end date. It is also advisable to define the responsibilities for planning, implementing, and documenting these activities and to set up a leaderboard. Furthermore, it must be regularly ensured that all partners are willing to invest the required time and show commitment to the project. It is especially important to involve all partners in decision-making situations.

To ensure a seamless collaboration of the actors in the project, close attention should be paid to the technical equipment for the implementation of the online activities and a contact point for support for these. Technical requirements and possibilities for online and hybrid communication should be discussed and tested in advance so that mishaps can be reduced to a minimum and the focus can thus be placed more on the project's content during the synchronous activities.

Theoretical and academic development: Regular training should be offered throughout the project for a common ontology and to acquire further competencies for institutional internationalization. Each international collaboration between academic and administrative staff holds unique potentials and challenges that can be exploited through a common knowledge base and competencies. A regular exchange between the actors and experts in the project via status groups also lends itself to this. This ensures a constant flow of information, and indifferences can be uncovered and dealt with at an early stage.

An empirical evaluation of the community of practice should be carried out to make the findings from the collaboration in the project available to future consortia. This way, good experiences can be passed on, and recommendations for hands-on optimization workflow processes in future communities can be made visible. The empirical evaluation should be understood as an iterative process with the goal of continuous improvement. Thus, the creation of lessons learned in an easily reusable format should not be missing. In this regard, the presentation as pedagogical patterns can be an appropriate option.

Practical recommendations: To 'move beyond mobility,' a commitment of all partners to the project is crucial in achieving the desired goals. Regular meetings and proper documentation of such, as well as a results-oriented project management plan which can be easily adapted to new decisions of the consortium, allow fluent processing of the project for the involved actors.

It became evident that differences in the directness of communication in the internationally mixed groups made automated identification of conflicts difficult using social learning analytics. Further research should analyze how other communication cultures influence the use of linguistic evaluation mechanisms and how these could be adapted if necessary.

Future research directions: Furthermore, future studies need to focus on the long-term effects of international, interdisciplinary, and intercultural collaborative virtual projects, especially concerning the quality of communication, further development of partnership, transfer of knowledge, etc. This research could also be extended to different perceptions of time, goals, and ambitions, as well as the use of physical and virtual spaces.

"Moving beyond" has been the main driver for the development of our project. Although intercultural theory and practice, practical and political aspects were considered and promoted in the collaboration, the limitations of this international exchange have become apparent and ask for even more consideration in future collaborations.

At the same time, we must ask ourselves whether only 'the sky is the limit' - or when thinking virtuality, not even that? How will we consider our limited resources of time and personnel, and how will we encounter limits of involvement and creativity?

While we successfully developed a truly international community with learning opportunities for all bottom-up, at what time do we need top-down support, i.e., to bring it all together and further a more strategic development?

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Digital Mindset as the Most Important Prerequisite for Learning and Teaching in the Future

Further development of student digital literacy: An interdisciplinary perspective

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Abstract

In order to successfully integrate new, digital teaching and learning formats into university teaching, not only technical, financial, and structural prerequisites must be created, but also competence-related prerequisites that enable students to deal with the new formats. In an interdisciplinary project, we derive 64 relevant digital competencies from interviews and a questionnaire study, considering the perspectives of teachers and students. As a result, a pronounced digital mindset emerges as the most important component.

In order to successfully integrate new, digital teaching and learning formats into university teaching, not only technical, financial, and structural prerequisites must be created, but also competence-related prerequisites that enable students to deal with the new formats. In an interdisciplinary project, we derive 64 relevant digital competencies from interviews and a questionnaire study, considering the perspectives of teachers and students. As a result, a distinctive digital mindset emerges as the most important component.

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1. Motivation

What digital skills do students need when dealing with new, digital teaching/learning formats? This question is being researched in the sub-project "sTUDents - student-oriented digital learning and teaching", one of a total of eight sub-projects in the interdisciplinary joint project "virTUos - virtual teaching and learning at the TU Dresden in an open source context", in which innovative teaching/learning formats are being developed using gamification, VR technology and robotics, among other things, in order to be introduced into everyday university life after a successful trial phase.

To this end, agile and interdisciplinary innovation teams from the departments of medicine, mechanical engineering, economics, and humanities will initially test the novel virtual and hybrid teaching/learning scenarios and then disseminate them to other departments. The central goal is the development of a common strategy for digitally supported learning and teaching at the TU Dresden. For this purpose, all prerequisites that are necessary for the successful establishment of the new formats in the university context are analyzed, including technical, financial and structural prerequisites. sTUDents approaches the objective from a further perspective and examines the competence-oriented prerequisites that are necessary on the part of the students in order to be able to benefit maximally from the new formats in the learning process.

In recent years, the training of digital skills in the university context has become increasingly important in order to prepare learners for the future challenges in everyday working life, so that universities are increasingly creating corresponding offerings [1,2]. This process was accelerated by the pandemic in order to be able to continue to use the digitalization efforts that have been initiated in the long term. Within the framework of virTUos, we want to contribute to researching the current need for student digital competencies in order to enable learners and teachers to perceive digitally supported teaching as an opportunity and not as a hurdle in the long term.

In this context, it is also important to delineate which competencies are actually digital competencies. Digital competencies are "... Skills that enable people to navigate and actively participate in a digitized environment" as defined by the Stifterverband [3]. The European Reference Framework for Digital Competences (DigComp) 2017 describes digital competences as "understanding information and data; communication and collaboration; creating digital content; security of devices, personal data and the environment when using digital technologies; problem solving strategies" [4]. However, according to Kerres (2017), these are not additional competencies, but pervasive skills of the previous learning world [5]. Consequently, "digital competence[s] ... are the ability[s] to use digital media, to develop them in a productive way, to use them for one's own life, and to understand reflectively, critically, and analytically their mode of action in relation to the individual and society as a whole, as well as knowledge about the potentials and limitations of digital media and their modes of action." [6].

In the context of the project, we take the definitional approaches listed here as a basis for exploring the competencies needed by students in the university environment of the future.

The question of the necessary digital competencies is inevitably followed by the question of their concrete training and further development. Since this is significantly influenced by the needs of students as the central target group, it is essential to involve students already in the development of the competence development formats.

2. Procedure

In order to approach the question of the necessary digital competencies, interviews were conducted with academic and student employees from all subprojects to collect the digital competencies that are considered necessary for the successful integration of the developed formats into everyday teaching.
In the next step, the results were critically reflected on the basis of the above-mentioned definitions and those competencies that cannot be specifically classified as digital competencies as well as duplications were removed. In this way, the total of 90 mentions was reduced to 64 items. In order to be able to struc-

ture the future offerings for competence transfer thematically in a meaningful way, the items were finally clustered and classified into the four categories: "Digital Mindset and Reflection", "Technical Knowledge", "Digital Teaching", and "Virtual Communication and Collaboration", whereby there is no claim to selectivity between the individual categories.

For capacity reasons, the remaining high number of 64 items necessitated prioritization, which will be used to guide the successive development of the competency development formats in the future. To this end, project staff were invited to select from all the digital competencies identified up to this point those that are relevant in their individual project contexts. In contrast to the first survey, which was carried out on a subproject-specific basis, it was now also possible to consider responses from other subprojects. After quantitative evaluation of the feedback, a ranking was finally produced. An overview of the methodological procedure is shown again in Figure 1.

The core of the sTUDents subproject then begins by involving students from the outset in the development of the innovative formats as well as the formats for the necessary competence development in accordance with the "Students as Partners" approach, in addition to teachers and university didacticians, and thus creating offers that are suitable for the target group [7].

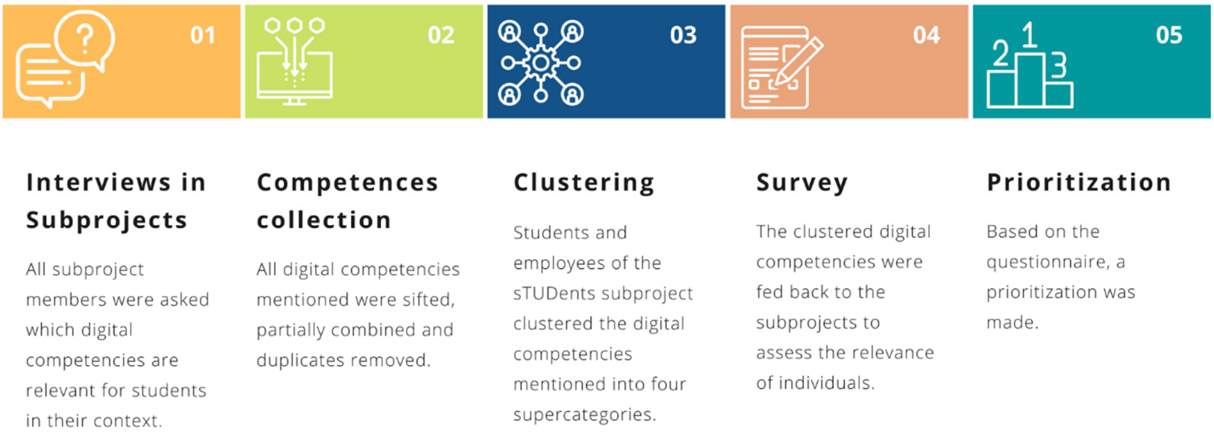

Fig. 1: Methodical procedure

3. Results

First of all, the interviews revealed how diverse and complex the field of digital competencies is and how they differ from those competencies that do not relate specifically to digital aspects. While proficient use of a learning platform or mastery of a programming language can be clearly assigned to digital competencies, self-organization, communication skills, and conflict management are competencies that were already important in traditional learning settings but are increasingly shifting to the digital realm.

In the in-depth analysis of digital skills, it becomes clear that about two-thirds are soft skills and about one-third are hard skills.

Quantitatively, the majority of the mentions from the interviews could be assigned to the category "Digital Mindset and Reflection" (see Fig. 2) and were confirmed once again by the contributors to the subprojects as the most relevant aspects in their areas of expertise during the questionnaire study.

This category includes competencies such as "acceptance of digital formats", "self-efficacy in digital learning processes" and "media resilience". The explicit naming of these competencies is surprising, as they are common to the so-called "digital natives," a generation, who has grown up in a digital world are often ascribed as a matter of course [8,9].

Based on the surveys in the departments and fields of action of virTUos, it can be deduced that a digital mindset and reflection competencies in their entirety are regarded as the core competencies in future everyday learning and work.

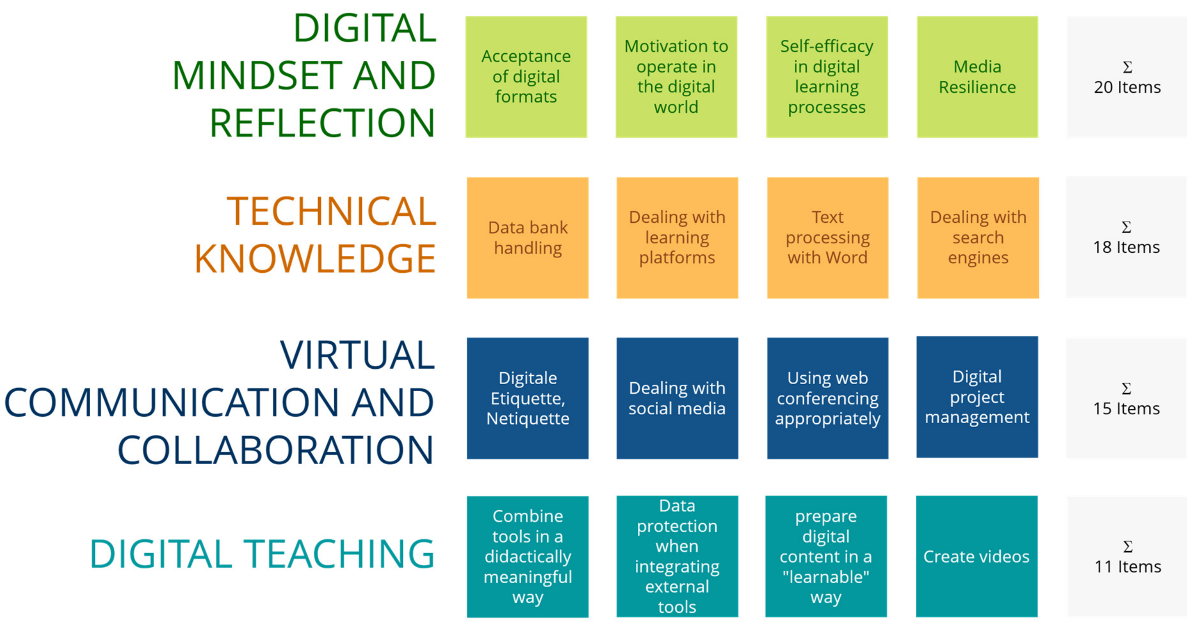

Fig. 2: Categorization of digital competencies

4. Implications

From the insights gained, we derive the mission to support students in particular in developing a digital and reflective mindset. It can be assumed that students who have competencies such as flexibility and openness in dealing with digital innovations will find it easier to access more specific competencies. The digital transformation imperatively requires the acquisition of new technological skills, for which an open-minded inner attitude and the perception of new possibilities of digitalization are fundamental. Companies increasingly need professionals who understand digital technologies, use digital tools to solve problems and act flexibly. In the next few years
cultivating a digital mindset will continue to be a major challenge, but one that holds a lot of potential: students benefit from acquiring transferable skills when they enter the workforce. In addition to higher productivity and satisfaction, studies highlight the positive impact on resilience [10]. Individuals with a strong digital mind set are less responsive to technological stressors, reducing the risk of reduced work and learning performance, lower job satisfaction, and higher dropout rates [11]. As current research findings show, forming the digital mindset is a top-down process [12]. Accordingly, university administrators and teachers should set a good example by acting sustainably and reflectively with digital media and enriching their teaching methods with open science and open education efforts.

For these reasons and the expected positive effects, the sTUDents subproject is taking on the challenge of equipping learners and, as a consequence, teachers with an open digital mindset and motivating them to actively participate in the digitization of university teaching and to act as role models in order to jointly achieve efficient ways of working with the support of digital media. For this purpose, existing artifacts will be collected as well as new artifacts will be created that address and educate this mindset. In doing so, we initially focus on the needs and priorities of the subprojects and increasingly expand them to other subject areas. The developed formats will be successively compiled in the OPAL course "Driver's License Digital Competencies" as well as addressed to students in workshops and subsequently made available for sustainable use as OER. The entire development process is largely shaped by students themselves and is based on studies on teaching/learning formats that have been proven to be conducive to learning or preferred by students in the context of university teaching [13,14].

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