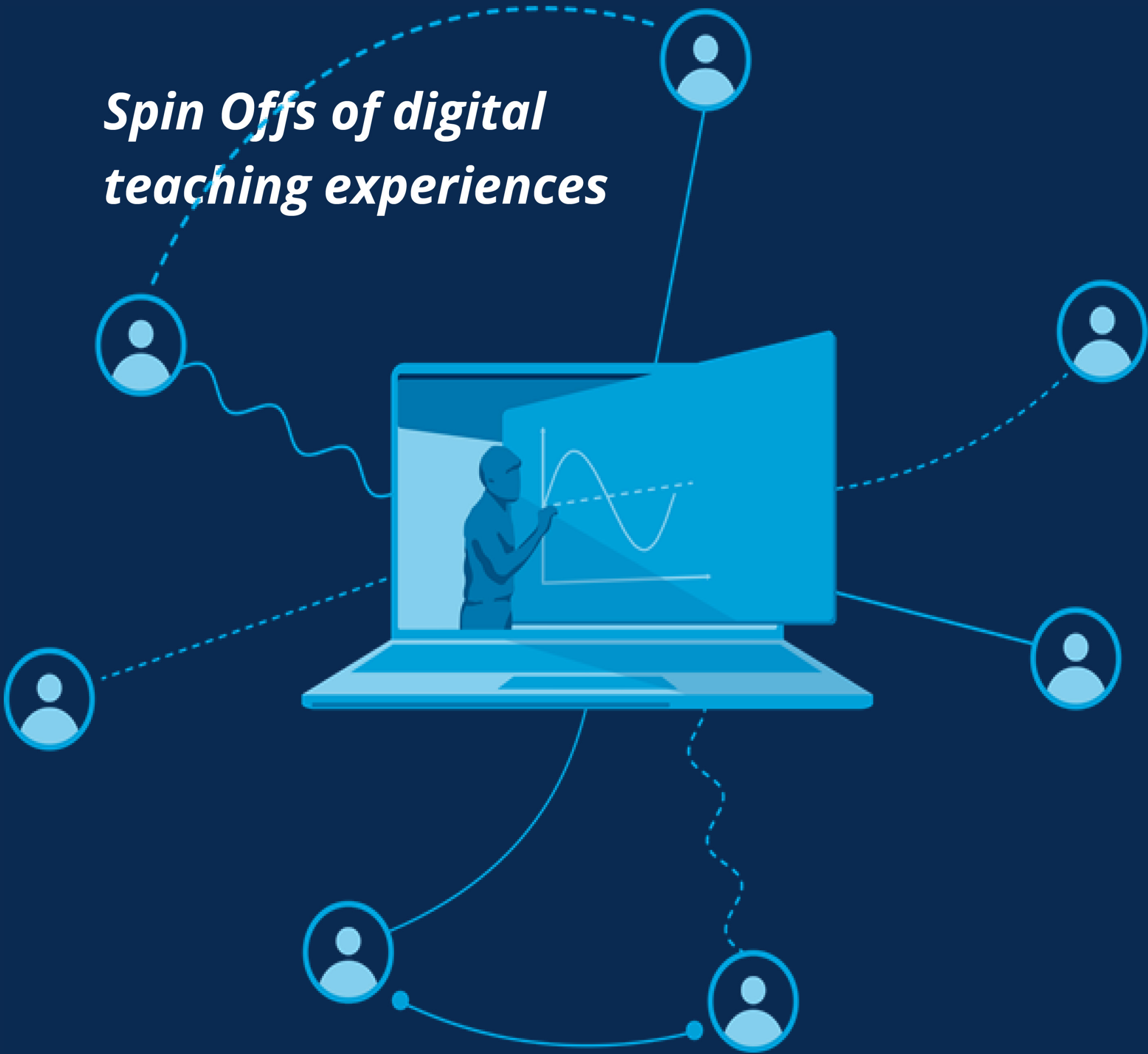
TECHNISCHE UNIVERSITÄT DRESDEN

Lessons Learned

Spin Offs of digital teaching experiences



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About the Journal

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

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

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Editorial

Issue five of the ***Lessons Learned Journal***, the first issue in the third volume - this issue contains the second part of the fourth ***Lessons Learned conference*** from the summer of 2022. The division of the contributions from the last ***Lessons Learned conference*** de-stresses the preparation of manuscripts after the conference. This allows many authors to much more easily prepare their manuscripts at their leisure than would be the case in a situation where all papers would necessarily be available a few weeks after the conference. Therefore, this structure of dividing contributions into two issues will be maintained. The issue to be published in winter 2023 will contain initial articles from the fifth ***Lessons Learned conference*** in summer 2023. All further contributions to this conference will then appear in the first half of 2024.

In terms of content, this issue is divided into two core blocks. On the one hand, it contains a number of methodological aspects that once again expand the toolbox with which one can try out modern novel concepts in teaching in one's own everyday teaching. From reading logs, which are intended to support the self-study process, to a podcast project for students and asynchronous hybrid lab courses, to concepts that go under the heading of gaming, a wide variety of concept ideas are presented here and described in such a way that you can experiment with them yourself in your teaching.

The other large block of topics deals with the increasingly important issue of blended learning. Here, the headings of the articles already show that such concepts which combine digital and presence elements, synchronous and asynchronous aspects and the most diverse forms of teaching/learning are complex in their design and are definitely not uniformly defined. Whether one speaks of blended learning, inverted classroom or other terms used in this context is still almost arbitrary at the moment, as there are actually no fixed definitions. This makes it difficult to find examples for the design of own concepts. With the four articles that appear in this issue, a broad spectrum of possibilities is shown and it also becomes clear where problems can arise. In any case, this is a topic that will have a firm place in teaching development in the coming years.

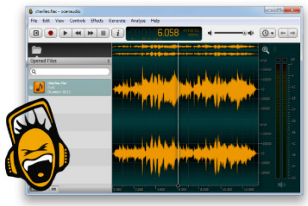
The issue opens with the topic of Open Educational Resources (OER) - a decidedly important thematic block: the free distribution of teaching/learning materials is a core source for disseminating novel teaching/learning concepts. In some ways, the ***Lessons Learned conferences*** and the associated journal are an ideal example of how a free exchange of ideas in teaching is possible and can be successful. But providing concrete materials is a bit more complicated than describing the teaching concepts. Issues of platforms, promotion of content, and its licensing open up a complex field that requires competent partners who can advise faculty on these issues. These are usually the university libraries - in the case of Dresden, the Saxon State and University Library (SLUB). Only the interaction of all forces can, in the long run, advance the modernization of teaching and keep it dynamic; and this dynamic will determine whether the dynamic modernization process that university teaching has been experiencing for the past three years will continue and lead to an overall modernized university teaching.

With this in mind, we are looking forward to the fifth ***Lessons Learned Conference,*** which will begin in a few days. New ideas, many discussions and exciting reports in the ***Lessons Learned Journal*** are to be expected.

Stefan Odenbach

Range of topics

Novel formats



Novel teaching/learning formats are one of the great achievements of the pandemic-driven renewal of teaching. The continuation of the development of new techniques in teaching can be the actuator for the further development of university teaching as a whole.

Blended learning formats

Among the most frequently used terms in the context of renewing university teaching are blended learning and inverted classroom. The contributions show how diverse this can be.

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SLUB Dresden as a hybrid learning center in the project virTUos

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Abstract

As the university library of the TU Dresden, the Saxon State Library - Dresden State and University Library (SLUB) supports its development of a hybrid teaching offer that combines analog and digital settings with the principles of openness and sustainability. Digital learning and teaching at the TU Dresden receives a resounding boost with the new program "virTUos" (Virtual Teaching and Learning at the TU Dresden in an Open Source Context); the emphasis is on the suffix -OS. As a state library, SLUB Dresden is working together with the Saxony Center for Higher Education Didactics (HDS) on a state-wide digital strategy for studying and teaching that is committed to the FAIR criteria under the umbrella of Open Science.

Als Universitätsbibliothek der TU Dresden unterstützt die Sächsische Landesbibliothek – Staats- und Universitätsbibliothek Dresden (SLUB) deren Entwicklung eines hybriden Lehrangebotes, das analoge und digitale Settings mit den Prinzipien von Offenheit und Nachhaltigkeit vereint. Das digitale Lernen und Lehren an der TU Dresden erhält mit dem neuen Programm „virTUos“ (Virtuelles Lehren und Lernen an der TU Dresden im Open Source-Kontext) eine klangvolle Stärkung; die Betonung liegt dabei auf der Endung -OS. Als Landesbibliothek arbeitet die SLUB Dresden gemeinsam mit dem Hochschuldidaktischen Zentrum Sachsen (HDS) an einer landesweiten digitalen Strategie für Studium und Lehre, die unter dem Dach von Open Science den FAIR-Kriterien verpflichtet ist.

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This article was originally submitted in German.

1. Publishing in an open scientific culture

Science policy is committed to the principles of openness and sustainability in order to make scientific processes and results more transparent, thereby ensuring quality and increasing social relevance. The new criteria based on Open Science pose major challenges for institutions in teaching, research, education and outreach, and require not only the necessary information technology systems but also an adapted evaluation system for measuring scientific performance. Governance must therefore be followed by sensitive change management in the scientific culture, which exemplifies an open attitude in (the) conduct of scientific practices and jointly tests and continuously improves them as a learning organization: no Open Science without Open Mind.

In their joint Open Access Resolution, the Dresden University of Technology (TUD) and the Saxon State Library - Dresden State and University Library (SLUB) commit themselves to openness and free availability of scientific publications. They are thus acting in a discourse space that already 20 years ago with the Berlin Declaration [1] pursued the goal of transformation from paid access via publisher distribution (closed access) to free access (open access) of research publications. The transformation initially consisted of replacing the purchase price for the exploitation of rights with a purchase price for the publication. In both cases, money flows to the publisher: in closed access, the trade and libraries pay for the acquisition of the publication; in open access, the authors pay the publisher for including the title in its program and then making it available free of charge. Publishers quickly adapted their business model to the new requirements and achieve high profit margins despite or thanks to the OA transformation. If it is a renowned publisher, authors in the OA process acquire for their money not only open access to their publication for all, but in addition the reputation associated with the publisher's name, which increases their impact factor and is relevant for measuring the performance of their scientific work. Through the Open Access Publication Fund provided by the DFG, researchers receive pro-rata financial support for their OA publications within the commercial publishing industry.

In 2014, the German Rectors' Conference was commissioned by the Alliance of German Science Organizations to launch the DEAL project to negotiate transformative nationwide "publish and read" agreements with the largest commercial publishers of scholarly journals on behalf of all German academic institutions, including universities, universities of applied sciences, research institutions, and state and regional libraries.

The DEAL negotiations aim to make all publications by authors from German institutions automatically open access, while guaranteeing attribution (CC-BY) and peer review. The DEAL institutions are to receive permanent full-text access to the entire title portfolio (e-journals) of the selected publishers as well as a pricing model based on the volume of publications ("publish & read model"). While DEAL agreements have been successfully negotiated with Wiley and Springer Nature, they have yet to be concluded with Elsevier.

At the same time, the scientific community is stepping up its efforts to make OA publishing commercially free and publicly owned. Research institutions, together with their academic libraries, are developing their own digital publishing infrastructures that not only host the finished pdf files and provide free access, but also support the entire publishing process from writing to editing and typesetting or layout to scientific quality assurance through review procedures. Heidelberg University Publishing [2] was the pioneer for publishing support independent of publishers, primarily in the humanities. In the meantime, TIB Hannover provides non-commercial publishing services with TIB Open Publishing, preferably for publications in the natural sciences and technology. [3] The new Open Access publisher Berlin Universities Publishing (BerlinUP) is operated by the Berlin University Alliance (BUA). [4] The Freie Universität Berlin, the Humboldt-Universität zu Berlin, the Technische Universität Berlin, and the Charité - Universitätsmedizin Berlin have joined forces to form this alliance. BerlinUP enables the scientists of the four institutions to publish the results of their research activities in quality-assured books and journals and supports them with corresponding consulting services. As one of the largest academic libraries in Germany, SLUB Dresden also offers publisher-independent, quality-assured, and sustainable OA publishing services and will continuously expanding both its technical infrastructure and consulting services.

According to the Council of Science and Humanities, the transformation of scientific publishing should be completed within the next few years, and the open publication of scientific results should become the standard, thereby increasing the quality of scientific research and accelerating scientific progress. Open access should also make scientific findings more readily available outside the scientific community, so that an increased transfer performance and higher social effectiveness of science can be achieved. Finally, competition among commercial and public publication service providers should reduce the unique position of publishers and improve the negotiating position of scientific research institutions vis-à-vis publishers. Overall, this transformation process aims to improve the innovativeness, cost transparency, and cost efficiency of the publication system, summarizes the Council of Science and Humanities in the position paper "Recommendations for the Transformation of Scientific Publishing to Open Access" [5]. It recommends first establishing sufficiently adequate and inclusive OA publishing conditions, and then extending the rules of good scientific practice to include OA publishing. In doing so, it follows the commitment to OA and Open Science in the coalition agreement 2021-2025 of the current German government [6] as well as the UNESCO Recommendation on Open Science [7] at the international level.

While Open Access initially focused on open access to scientific publications, Open Science also targets the upstream and downstream processes of scientific work and publishing. Accordingly, in its most recent position paper, the DFG considers Open Science to be an integral part of the overarching discourse on scientific culture. [8] In the sense of good scientific practice, Open Science practices enable processes of quality assurance, reproducibility and replicability in addition to facilitating the acquisition of knowledge, as they contribute to better traceability of methods and results. In addition to open access to scientific and scholarly publications, the DFG is therefore focusing on open data, research and infrastructure software (open code) and their legally protected subsequent use.

According to the DFG, the term "open science" is associated with high expectations of science. In order to be able to meet these expectations, awareness must first be raised of the fact that, in the context of open research, all actors, from researchers to infrastructural institutions to data intermediaries, bear a greater responsibility: not only with regard to the selection of publication organs and portals for publication, but also with regard to the curation of research data, metadata and contextual information. In addition, within the framework of Open Science, the group of users will be given greater responsibility, on the one hand with regard to research and legally secured subsequent use, and on the other hand with regard to checking and interpreting the freely accessible information. These preconditions must now be developed and ensured on an individual level through suitable training and educational measures and on an institutional level through incentive and support structures in the scientific environment. SLUB Dresden reacted to this by opening the Open Science Lab, where trained staff (data stewards) provide a corresponding range of consulting and training services to support research.

The DFG also calls on the scientific institutions to develop appropriate governance in order to establish the necessary infrastructures for open science on a binding basis. In its most recent position paper, it also critically discusses the performance measurement of scientific work, which is (still) intertwined with the publication system. [9] The international initiatives "San Francisco Declaration on Research Assessment" (DORA) [10] and "Coalition for Advancing Research Assessment" (CoARA) [11] are working on the development of alternative models.

To what extent can these challenges posed by Open Science and the associated tasks for scientific institutions be transferred to the field of teaching and learning?

2. Publish open teaching and learning materials

It is surprising, after the commitments to Open Access and Open Science cited above, that the German Council of Science and Humanities makes no direct reference to this in its "Recommendations for a Sustainable Design of Teaching and Learning" [12], assuming that scientific teaching should aim at training researchers in the context of Open Science. However, it does address some of the challenges posed by facilitated digital access:

"The digital transformation is fundamentally changing educational processes and knowledge cultures. Today, an overabundance of information is available whose reliability, quality and truth content are not sorted and evaluated by any authority. In the future, a course of study should therefore enable students even more than before to evaluate and contextualize information and to acquire new knowledge independently. This will also create conditions to prepare students for lifelong learning." [12]

Surprisingly, open educational resources (OER) do not play a significant role in the recommendations. Only in the subchapter "Teaching as a collaborative task" [12] is the sharing and mutual review of OER mentioned among other recommendations for cooperative division of labor. The use of OER is recommended here as a means to the end of making work easier in the face of high student numbers. Other benefits cited in the use of OER include the increased reputation of instructors due to greater visibility, as well as the associated opportunity for financial support from the university. Even if only in passing, transparency as a relevant criterion in the context of Open Science is mentioned, as well as quality assurance through peer review. Finally, the Council of Science and Humanities points to the still outstanding and to be adjusted assessment of the teaching load, since the production and adaptation of OER are not adequately taken into account in contrast to face-to-face courses. [12]

Although the "Recommendations for a Sustainable Design of Teaching and Learning" of the German Council of Science and Humanities are still far from the expectation of an open standard for OER to be established as in the case of Open Access, open access to teaching and learning materials is under the same auspices as open access to research publications and will have to develop accordingly under the umbrella of Open Science as a standard.

At TU Dresden, therefore, an initiative has emerged that highlights the benefits of OER and pursues the goal of an OER policy by the university management, which ties in with the joint Open Access Resolution of TU Dresden and SLUB Dresden. [13] On the one hand, the stakeholders point out that knowledge created in an open scientific culture must be available to all and that OERs play an important role in this. On the other hand, in increasingly complex teaching and research contexts, constructive cooperation between teachers and learners under a common objective in new communities of practice will be very important for the significance that teaching and research locations can have in the international higher education landscape in the future. With an agreement on OERs to be striven for, they want to lay a foundation for contributions from teaching and research in education and outreach to the knowledge society of the 21st century.

Together with SLUB Dresden and the Center for Interdisciplinary Teaching and Learning (ZiLL) at TU Dresden, they would like to create the framework for this. Teaching and learning materials used at TU Dresden should be freely available as Open Educational Resources (OERs), publicly accessible and barrier-free.

SLUB is monitoring the data management of OER: it indexes the metadata of OERs and ensures their cataloging in order to meet the internationally valid FAIR criteria: Findable, Accessible, Interoperable, Re-usable. For teachers at TU Dresden, SLUB offers support in license management and technical issues in the course of creating and publishing their own OERs, while ZiLL assists in the didactic conception of OERs. The advantages of OER are summarized by the stakeholders in the cited position paper:

The increasing dissemination of OERs helps teachers to create qualitative teaching materials more quickly, as they can draw on a large and diverse range of open sources. This gives them more time for research and innovation in teaching. As with scholarly publications, making re-used content recognizable contributes to the reach and reputation of educators. The cross-regional visibility of OERs also facilitates professional exchange and interdisciplinary collaboration. Finally, the openness of teaching and learning materials is the basic prerequisite for participatory knowledge acquisition without social barriers. With the publication of OERs, learners are given the opportunity for feedback and active participation, which in turn increases the quality of the teaching materials.

3. CC licenses and standardized metadata for OER

SLUB and ZiLL have designed a consulting and training offer that provides concrete techniques, tools, and presentation forms for the creation and publication of OER, primarily for the frequently requested topics of license management and metadata, as well as for didactic issues.

Authors of OERs determine for themselves the extent to which their materials may be reused by third parties by licensing them under Creative Commons (CC) and thereby transparently regulating their reuse. These standard licenses allow authors to control the reuse of their OERs in terms of attribution, modification and commercial use. [14]

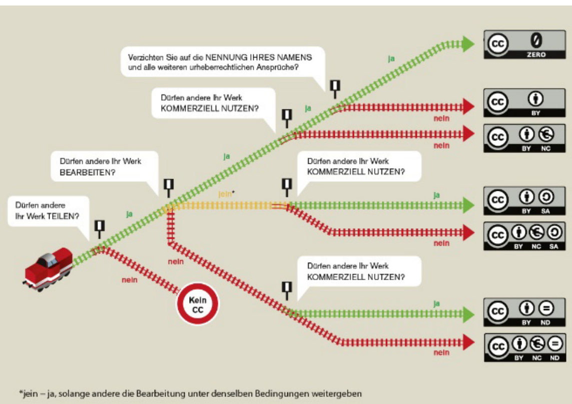

Fig. 1: Graphic: Jöran Muuß-Merholz for wb-web, edited by Michael Menzel. License: CC-BY-SA 3.0

In order to ensure their correct citation and findability, OERs must be provided with sufficiently standardized metadata that show information about authorship, the reason for their creation, and when they were created. The use of standardized file formats that can be used across platforms is an important prerequisite for this.

In addition, OERs must be available on technically suitable and maintained web-based platforms so that they are freely accessible to all. In this context, OERs are not subject to any media boundaries; they include scripts, exercises, lecture slides, podcasts, videos, and their combination(s), among other things. Due to this media complexity, OERs place higher demands on the technical infrastructure of a publishing platform than the pure text formats used in OA publishing to date. Until a central educational platform will be available, SLUB Dresden supports with the self-developed OER display to make teaching and learning materials of different platforms from Opal to Videocampus to Spotify and Youtube visible and reusable in a showcase across media types. The OER displayed there can also be found worldwide via the SLUB catalog and the reference systems linked to it. The code for the OER display is available as open source software for reuse on GitHub.

The Free State of Saxony has commissioned the Higher Education Didactic Center Saxony (HDS), the Working Group E-Learning of the State Rectors' Conference (LRK) and the SLUB Dresden with a study to determine the needs of Saxon universities with regard to a statewide educational platform for OER. At the same time, it is developing a strategy paper on the digital transformation at Saxon universities that takes a look at the areas of research, education, and administration and asks about the change processes, challenges, and opportunities for optimization resulting from digitization in the university landscape. The results will be incorporated into Saxony's higher education development plan.

A national education platform funded by the Federal Ministry of Research and Education is to be established by 2025 and facilitate the discoverability and secure subsequent use of digital education offerings. As a metaplatform, the digital education space is to represent an education ecosystem based on open standards, common formats and interoperable structures that is internationally connectable.

4. SLUB as a hybrid learning space in the project virTUos

The goal of strengthening digital teaching, as formulated in the coalition agreement of the Federal Government, is implemented by the Foundation Innovation in University Teaching with the funding guideline "Strengthening University Teaching through Digitization". The TU Dresden is participating in this measure together with the SLUB Dresden, the University of Continuing Education of the TU Dresden (DIU) and the Carus Academy at the University Hospital. Its project virTUos (virtual teaching and learning at TU Dresden in an open source context) is a cross-departmental network for the further development of digitally supported university teaching with the strategic goal of anchoring modern teaching and learning concepts in the curriculum and is funded as an individual project from 2021 to 2024. In the network, concepts of open teaching as Open Educational Practices are developed interdisciplinarily and further developed and used across universities.

At the project launch of virTUos, Lasch reflects on the project within a culture of digitality according to Stalder and points out how the institution of the university can discard its old orders in the face of the digital transformation and commit to openness: through a common goal and value orientation for more transparency, generosity and participation. [15]

In the virTUos project, the (scientific) culture of digitality is characterized by three aspects of openness: direct publishing on a blog, sharing and reusing open teaching and learning materials (OER) and open educational practices (OEP), and finally, participatory collaboration with students and citizen science researchers in an open university where learning takes place together, about each other, from each other, and with each other. Even though Open Science urgently needs the appropriate governance of the university leadership, open teaching cannot simply be decreed, but can only be worked out together and needs role models that inspire confidence and invite participation. The virTUos project creates experimental spaces for participatory learning in order to provide an institutional framework for the possibilities of change and design of digitally supported university teaching. Therefore, in addition to the strategic orientation, it also takes a look at concrete challenges: In digital teaching at TU Dresden, isolated solutions geared to specific fields of application can still be found, making data exchange difficult, and common technical platforms such as Opal or Videocampus are also reaching their limits. Furthermore, relevant event formats such as internships have hardly been implemented digitally due to their special didactic challenges. In addition to a strategic goal orientation that strengthens openness and collaboration, it remains of particular relevance for academic teaching that innovative and successfully evaluated virtualizations are anchored in the long term in course development, in the interpretation of examination law and in the curricula.

Especially in the design of experimental spaces for open educational practices (OEP), SLUB bears a great responsibility for university teaching with its learning spaces and services and shapes this area of responsibility in a participatory way with sustainable human and spatial resources. In our Labs, teachers and students from TU Dresden or other universities work with the library's subject experts as well as with their volunteer and citizen science colleagues and learn with and from each other in various projects. In the SLUB TextLab, methods and practices of digital humanities are tested in an application-oriented way, for example in the context of the virTUos subproject Digital Herrnhut [16] or in the master's program Digital Humanities. In the Open Science Lab, new technical infrastructures for publisher-independent Open Access publishing are being created in cooperation with the TU Dresden. These infrastructures integrate the aspects of quality assurance through review procedures described above, as well as alternative models for performance measurement and new formats of scholarly communication. The publishing of research data, of research software and last but not least of Open Educational Resources under consideration of the FAIR criteria are further components of the service offer of the Open Science Lab. The SLUB Makerspace has set up podcast and video studios, including VR and AR technology that can be borrowed, which teachers can use to produce audio and video material for OER. SLUB experts advise on the use of the technology as well as on license management according to Creative Commons or on the FAIR criteria for publication. Colleagues from the ZiLL are available to answer questions about higher education didactics and round off the range of services for OER.

The steadily increasing numbers of visitors to the library show that, despite or even because of increased digital teaching, the various learning spaces in the library are of great importance to students, be they individual workstations or group workstations, or the cafeteria Biblounge as a casual meeting place. Unlike in teaching, where students in many cases opted for virtual participation after the campus reopened with hybrid offerings, they quickly returned to visiting the library in presence after the pandemic-related closure to learn and work together in a variety of ways, or use it as a meeting place for other activities. A seemingly paradoxical effect was already evident in the library statistics before the pandemic: while the number of visitors increased continuously, the number of actively valid library user cards decreased at the same time. The SLUB user card is necessary for borrowing print or AV media as well as for magazine orders and reservations, and the lower number of holders of a user card illustrates that these classic services of local lending have become less relevant after about three quarters of the annual acquisition budget has gone into electronic media. Library visits, on the other hand, are also possible without an SLUB user card, and all digital library services from online literature supply to the use of online consulting and training services related to research and literature management are available to members of the TU Dresden in the library rooms via Eduroam and ZIH login even without an SLUB user card. It can be deduced from this that students value their library as a hybrid place of learning. They stay in the rooms to use digital offers and to learn together.

Conclusion: By participating in the virTUos project, SLUB is gaining further experience as a hybrid place of learning and will consistently align its services with the requirements of virtual teaching and learning at the TU Dresden in an open source context. It will also intensify user research in order to better differentiate its hybrid services: Which services are relevant on-site, which services are preferred online? How do the premises have to be equipped technically and with personnel in order to offer optimal service as a hybrid learning space? SLUB contributes its experience and expertise not only in the cooperation with TU Dresden, but state-wide through the cooperation with the Higher Education Didactic Center Saxony and the AK E-Learning of the State Rectors' Conference. It is a competent companion of the digital transformation at Saxon universities and pursues the goal of an open scientific culture of digitality [15].

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Gamification of Science

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Abstract

Digital development and the greater spread of social media with, among other things, special academic channels are leading to a change in students' expectations of teaching. At the same time, the requirements for graduates are changing towards interdisciplinary knowledge. The goal of the learning project to be implemented is to combine the previous individual formats with the application of a type of business game in order to strengthen interaction as well as attendance participation in this way. This makes it possible to link theoretical knowledge directly with practical components and thus to illuminate energy technology issues from different points of view. Elements of gamification are used to create a motivating learning situation for the students, which promotes a high level of interaction. The first implementation takes place in the context of the lecture "Analysis of complex energy systems", in which a building model is to be created and the heating system is to be designed.

Die digitale Entwicklung und die stärkere Verbreitung von sozialen Medien mit u. a. speziellen wissenschaftlichen Kanälen führt zu einem Wandel der Erwartungshaltung der Studierenden an das Thema Lehre. Gleichzeitig wandeln sich die Anforderungen an die Absolventen hin zu einem fachübergreifenden Wissen. Ziel des umzusetzenden Lernprojektes ist es, die bisherigen Einzelformate mit der Anwendung einer Art Planspiels zu kombinieren, um auf diese Weise die Interaktion sowie die Präsenzteilnahme zu stärken. Dies ermöglicht, die theoretischen Erkenntnisse direkt mit praktischen Komponenten zu koppeln und somit energietechnische Fragstellungen aus verschiedenen Standpunkten zu beleuchten. Durch Elemente der Gamification wird hierbei für die Studierenden eine motivierende Lernsituation hergestellt, welche eine hohe Interaktion fördert. Die erste Umsetzung erfolgt im Rahmen der Vorlesung „Analyseverfahren von komplexen Energiesystemen“, indem ein Gebäudemodell erstellt und die Heizungsanlage ausgelegt werden soll.

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This article was originally submitted in German.

1. Background and idea

Up to now, topic-specific knowledge has been imparted via the familiar formats of lecture, seminar and practical courses. Depending on the subject area, these are coordinated with each other - in each case related to a focus - with a defined interaction between students and teachers.
Through the aspect of gamification, this previous stationary process is to be broken up and the students are to be directly involved in the transfer of knowledge in the form of a business game, enabling participation in courses hybrid, in presence and online. Especially in the field of energy technology with the question of a future CO_2 -neutral and resilient supply, holistic and partly controversial points of view and approaches must be considered with the theoretical foundations and new developments and combined in teaching. The question raised by this example cannot be answered from a technical point of view alone, but must be seen in a holistic context, since there is considerable tension between climate protection, reliable energy supply, acceptance of technology and economic issues.

2. Aim of the teaching project

The goal is to develop a gamified learning environment for the development of "Cellular Energy Systems", which links the aspects of electrical engineering and thermal power engineering. For this purpose, it is planned to embed the game to be developed in realistic, authentic scenarios and to integrate these - moderated by qualified (tele-)tutors from the environment of the TUD - into various courses or teaching modules. Here it is necessary to test didactics, understanding and handling of a game for methodical knowledge transfer (principle: train the trainer). In the course "Analysis methods of complex energy systems", elements of gamification are integrated into the existing concept within the framework of the seminar. The aim here is to create a motivating and challenging competitive situation between the students in connection with the processing of a holistic task over several seminars. For this purpose, ecological as well as economic evaluation indicators and rules of the game (e.g. compliance with the comfort level in the buildings) are used in order to make the different solutions of the students comparable. The task is directly related to a part of the lecture, in which several technically relevant questions are to be answered. Fig. 1 shows an example of the graphical user interface of the previous RVK simulator game, which was developed in the context of a research project on the "Regional Virtual Power Plant (RVK)" [1]. It thus represents the preliminary stage of a cellular energy system. In this game, the user can control the respective purple cells. Each cell represents a building with thermal buffer storage and a combined heat and power plant. Several of these cells can be virtually connected to form a larger cell. Finally, all purple cells are bundled in a central station, which is exemplarily shown as a power plant in the picture. The goal of the game is to achieve the highest possible revenue with the virtual power plant over the course of a day. Among other things, the electricity price, electricity consumption and thermal consumption in the building are taken into account (diagram in the picture). By "switching on and off" the respective purple cells, the user can influence the course of the game and thus the revenue.

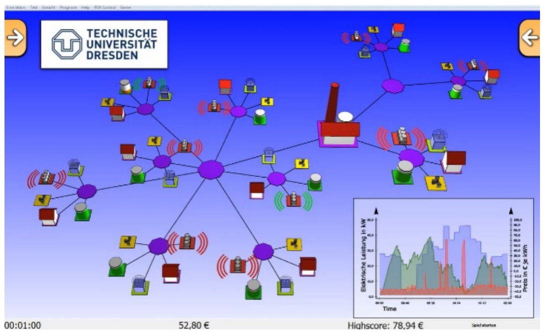

Fig. 1: Illustration of the predecessor game "RVK Simulator" [1, 2].

3. Practical implementation

The first implementation is carried out on the example of the holistic consideration and design of a heating system in a residential building (as the smallest energetic cell) in the context of the lecture "Analysis methods of complex energy systems". The idea is presented below.
For the consideration of a cellular energy system it is necessary at the beginning to consider

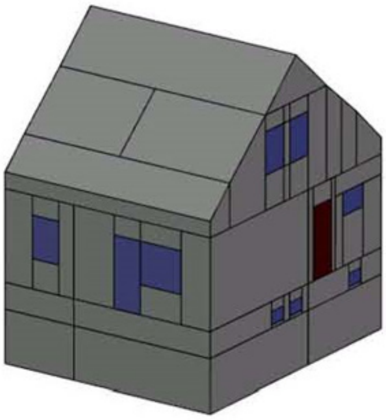

Fig. 2: Representation of the building model

the different levels of detail separately. This means that in the first step a single building is considered as the smallest unit of a cellular system.

This includes the building cubature as well as the installed generation system (heating and air conditioning), which is adapted to the respective building.

In the second step, several buildings are then combined to form a district. It is also possible for several buildings to be supplied with energy together as a district solution. In a third step, several quarters are then combined to form a holistic energy system.

Thus, the holistic goal would be a resilient energy supply of all energetic cells among each other. This means that the energy supply is characterized by a high degree of resilience in that many different small controllable generation and consumption plants take over the energy supply as a network and the individual energy cells thus secure each other with the exchange of energy. Since this task is very extensive and complex in its entirety, subtasks have been developed from it. These subtasks are revised during the semester according to the playful approach, so that the theoretical basics can be applied directly to a practical example. In this context, playful means that points are awarded for subtasks and that the students can determine the respective evaluation focus before starting the subtask. This can be, for example, low operating costs, high efficiency or a high regenerative share of the building's energy supply. In this way, a different focus (within specified limits) can be placed in each seminar.

As described, the first implementation of the concept is carried out on the smallest unit of a cellular energy system, a residential building. For this purpose, the building and system simulation tool TRNSYS-TUD [3] developed at the professorship is used.

The following tasks must be completed by the students:

- Creation of a building model (see Fig. 2)
- Carrying out a heat demand calculation
- Creation of a model of the heating system (heat distribution and transfer, see Fig. 3).
- Creation of different heat generator models
- Scenario investigation by means of building and system simulation

The building model, which has the same boundary conditions for all participants, is based on predefined construction plans, wall structures and user behavior. With the heating system, in turn, the variable implementation begins through different options for heat generation and transfer, such as:

- Underfloor heating or radiator
- Air-source heat pump, ground-source heat pump or gas boiler
- Solar thermal
- Buffer storage volume
- Type of domestic hot water production
- Type of regulation

With these variations, students can test up to five scenarios using an annual simulation.

The task can be supplemented with additional components of economic efficiency, the use of renewable energies or specific questions from other teaching areas. Essentially, the area of electrical energy supply should be mentioned here, which has a decisive influence in the context of a holistic energy supply using sector coupling. Questions in this context are therefore, for example, whether the building within a cellular energy system will represent a pure consumer or a producer in terms of energy in the future. In this way, the task will be constantly expanded.

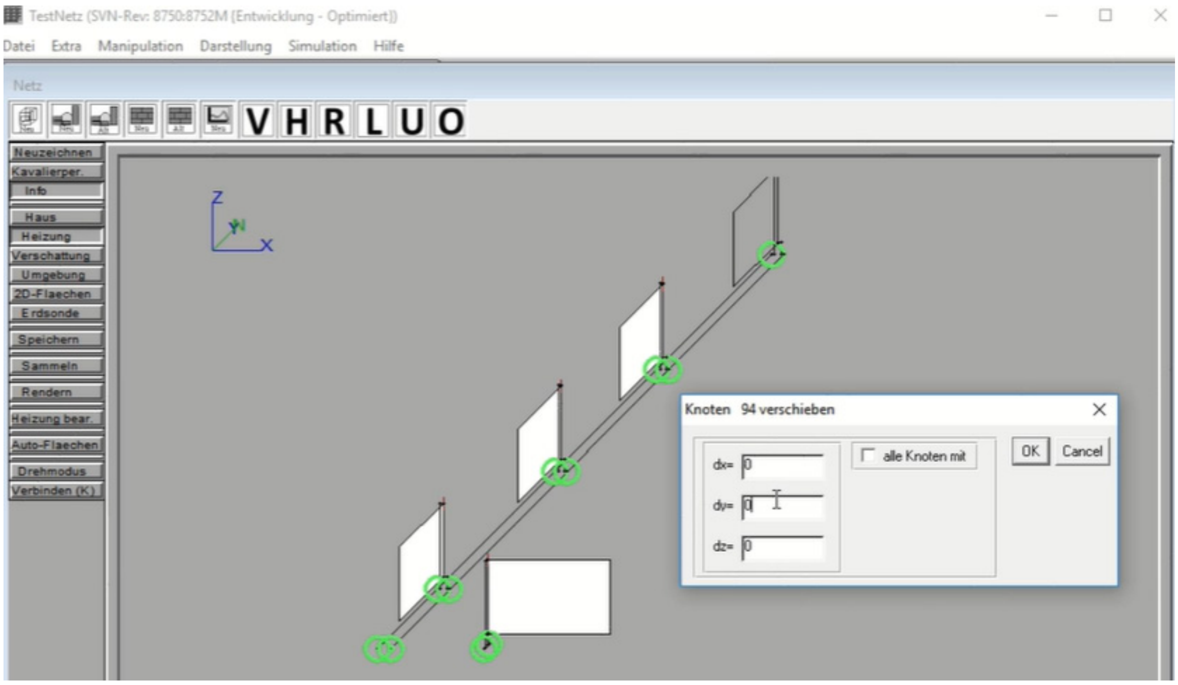

Fig. 3: Interactive editing of subcomponents (simulation model of the heating network) using the example of the placement and dimensioning of radiators.

4. Evaluation within the game/seminar

Within the framework of the seminar in connection with the lecture, the paths on the way to different answer options are given in a structured way (depending on the task focus and teaching module combination). During the processing, support is offered by the lecturers, which means that complete failure is not possible. Rather, the result quantifies how well different goals were achieved. In this way, several winners can also be determined.

The main evaluation of the task presented here is based on two main parameters. These are the annual heat consumption of the building and the maintenance of room temperatures during the time of use. Further evaluation criteria used are the primary energy demand and the economic efficiency with a simplified calculation of the costs for installation and operation of the system.
In this way, different solution approaches and concepts can also lead to winning the task with regard to the use of regenerative energies. The weighting of the individual factors can be determined jointly by the students at the beginning (such as a team with the lowest costs, a team with the lowest CO_2 emissions).

The most important aspect here, however, is the discussion and the holistic approach across individual subjects (mechanical/energy engineering as well as electrical engineering away from a given problem. This process takes place over the course of an entire semester or, alternatively, over the course of several seminars on a smaller scale.

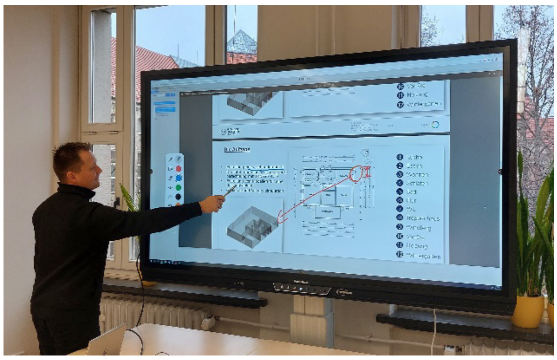

Fig. 4: Practical implementation and live processing during the seminar.

Through this new concept, the previous learning mode of single task processing was made more flexible and broken up. The feedback from the students was very positive, as theoretical considerations were directly linked to real-life applications. It should be noted, however, that only six students participated in the lecture during this first run.

5. Type of implementation

The implementation of the idea was very variable. This means that the test run of the seminar was implemented as a playful competition hybrid. This includes the processing of the task on site in presence (see Fig. 4) as well as by means of online access. The central point is that a platform was created in which the students can interact and use the software for building and system simulation within the campus network. Various tools and items are used for this purpose. These include tools for surveys [4], shared whiteboards and interactive slides/presentations, and a newly procured digital whiteboard [5] that greatly increased interactive collaboration over traditional PowerPoint presentations. In this way, the task as well as different approaches and detailed problems could be discussed interactively with the students.

Another point, which was planned but could not yet be fully implemented, is the use of additional digital possibilities of knowledge transfer (e-learning) to complement the teaching in presence. Within the current time frame, however, it was possible to create a first tutorial in the form of a video for the introduction to the simulation software. This includes a part of the PowerPoint presentation of the lecture as well as an on-screen video of the creation of an example building with explanations.

The continuing online offer for the students will be created by setting up a kind of recording studio in the laboratory of the professorship. For the implementation, a higher-quality webcam and a green screen will be used. The editing of the recording will be done with the software Camtasia [6], with which videos of presentations can be recorded interactively with more effects. For the provision of videos, knowledge content and knowledge tests, resources from the Saxony Education Portal will be used within the framework of Opal.

6. Transferability

The concept of gamification of courses/seminars can be applied to almost all topics of an entire teaching module or only individual lecture series.

Examples could include:

- Ventilation and air conditioning / development of ventilation and air conditioning strategies
- regional virtual power plants / development for supply strategies
- Gas technology / development of strategies for H_2 integration (resilience)

Taking the lecture series "Ventilation and air conditioning" as an example, aspects such as the climatic boundary conditions, the structure and design of components (heat exchangers, fans, etc.) and questions relating to air purity and pollutants (CO_2 concentration, pollutant load) should be mentioned. These technical questions are coupled with practical approaches in that the students work out certain boundary conditions (such as the space conditions or the structural conditions) on site as a technical excursion, e.g. behind the scenes of the lecture hall center.

7. Note

Due to the current situation with very long delivery times, direct practical implementation could not yet be fully started. For the first test, the task of planning and designing a heating system for a residential building was implemented by means of simulation with playful approaches within the framework of a seminar as a basis. This additionally included the creation of a building model based on given construction drawings or piping and installation diagrams (R&I) as well as taking into account different user behavior as well as thermal insulation standards of the building.

The concept is continuously extended to further partial aspects up to the holistic consideration of a cellular energy system. In the next step, several buildings have to supply each other with energy and the economic consideration is included in the task design.

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Use of Reading Logs in the Flipped Classroom

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Abstract

For a successful implementation of the inverted classroom format, it is important that students come to the classroom sessions well prepared. This includes, above all, a reflective engagement with the course content and materials. To support this process, we have tested the use of Reading Logs, sometimes referred to as Learning Assessment Journals, in several courses. The Reading Logs are designed to guide students to reflective engagement with the new content by asking leading questions. This, combined with ideas of Just-In-Time Teaching, has led to much more effective use of face-to-face time. An evaluation in two courses of the physics teaching degree program also showed that the students were significantly more motivated and satisfied despite the (supposed) additional work.

Für eine erfolgreiche Anwendung des Inverted Classroom Formats ist es wichtig, dass die Studierenden gut vorbereitet zu den Präsenzterminen erscheinen. Hierzu zählt vor allem eine reflektierte Beschäftigung mit den vorzubereitenden Inhalten und Materialien. Zur Unterstützung dieses Prozesses haben wir in verschiedenen Lehrveranstaltungen den Einsatz von Reading Logs (Logbücher), manchmal auch als Learning Assessment Journals bezeichnet, getestet. Die Logbücher sollen die Studierenden durch Leitfragen zu einem reflektierten Umgang mit den neuen Inhalten anleiteten. Dies hat, in Kombination mit Ideen des Just-In-Time Teaching, zu einer deutlich effektiveren Nutzung der Präsenzzeiten geführt. Eine Evaluation in zwei Veranstaltungen des Physik-Lehramtsstudienganges hat darüber hinaus ergeben, dass die Studierenden trotz der (vermeintlich) zusätzlichen Arbeit deutlich motivierter und zufriedener waren.

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1. Introduction

In response to the teaching challenges posed by the Corona pandemic, many teachers have made their first experiences with the "flipped classroom" format and have come to appreciate its advantages. In contrast to the classic lecture, in the flipped classroom the students are responsible for learning new content outside of class time. For this purpose, course materials (e.g. lecture notes or videos) are made available in advance. The in-person class time is then used to clarify comprehension problems and to deepen the understanding through exercises, discussions, etc. The students are significantly responsible for their own learning.

The flipped classroom has numerous advantages over the traditional lecture format. It shifts the focus away from the teacher to the learners. The learners are flexible in their timing and can determine individually the learning pace. However, the format can also harbor dangers that should be countered with appropriate measures. In particular, it is important to ensure that students reflect on the content to be learned. This initial reflection on content is a basic prerequisite for a sensible use of the classroom times.

In this paper we want to introduce the concept of the Reading Log [1,2], sometimes also called Learning Assessment Journal, which we have tested and evaluated in numerous courses of the physics teaching program at the University of Cologne [3]. In the process, a possible influence on learning motivation was also investigated in more detail.

2. Flipped Classroom

In the traditional form of teaching, there are usually two phases that alternate regularly. In the first phase, the content is taught or developed; in the second phase, the content is deepened through exercises, discussions or further research. The content is usually taught by the teacher or the lecturer in the form of prepared teaching formats in person. In the university context, this means that the content of a lecture is conveyed by the lecturer. Subsequently, the content is deepened independently by means of provided exercises or learning quizzes. The second phase is therefore an individual learning phase in which the students are independently responsible for their consolidation of learning, regardless of place and time (cf. [4], p. 4).

In the Flipped Classroom model, however, the activities are reversed. The 1st phase is used for individual concept transfer and concept development, in which the students acquire the new material individually through their own work ([5], p. 46). The content and media with which the students deal depends on the teacher. The teacher must prepare the materials accordingly and make them available. In addition, the role of the teacher changes. He or she is no longer merely a person who imparts knowledge, but a contact person, advisor and learning helper (cf. [5], p. 46). It should be noted, however, that there should not be a reduction in in-person classtime. Therefore, the self-learning and presence phases must be well coordinated [5]. The in-person classtime can then be used - under the guidance of the teacher - for discussions, reflections and problem-based learning [6]. However, the model is not a completely new method, but has been used in its basic features for a long time. By using modern media, however, it is possible to apply and use this approach in a completely new way (cf. [7], p. 19). A main goal of the inverted classroom model is to increase the effectiveness of the in-person class [7]. Fig. 1 summarizes the essential idea of the inverted classroom concept in a compact way.

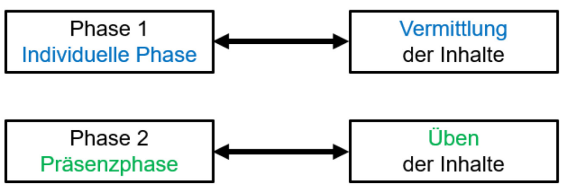

Fig. 1: Structure of the Inverted Classroom format (after [4])

There are some essential requirements for the successful implementation of the in-person classroom phase. These should of course be prepared as well as possible in the individual phase. To this end, a reflective engagement with the new content is essential. It should become clear to the students in the individual phase to discover which open questions and problems still exist and at which points there is still a need for clarification. In addition, the barriers to address problems in the presence part should be as low as possible.

An obvious idea for checking acquired understanding is quiz questions, e.g. in an online quiz. While this allows for immediate feedback, especially in a multiple-choice format, it usually tests factual knowledge rather than understanding or interconnectedness of knowledge. Alternatives, such as homework that is then handed in and graded, contradict the basic idea of the Flipped Classroom format.

Typical problems that can occur in the individual phase relate, for example, to accomodating and classifying the new information, which is imperative for a deeper understanding. In addition, questions that arise cannot be answered immediately. One possible solution to this is discussion forums, which can be set up in many online learning environments. However, many years of experience have unfortunately shown that practically no use is made of this option. It can be assumed that the lack of anonymity in these forums plays an important role here and social pressure from students reading along is avoided, which can arise even with anonymized contributions.

3. Reading Logs

To increase the motivation and quality of preparation, we have used reading logs in various courses. These contain concrete work instructions for the students in the form of guiding questions that are to be answered briefly. The reading log is intended to guide students to a structured engagement with the material to be prepared and to encourage them to reflect on what they have learned. They also offer the possibility of direct individual contact with the lecturers without having to expose themselves to the risk of social pressure.

The reading logs had to be edited and handed in weekly for the respective content to be prepared. This was done by uploading a pdf file in the learning platform Ilias (Integrated Learning, Information and Work Cooperation System) [8]. For this purpose, students were provided with a template in pdf and doc format to allow for the most flexible form of editing. Most students used the pdf format for submission, in which the answers were inserted using the comment function. Handwritten completion of a printed template and submission of a scanned version was also possible in order to keep the technical effort for the students as low as possible.

The timing of a tasking cycle typically looks like this:

- Students will be informed about 10 days before the corresponding attendance date which part of the course reader or textbook has to be prepared.
- You will then typically have 7 days to complete the associated reading log and upload it to the Ilias electronic learning platform.
- The uploaded logbooks are then reviewed and commented on by the lecturers. The feedback is also made available to the students via Ilias in good time before the in-person class session.

The weekly submission of the reading logs is mandatory in order to motivate the students to deal with the course contents on a regular basis. An extension of the deadline is possible in justified cases.

The reading logs give the lecturer the opportunity to identify problems and to take this into account in the design of the in-person phase (see section 5). Feedback BEFORE the in-person phase has been shown in the evaluation to be an important factor for acceptance and motivation (see section 6). However, it is not limited to criticism and answering questions, but also includes praise, e.g. for particularly successful summaries.

4. Structure of the Reading Log

The form of reading log used goes back to D. MacIsaac [2], which in turn builds on preliminary work in [1]. The reading log was adapted accordingly for use in teaching at German universities. Unlike the original template, which was two-sided to fit on a sheet of paper, the reading log used consists of 4 pages. This change is due to the format with an online submission. The students should have enough space to upload their handwritten texts in a legible form. However, the content of the reading log is largely identical to the two-page template.

As already emphasized, the reading log should help the students to reflect on the contents to be worked on. It is therefore important to ensure that, for example, the course material provided is not only looked at once superficially, but that it is worked through as many times as possible - ideally from different perspectives. This is to be achieved by answering guiding questions.

The reading logs consist of three parts. The first part is for assignment purposes only. Here, the name of the student and the chapter of the lecture worked on are requested. The other two parts are titled *"Notes after first reading"* and *"After second reading"* (Fig. 2). As described earlier, they are intended to ensure that students work through the material multiple times.

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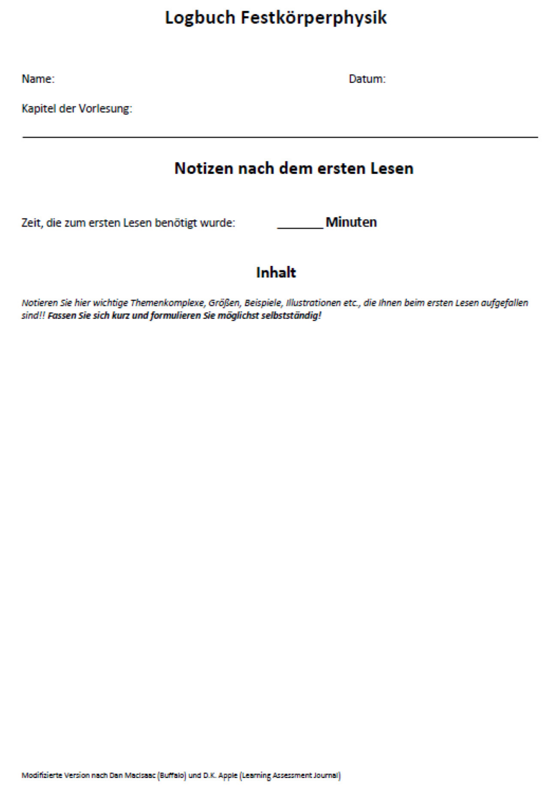

Logbuch Festkörperphysik

Name: Datum:

Kapitel der Vorlesung:

Notizen nach dem ersten Lesen

Zeit, die zum ersten Lesen benötigt wurde: ______ **Minuten**

Inhalt

Notieren Sie hier wichtige Themenkomplexe, Größen, Beispiele, Illustrationen etc., die Ihnen beim ersten Lesen aufgefallen sind!! ***Fassen Sie sich kurz und formulieren Sie möglichst selbstständig!***

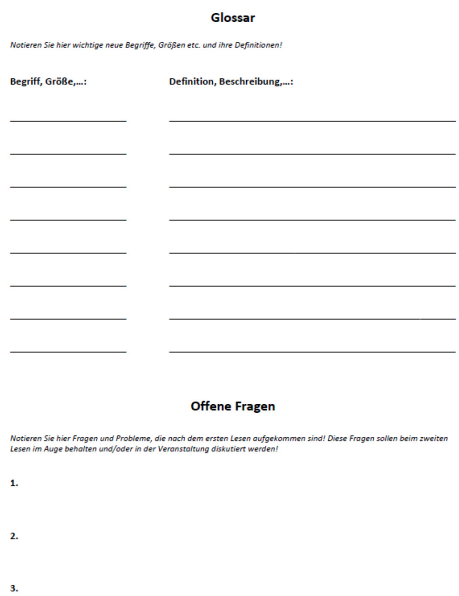
Modifizierte Version nach Dan MacIsaac (Buffalo) und D.K. Apple (Learning Assessment Journal)

Fig. 2: First page of the reading log for the course "Solid State Physics".

First, a part of the lecture notes/textbooks is to be read and the essential topic concepts are to be summarized briefly. The work instruction for this is "Write down *here important complexes of topics, quantities, examples, illustrations, etc., which struck you during the first reading!!! Be brief and formulate as independently as possible!*" This answer can be in the form of keywords, graphs or similar and should not be longer than half a page (Fig. 2). The restriction to "important" topics should encourage the students to structure the new content to a certain extent. The request for "independent" formulations should help to avoid simple cut-and-paste from the lecture notes/textbooks.

On the second page (Fig. 3), the essential new terms and their definitions are then recorded in a glossary. The work instruction is "*Write down important new terms, quantities, etc. and their definitions here!*" The glossary can thus be used later as a kind of reference book.

To promote reflection, students are then to formulate a maximum of three open-ended questions ("Note here questions and problems that arose after the first reading! These questions are to be kept in mind during the second reading and/or discussed in the course!"), which came up during the first reading and to which special attention is to be paid in the second reading.


Glossar

Notieren Sie hier wichtige neue Begriffe, Größen etc. und ihre Definitionen!

Begriff, Größe,…: **Definition, Beschreibung,…:**

Offene Fragen

Notieren Sie hier Fragen und Probleme, die nach dem ersten Lesen aufgekommen sind! Diese Fragen sollen beim zweiten Lesen im Auge behalten und/oder in der Veranstaltung diskutiert werden!

1.

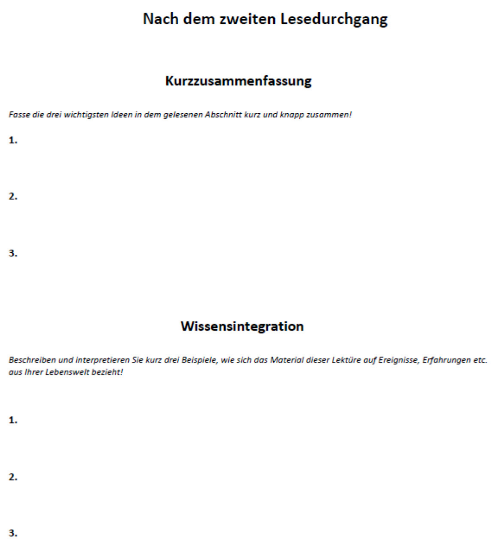
2.

3.

Fig. 3: *Second page of the reading log for the course "Solid State Physics".*

After the second reading, the most important new ideas, concepts, etc. are summarized in a few words (*"Summarize the three most important ideas in the section* you *have read!"*) (see Fig. 4). The restriction to a maximum of three aspects is intended to stimulate further reflection on the content. Another important point is knowledge integration, in which cross-connections are to be made to already known phenomena or examples from everyday life *("Briefly describe and interpret three examples of how the material in this reading relates to events, experiences, etc. from your real life!").* The new content here should be linked to familiar content, ideally from the students' real life.

By asking the question *"What new interpretations and insights of the essential physics concepts you listed at the beginning have emerged after rereading? Discuss this briefly!"* the learning process itself can be reflected upon (Fig. 5). This aspect is especially important for prospective teachers.



Nach dem zweiten Lesedurchgang

Kurzzusammenfassung

Fasse die drei wichtigsten Ideen in dem gelesenen Abschnitt kurz und knapp zusammen!

1.

2.

3.

Wissensintegration

Beschreiben und interpretieren Sie kurz drei Beispiele, wie sich das Material dieser Lektüre auf Ereignisse, Erfahrungen etc. aus Ihrer Lebenswelt bezieht!

1.

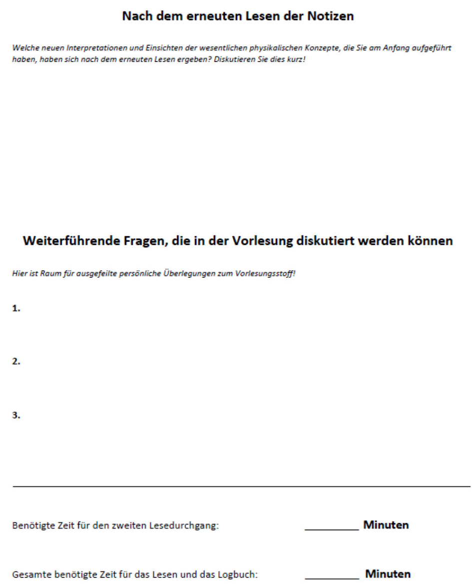
2.

3.

Fig. 4: Third page of the reading log for the course "Solid State Physics".

Finally, there is the possibility to ask further questions to be discussed during the in-person classtime. In addition, the completion time is recorded, for the second run and the total time including the creation of the reading log. The indication of the completion time is intended to help the students primarily in their reflection, e.g.to assess for themselves whether they have dealt sufficiently with the material. This is also communicated at the beginning of the course. In addition, the information provided by the teacher helps students to assess which topics are considered difficult and whether the amount of material was appropriate. This was also explained to the students at the beginning of the course when the reading log was presented.

Students receive individual feedback on the completed reading logs before the classroom session. By submitting them early, the lecturers have enough time to prepare the discussion of problems that have arisen during the in-person class time in the sense of just-in-time teaching (section 5).



Nach dem erneuten Lesen der Notizen

Welche neuen Interpretationen und Einsichten der wesentlichen physikalischen Konzepte, die Sie am Anfang aufgeführt haben, haben sich nach dem erneuten Lesen ergeben? Diskutieren Sie dies kurz!

Weiterführende Fragen, die in der Vorlesung diskutiert werden können

Hier ist Raum für ausgefeilte persönliche Überlegungen zum Vorlesungsstoff!

1.

2.

3.

Benötigte Zeit für den zweiten Lesedurchgang: ________ **Minuten**

Gesamte benötigte Zeit für das Lesen und das Logbuch: ________ **Minuten**

Fig. 5: Fourth page of the reading log for the course "Solid State Physics".

5. Just-in-Time Teaching

An invaluable advantage of Reading Logs is the possibility of Just-in-Time teaching [9]. This refers to the dynamic adaptation of the content in the face-to-face part to the needs of the students. The online quizzes and reading logs help to identify problems and deficits. From the summaries in the reading logs, it can be seen whether the students have recognized and understood the essential aspects of the new material. If this is not the case, it can be addressed in the in-person class.

The item *"Further questions"* from the reading log provide important clues to problems or points of interest. In contrast to open formats (such as lectures), comprehension questions are often asked here and a lack of prior knowledge is addressed. This can then be specifically addressed, which is particularly important with a relatively heterogeneous group of students (see section 6).

For the application of Just-in-Time-Teaching it is crucial that the students submit the reading logs early enough before the face-to-face session . Only in this way do the lecturers still have enough time to adjust the planning for the face-to-face sessions. As a rule, an interval of 2 days is sufficient if there is already a basic concept for the in-presence lecture preparation to which only adjustments would need to be made.

The just-in-time concept helps to keep the attention of the students high in the in-person classtime, because one can avoid the repetition of trivialities or over-complex contents. The face-to-face time can thus be used more effectively.

6. Evaluation

The concept was tested and evaluated in several courses within the framework of the teacher training program in physics. The results are very promising, both from the point of view of the lecturers and the students. Students came to the face-to-face sessions significantly better prepared. At the same time, they found the increased autonomy in developing the new content to be positive.

The evaluation of two physics lecture courses took place towards the end of the summer semester 2021 in the course of a master thesis [3]. In this thesis, the influence of the reading logs on the motivation of the students regarding the contents of the lecture course was investigated. One lecture course was on atomic physics and the other on relativity theory. The lecture course on atomic physics is a compulsory course for the bachelor students of the teaching profession secondary school (HRG) in the subject physics, whereas the lecture on relativity theory is attended by students with a major in physics (in the teaching profession secondary school, HRG or special education) as well as bachelor students who study another natural science and can choose this lecture as a supplementary module. For atomic physics, this results in a homogeneous population, while relativity has a rather heterogeneous population in terms of prior knowledge and interest in physics. This poses special problems for the teacher, since the different prior knowledge must first be diagnosed and then compensated. For this purpose, reading logs appeared to be an ideal tool.

In both courses, students were provided with lecture notes. These were originally created for a traditional course. They contain an elaborated presentation of the material analogous to a classic textbook. A special revision for use in the inverted classroom scenario did not take place (initially). Further materials were not needed or mentioned in the lecture notes (e.g. links to simulations). The lecture notes are about 100 pages long. With 13-15 class sessions per semester, each reading log has a typical amount of material of 6-8 pages per week to be analyzed.

For both courses, according to the module regulations, 30h contact time and 60h self-study are scheduled. Since there was no further homework besides the reading log, the students could spend about 4h per week on content preparation and the reading log. According to the students' statements on the actual time spent in the reading logs, this was almost always less than 4h.

The number of participants in the courses was about 20-25 students. The review of the reading logs was solely in the hands of the teacher, who thus had to review 40-50 reading logs per week. During the test phase, however, it seemed important for the teacher to keep a complete overview. The workload was high, especially at the beginning of the semester (about a full workday), but the workload was reduced significantly after both students and teacher gained more experience with the format. For example, student responses became much more concise and questions and naming of problems more precise. This resulted in significantly less time spent providing feedback.

For the evaluation, anonymous surveys were conducted in both lectures towards the end of the semester, asking for an initial personal assessment of the usefulness of the Reading Logs. From these surveys, people were then randomly selected and requested for interviews[1]. In the lecture Atomic Physics only one person agreed to be interviewed, in the lecture Relativity nine, of which four persons were interviewed. The interviews were problem-oriented, guided interviews [3], which were conducted individually via video call and transcribed afterwards. The focus of the interview was on the students' personal thoughts and emotions, which allowed conclusions to be drawn about their motivation regarding the processing of the readeing logs and participation in the face-to-face sessions.

The subsequent theory-based analysis of the interviews was conducted using qualitative content analysis according to Mayring [10]. The categories necessary for analysis are taken from the Self-determination theory according to Deci & Ryan [11], according to which the type and degree of learning motivation can be positively influenced by a learning environment that fulfills the need for autonomy, experience of competence and social belonging.

The results of the analysis in [3] suggest that students experience themselves as more motivated and competent by working through the reading logs before the face-to-face session than in previously attended lectures. According to the students, autonomy in editing, timely feedback from the instructor, which is perceived as appreciation towards the students' work, and better understanding due to intensive engagement with the content played a major role. Participation during in-person sessions was higher, and at the same time the dropout rate was lower than in comparable lectures. Overall, it could be shown that the use of the Reading Logs had a positive influence on the motivation and learning growth of the students.

7. Outlook

Reading logs have proven to be very useful tools in the flipped classroom format. When implemented consistently, both students and instructors reap the benefits.

These consist first of all in better preparation for the in-person phase, which can therefore be used more effectively. The reflective interaction with the content to be prepared not only helps students to articulate their problems more clearly, but also to ask deeper questions that can serve as a basis for further discussions. On the other hand, lecturers can diagnose typical problems early on and plan the in-person phase accordingly. Here it helps that the reading logs offer a low-threshold opportunity for comprehension questions due to their relative anonymity, without building up social pressure from other students.

As shown in an evaluation, despite initial skepticism (" make work"), students have found reading logs to be a valuable tool. The high level of acceptance among students has contributed to the reading logs being worked on regularly and well. It has also been shown that the concept works not only in conjunction with a handed-out lecture notes, but just as well with pre-recorded lecture videos in a fully digital setting.

The problems that have arisen mainly concern the synchronization of the various steps in terms of time (creation of the reading logs, correction, and in-person sessions). Here it is important to avoid time pressure for the students and the lecturers and at the same time not to let the time between the processing of the lecture notes, creation and submission of the reading logs, its correction with feedback and the associated in-person session become too large. A weekly course often leaves only 2-3 days for each phase. Time pressure on the students sometimes leads to less reflective interaction, in which the reading logs were generally created by cut-and-paste of content from the lecture notes.

Another problem is the question of scaling. Our experience with the concept is mainly based on events with a maximum of 30 participants. For larger courses, it is important that the tutors, who are responsible for providing

[1] The lecturer of the course did not participate in the interviews.

feedback to the students, also inform the lecturer exactly about the problems that have occurred so that the in-person session can be planned accordingly. This is an additional step in the cycle that takes additional timeTherefore, the students should be given the opportunity to deal with the content flexibly in terms of time by announcing the respective tasks early on.

One problem that should not be underestimated is the lecture materials provided for the individual phase. These are often not optimized for self-study, since, for example, already existing lecture notes intended for traditional lectures are used. Here, care should be taken to ensure that the materials are adapted for use in an inverted classroom scenario.

Acknowledgement

We thank Kathleen Falconer and Dan MacIsaac for helpful discussions. Additional thanks to Kathleen for help with the English translation!

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Podcasting in and for teaching

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Abstract

This short paper is intended as a workshop report, in which experiences from academic teaching are shared. The focus is on possibilities of low-threshold podcast production and hosting, as well as their integration into teaching. For this purpose, three podcasts with different goals and addressees are presented in order to illustrate how these media-specific formats are interconnected and can be made fruitful as a possible form of dissemination for science communication and in the context of Citizen Sciences.

Der Artikel versteht sich als ein Werkstattbericht, in dem über Erfahrungen aus der akademischen Lehre berichtet wird. Im Mittelpunkt stehen Möglichkeiten der niederschwelligen Podcastproduktion und des -hostings, sowie deren die Einbindung in die Lehre. Dazu werden drei Podcasts mit unterschiedlichen Zielen und Adressat:innenkreisen vorgestellt, um zu illustrieren, wie diese medial spezifischen Formate miteinander vernetzt sind und sich als eine mögliche Form der Dissemination zur Wissenschaftskommunikation und im Kontext von Citizen Sciences fruchtbar machen lassen.

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This article was originally submitted in German.

1. Starting points

Due to pandemic conditions, podcasts, which had a first strong boom at the end of the 2000s, also experienced a second spring in (higher) education. Receptively, they are now part of the inventory of digitally supported teaching (cf. [1] Blume 2022: 96f.), but productively, also for science communication, they are still rarely used ([2] WiD, DZHW, NaWik 2021: 12). Podcasts are thus neither a new (cf. [3] Nölting, Schnekenburger & Tavangarian 2006), nor a particularly innovative means of addressing content to a heterogeneous audience - however, they have never been as easy to produce, host and network as they are today. This can make them a very valuable element of academic teaching: Podcasts can be used (asynchronously) to (a) convey knowledge content, (b) document student presentations, and (c) make teaching as well as research projects visible. In the article (2) a low-threshold form of podcast production and hosting is presented briefly and exemplarily. Subsequently, (3) three podcasts representing the above-mentioned three aspects will be brought into focus. Special attention is paid to how these media-specific forms (4) are interconnected (cf. [4] Brittain et al. 2006), and how podcasting can be fruitful as a possible form of dissemination for science communication and in the context of Citizen Sciences.

Linguistics describes the term "podcast" as a "portmanteau", namely from "broadcast" on the one hand and "pod", an acronym for "play on demand", on the other - commonly they are thematically bound audio recordings, which, designed for subscription and continuation, are offered online via RSS (Rich Site Summary) in a web feed for an unspecified audience. Before asking how useful, for example, audio recordings of courses without an associated presentation might be, it is worth considering the advantages that podcasting offers. Podcasts can be used asynchronously and can be received without requiring attention on the visual perception channel. Even more, asynchronous audio input can be used in any type of knowledge delivery without tying the recipient:s to a visual output device such as a display on a smartphone, tablet or computer. The transmission is more data-friendly; the provision options are diverse and technically mature, ranging from self-operated blogs to commercial hosting services. Distribution via RSS is not platform-bound. Even without video support, podcasts are used to open up new subject areas -- this also applies to academic teaching. Students can also receive podcasts in order to repeat and consolidate central contents of a field of knowledge, to follow up courses and to prepare exams. The question, e.g., of the Dresden student body, about asynchronous provision of teaching content could easily be answered with podcasts.

2. Podcasts: production and hosting

The number of options for podcast production and hosting increased significantly in recent years; in this article, production with OcenAudio (see Fig. 1) and hosting via Castbox (see Fig. 2) are briefly presented, with special attention paid to the fact that existing (and, for example, pandemic) video recordings can also be appropriately edited and re-injected (see Section 3). Distribution can be done via Castbox and additional podcast platforms (Spotify in the example, see Fig. 3). In the following section, these aspects of production and hosting as well as the exemplary workflow, which in principle is no different even with alternative tools, are first outlined, and then described in more detail in section 3 using exemplary podcasts. It should be emphasized that although the technical options are subject to change, especially for already existing media formats (such as lecture recordings) the conversion (from MP4 to MP3) and the renewed provision (via RSS) will not change in principle in the foreseeable future. However, the presented tools can be replaced by others as desired.

Podcasts are now probably the easiest and cheapest medium to use for teaching, enabling asynchronous knowledge transfer as well as the presentation and documentation of student work. Furthermore, they are relevant for courses of study with few students, highly specialized research contexts, or special interests in general, since podcasts can also be used to make topics accessible to an audience that tend to lie outside of the public interest and would rarely reach a broad audience in a presence.

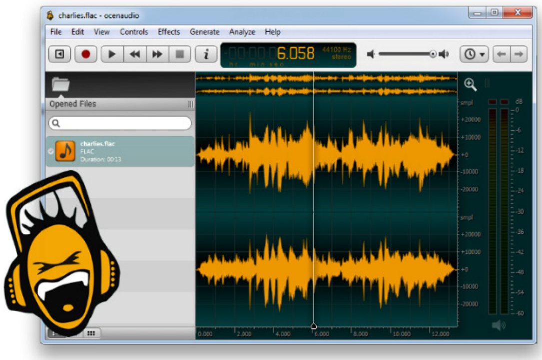

Fig. 1: Production via ocenaudio (https://www.ocenaudio.com/). Ocenaudio is an easy-to-use audio editing program and freely available for Windows, MacOS and Linux.

Ocenaudio (see Fig. 1) is currently one of the easiest to use and freely available recording, converting and editing environments for audio content. Recording, converting, editing, fading or normalizing can be done intuitively and easily in this WYSIWYG editor. Exporting can be done to the most common formats, including MP3 and MP4 (or M4A) without installing additional Codex packages. Since Castbox accepts WAV and AAC formats as well as the more data-friendly MP3 and MP4 (or M4A) up to a maximum file size of 400 megabytes, working with Ocenaudio forms an excellent basis. The only disadvantage of Ocenaudio compared to other programs of this kind (such as Audacity) is that it does not have a multi-track editor. With a little practice and the blending of separate audio content, this shortcoming can be easily compensated.

Registration and use of the hosting service Castbox (see Fig. 2) is free of charge - here we play our audio content produced in Ocenaudio as episodes into a podcast, which is called a "channel" at Castbox. Of course, other services for hosting would also be conceivable, however I have had very good experiences with them - also and especially in academic teaching. First, it is relevant that no separate program (as with Ocenaudio) is necessary; Castbox works browser-based. Secondly, the number of channels, i.e. podcasts, is not limited, nor is the number of episodes per channel. Thirdly, Castbox creates an RSS feed that can be embedded and reused in all other environments. Thus, Castbox supports sharing with services such as Spotify, Apple and Google Podcasts - just to name a few.

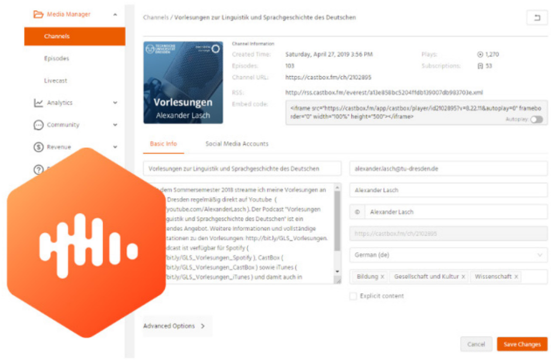

Fig. 2: Hosting via castbox.fm (https:/castbox.fm/). The service is easy to use and browser-based. Podcasts have their own page; claiming is supported. Broadcasting & recording is possible via an app for iOS and Android.

Fourth, each channel has its own landing page that can be accessed via URL. An appealing web player, fifthly, can be embedded on websites and blogs via iframe. The announcement with Podcastportalen (e.g. https://www.podcast.de/) takes place however manually via RSS feed and does not belong to the scope of supply of Castbox. It should also be mentioned in passing that episodes can be added to the channel at any time via the Castbox app for iOS and Android. But back to the workflow: The audio file produced in Ocenaudio is added as an episode to a created channel via drag & drop. A channel thumbnail, the preview image that makes the channel easily recognizable, must be created beforehand and is then automatically applied to the episode assigned to the channel. Due to memory limitations for Apple's iPod, for a long time a resolution of 1,400x1,400 pixels was defined for the thumbnail, and the total file size could not exceed 400 kilobytes - Apple's podcast platform refused the thumbnail otherwise. However, these regulations have been gradually softened, but it is still advisable not to lose sight of them completely and to use these parameters as a guide when creating thumbnails. After uploading, various other options are available (specifying title, description with 'talking links', specifying publishing dates). The workflow can be followed step by step in a podcasting tutorial (https://youtu.be/8xDtUXQ4Tb8?t=583).

Claiming podcasts, that is, displaying podcasts and their authorship on podcast portals, is useful for making created content easily accessible to a wide audience in a professional environment.

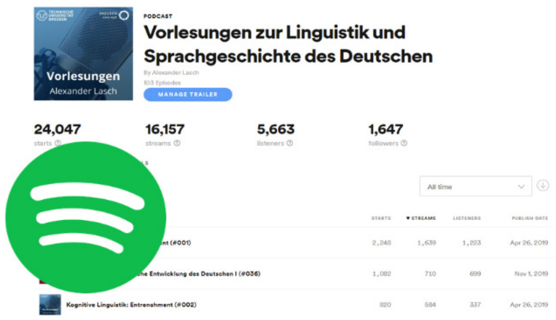

Fig. 3: Sharing e.g. via Spotify [(https://podcast-ers.spotify.com/)](https://podcasters.spotify.com/): Castbox.fm provides RSS feed and web player. A broader audience can also be reached via podcast platforms.

As with the well-known "podcast" portal (e.g. https://www.podcast.de/), the podcast already publicly available on Castbox must be reported manually by specifying the RSS feed. This is possible even if one is not responsible for the podcast. With claiming, one claims ownership of a podcast to a portal. To name four major portals, this can be done, for example, with Spotify (https://open.spotify.com/), Apple (https://www.apple.com/de/apple-podcasts/), Google (https://podcasts.google.com/) or Amazon (https://www.audible.de/). The procedure is almost identical for all services, but must be done separately for each, as I would like to illustrate in the next section using a podcast as an example. For me, the focus is on the podcast portal of Spotify (see Fig. 3), since this service has become increasingly popular in recent years. It should be explicitly pointed out that commercial providers and portals may at first glance only offer a further possibility of distribution and thus of finding produced content, but at second glance they are also interesting for producers because they allow an insight into usage statistics that would not be possible at all with hosting on a blog or website.

3. Three examples: Lectures on Linguistics and Linguistic History of German, lasch not least, Old Writings.

The low-threshold production and distribution possibilities make podcasts an ideal means for (a) conveying knowledge content in academic teaching (using the example of the "Lectures on Linguistics and the History of German"), (b) documenting student presentations (using the example of "lasch not least"), and (c) making teaching and research projects visible (using the example of "Alte Schriften"). For these three examples of use, I will also include usage statistics that are not usually disclosed, although I will only provide a detailed insight for the "lectures" (see Fig. 4).

I would like to illustrate two things with this: First, how extraordinarily platform-dependent the use of an offering is, and second, that production effort and usage potential do not always have to be in balance - this will become immediately clear with the podcasts "lasch not least" and "Alte Schriften," for which I will only consider figures from Spotify.

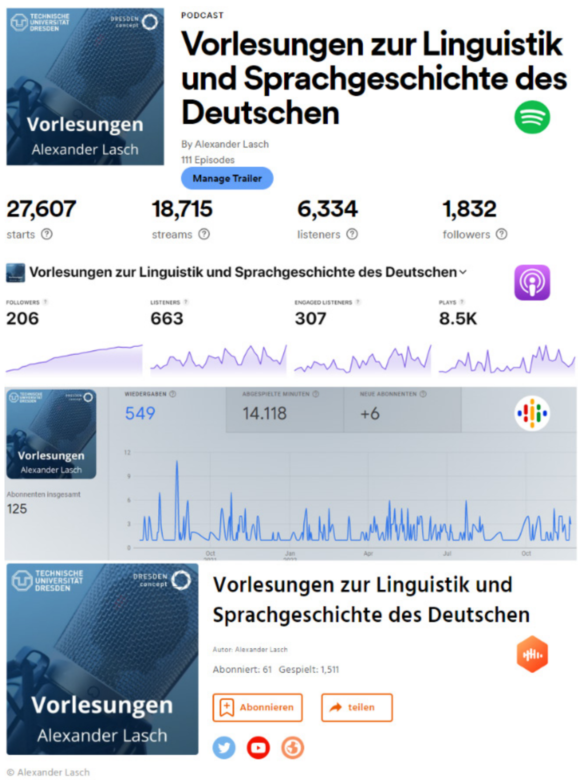

Fig. 4: Usage statistics of the podcast "Vorlesungen zur Linguistik und Sprachgeschichte des Deutschen" on Spotify, Apple, Google and Castbox (date: 23.11.2022). High-resolution variant of the graph at: https://doi.org/10.5281/zenodo.7351269.

Looking at the usage statistics (see Fig. 4), one will be able to say without hesitation that Spotify, as a commercial podcast portal for the distribution of content, is far superior to all other portals in terms of reach and usage - the "podcast" portal (https://www.podcast.de/), here the networking of content in the German-speaking region began, is not included in the

representation because of four followers, nor is Amazon (https://www.audible.de/), for which the usage figures are also negligible. Even if the statistics cannot be precisely mapped to each other (the differentiation between "start" and "stream" at Spotify, for example, does not exist at the other portals, etc.), it is obvious that a broader audience can be reached if different distribution channels are used. For example, the hosting service Castbox, which provides the basis for further use, is not nearly as wide-reaching as the portals that embedded podcasts early on along with other audio offerings (Spotify and Apple).
The effort for the production of the podcast "Vorlesungen zur Linguistik und Sprachgeschichte des Deutschen" (https://kurzelinks.de/itd6) is extraordinarily low - it is the audio tracks of the recordings of the Youtube livestreams (https://kurzelinks.de/xt5e) of the lectures, which are available as MP4 after broadcast, normalized and shortened in Ocenaudio, converted to MP3 and recorded at Castbox. The post-production is therefore limited to minimal optimizations: Nothing is dubbed, nothing is glossed over. Everything that goes 'on tape' in the lecture is also unfiltered content of the podcast. With the one-time claiming of the podcast (e.g. in the case of Spotify via https://podcasters.spotify.com/catalog under the indication of the associated RSS feed of Castbox, see Fig. 2), the episode is also accessible a few minutes later via Spotify, Apple, Google or Audible (Amazon). The lecture presentations are available independently of the video stream and podcast in a blog, which is explicitly referred to in the description of each podcast episode, e.g. in the last episode (https://kurzelinks.de/dvin): "Beispielanalyse des 'Erlkönigs' aus Perspektive der Kognitiven Poetik. Lecture 'Cognitive Linguistics' in WiSe 2022 at the TU Dresden. Information & material: https://kurzelinks.de/fl7f. Video recordings: https://youtube.com/@AlexanderLasch. Intro: 'Reflections' by Scott Holmes (CC BY via FMA). #linguistics #OER #language".
Even if one could follow the lecture directly on Youtube (live and recorded), more than 1,800 followers, e.g. on Spotify, obviously do not or not exclusively do so. For them, the offer opens up very different usage options, as is clear from (unfortunately very rare) letters: "In one of your current lectures, you asked a bit in amazement who actually listens to the lecture on Spotify. As a student of German Studies at the University of Duisburg-Essen, I basically listen to your lectures like a podcast on car trips, on the train or while walking. I came across you in the course of your lecture on colonial linguistics, which I listened to with enthusiasm."
Thus, repurposing an already existing offering and opening up additional distribution channels makes it possible to address a broader audience. By expanding the OER portfolio, one not only contributes to the digital transformation of the knowledge society, but can also promote one's own subject, the favored subject content, the science location Dresden, and the opening of the science culture (cf. [5] Lasch 2021). The fact that video recordings, which, due to the pandemic, have offered many lecturers a good opportunity to convey knowledge asynchronously, can be transferred into podcast formats either via manual conversion or, in the case of YouTube, by using the download of audio tracks via instances of Invidious (https://invidious.io/), should therefore be explicitly emphasized once again as an option.

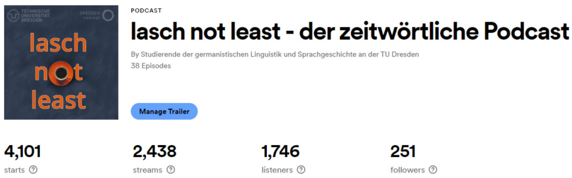

Fig. 5: Usage statistics of the student podcast "lasch not least" on Spotify (https://podcasters.spotify.com/, date: 23.11.2022).

The podcast "lasch not least" (https://kurzelinks.de/x4zf) is a student podcast that is created collaboratively in seminar contexts and used for teaching - the logo and name of the podcast as well as the intro were developed together with students. In a total of 37 thematic episodes on the topics of "Accessible Communication", "Morphology", "Cognitive Grammar", "Internet Linguistics", "Colonial Linguistics", "Small Text Forms", "Grammars of German" and "Auxiliarity", students present the results of their joint work on a topic, Depending on the learning goals they have set themselves for the course, they either take the production and hosting into their own hands - with technical support in the context of the course they are attending - or simply take care of the elaboration and produce with support. The effort that goes into each episode produced specifically for the podcast is much greater than for the "lectures." However, the significantly higher effort does not correspond with the call-up figures - for the implementation of teaching and learning projects, this should never be relevant, and this can also be argued accordingly after evaluating usage statistics. For: students have the opportunity in courses to practice a digital presentation technique, to reflect on the possibilities and limits of the technology, to consider its use in other contexts, and to make their elaborations, often as #OER with a CC-BY license accessible to a wider public. Knowing that your voice will be heard for the first time on Spotify, Apple, or Google Podcasts is an incentive for many (but by no means for all), and it certainly helps to raise the quality of a topic's presentation.

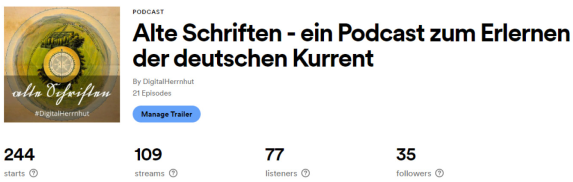

Fig. 6: Usage statistics of the project podcast "Ancient Writings" on Spotify (https://podcasters.spotify.com/, date: 23.11.2022).

The project podcast "Alte Schriften" (https://kurzelinks.de/l3p4) can stand for the third purpose of podcasts for and in academic teaching. It includes handwritten sources and is therefore directly linked to manuscript digitisations on sachsen.digital (https://sachsen.digital/). It enables, with accompanying offers and self-learning courses, a low-threshold learning of the so-called German Kurrent(schrift), is thematically closely linked to the work in the Moravian Knowledge Network (MKN), supports the research efforts in the context of the virTUos project "Digital Herrnhut" (https://tu-dresden.de/gsw/virtuos) and finally builds the bridge to Citizen Science. Of the three exemplary podcasts, it is certainly the most elaborate in production and reaches only a very, very small audience, which is largely due to the very specific cut of the podcast. Nevertheless, it is an important tool for the MKN: numerous sources of Herrnhuterian provenance from the 18th and 19th centuries are exclusively available in handwritten form and must be gradually made accessible in order to develop them as the basis of various research subjects (cf. in detail [6] Lasch, Hetjens, Schuppe 2022). For the reading of the sources, readers have to be identified, who are often already active as volunteers in Citizen Science projects of the SLUB, but at the same time are only in rare exceptional cases able to produce an episode for a podcast. The production of each episode of the podcast requires the cooperation and collaboration of different actors with different competencies and is a considerable coordination challenge, which, as is to be expected with the special design, is not reflected in the call-up figures of the podcast. As an asynchronously provided OER, however, not all usage scenarios and distribution possibilities have been explored yet, which will arise in the future, e.g. in international cooperation.

4. Networking and science communication

All three podcasts serve not only to provide knowledge content for teaching asynchronously for a closed circle of addressees, but also to a broader public. In any case, podcasts reach a broad audience, which makes not only the university location Dresden, but also the topics covered in the podcasts better known. Ideally, new incentives even arise directly in teaching or in Citizen Science contexts for more in-depth engagement with a topic or how to make it available digitally supported asynchronously - in teaching and learning scenarios, this can also be a learning objective. For science communication, it is further very helpful that each of the podcasts presented here is closely related to a specific blog, because they are enhanced, extended podcasts (https://www.e-teaching.org/didaktik/gestaltung/ton/podcast). The podcast on lectures is interlocked with the blog of the Chair of Germanic Linguistics and Language History (https://www.gls-dresden.de/tag/podcast_vorlesung/) in order to clearly compile (as of April 2019) presentation material, organizational information, sample exams, and video recordings. The pandemic-driven student podcast "lasch not least" has also been expanded to include presentation materials and partly refers to video recordings; it is also closely linked to the professorship's blog. However, individual topics are additionally prepared specifically for the blog "lingdrafts - Linguistic Workshop Reports" (such as the presentation of the podcast itself https://lingdrafts.hypotheses.org/1837). The same is true for the project podcast "Alte Schriften" (https://lingdrafts.hypotheses.org/2000), which is furthermore, however, closely linked to the blog of the Moravian Knowledge Network (MKN) (https://dhh.hypotheses.org/) and is also used here as OER in other digital environments - such as the virtual model of the sisters' house Kleinwelka ([7] Hetjens et al. 2022).

5. Outlook

Podcasts are neither a new nor a particularly creative means of, on their own, opening up topics and making them available to a wide audience asynchronously. However, production and hosting have never been easier, and much content already produced, such as video recordings of lectures, can be fed into enhanced podcasts in an alternative distribution channel that opens up new usage scenarios. The workflow presented here does not change in principle, especially when using existing video recordings, even if other software solutions are favored.

Besides the further use of already existing recordings, podcasts can be used on the other hand as a tool for presentation, as a learning tool to practice the digitally supported presentation of elaborated topics. Thirdly, they can be used to establish specific research subjects, to make research visible and, above all, more audible, and to better connect to Citizen Science projects, if this is thematically possible. They are therefore to be understood as a means in knowledge transfer as well as science communication and always open up new possibilities for involvement and further development.

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The Logistics Lab: From a one-week block lab to an asynchronous hybrid course

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Abstract

The article describes, driven by the Corona pandemic, how the "Logistics Lab" laboratory course was/is being transformed from a conventional face-to-face block course into an online and now hybrid format. The pandemic acted as a catalyst for change, as concepts had to be recapped and realigned within a short period of time. The chair's aim consists in finding an advantageous balance between further development on the one hand and the retention of established content and teaching concepts on the other.

Der Beitrag zeigt, wie das Praktikum „Logistics Lab“ vor dem Hintergrund der Corona-Pandemie von einer konventionellen Präsenzveranstaltung erst in ein Online- und anschließend in ein Hybridformat überführt wurde bzw. wird. Die Pandemie übernahm dabei die Funktion eines Entwicklungsbeschleunigers, da bestehende Konzepte binnen kurzer Frist hinterfragt und neu ausgerichtet werden mussten. Dabei besteht der Anspruch des Lehrstuhls, eine vorteilhafte Kombination zwischen einer Weiterentwicklung einerseits und der Beibehaltung etablierter Inhalte und Lehrkonzepte andererseits zu erreichen.

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1. Introduction

Lab courses are a core element of engineering education. They allow students to apply and recap theoretical knowledge in a practice-oriented context and thus acquire job-related, practical competences (cf. [1]).

The design of lab courses is complex and challenging. An existing concept will usually be applied over multiple semesters. However, against the background of the Corona pandemic and managing regularly changing requirements, a high degree of flexibility and speed of adaptation was and is necessary. The aim of the chair is to achieve a suitable balance between refining the lab course on the one hand and the retention of tried and tested concepts on the other.

This paper describes how the course "Logistics Lab" has been and still is being transformed from a conventional face-to-face lab course into an online and subsequent, hybrid format. For this purpose, in this paper the lab course is first described regarding its focus and its content (see Sections 2 and 3). Subsequently, the individual development stages are shown (see Section 4). A special focus is given to two aspects: the analysis of the students' results from the online-based lab course format documented in the submitted reports (see Section 5) and the extension of the course's content by a novel data transmission technology (see Section 6). Section 7 summarizes the contribution, with special focus on the findings of the transformation process.

2. Classification of the lab course

The "Logistics Lab" is an application-oriented course offered by the Chair of Material Handling and Logistics Engineering on a semester basis. Its objectives are to give students of all semesters and different disciplines without domain-specific prior knowledge an understanding of using actuators, sensors, and their programming by applying simple models.

The lab course is designed to support students in acquiring skills in the areas that are typical for engineering courses (cf. [2]), in detail:

- to grasp the necessary basics by researching literature,
- to conduct simulation studies and interpret their results,
- to design, conduct, and evaluate experiments to derive appropriate conclusions,
- to evaluate the significance of experiments by error analysis and considering uncertainties, and
- to evaluate the design of equipment and processes.

In accordance with the chair's research topics, the focus of this lab is on tasks concerning the control and dimensioning of transport systems for intralogistics applications. The contents of the "Logistics Lab" are based on the current research focus of the chair—especially the control of automated guided vehicles (AGVs, see Figure 1) with special focus on task-to-vehicle assignment, route selection, and position detection.

Figure 1: Example of an AGV in intralogistics [3].

In total, there are 15 Lego Mindstorms robots and 15 Turtlebot platforms available for the lab course (see Figure 2). Both systems are designed for lessons at schools and universities and allow the development of driving robots on a small scale. They provide a low threshold into first robotics applications, but also complex projects.

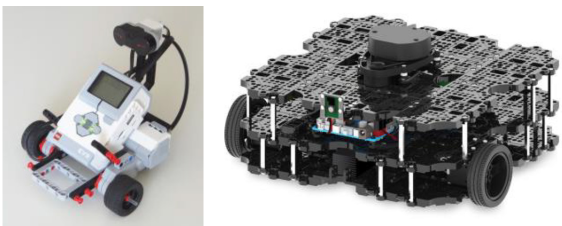

Figure 2: AGV transport vehicle models—Lego Mindstorms (left) and Turtlebot (right) [4], [5].

3. Content of the lab course

Having the aim to provide low-threshold participation in the course, a major challenge is the design of tasks that comply with a wide range of students' prior and specific knowledge. Methods from the field of "gamification" are used to encourage the students and support the learning objectives' achievement (cf. [6], [7]). This allows teaching technology and practical elements playfully and provides a low risk of injury or damage.

Basically, there are three subtasks within the scope of the lab course. These are based on the planning, launch, and control of a transport system (cf. Figure 3).

Subtask (1) is about creating a theoretical operational plan for all vehicles to execute given transport orders in minimal time (Makespan). This is a typical problem in intralogistics and usually clearly defined in mathematical models. Unfortunately, for solving these models, there is no dominant and generally applicable procedure or algorithm (cf. [8]). In the field of research as well as in teaching, there is always the challenge of managing the ambivalence between solution quality and effort.

In subtask (2), a Turtlebot or Mindstorms robot vehicle needs to be programmed so that a series of specified experiments can be carried out to characterize the driving behaviour. For this purpose, the students must design and run experiments and evaluate the results.

Subtask (3) combines the insights of the two previous subtasks: the results of the operational planning from a theoretical perspective and the results gained from the vehicles' experiments. Both need to be combined to critically reflect the transferability of planning and control approaches into practice.

The lab course allows and requires the independent and practical application of existing prior knowledge. To increase motivation, the "Logistics Lab" encourages mutual exchange and competition for the "best" solution (e.g., operational plans with short execution times).

The tasks are designed to be solved collaboratively through group work. The students are only faced with given goals, but no specific solutions or methods are given. Each group has to find its solution through prior knowledge, creativity, and "engineering expertise". In an initial lesson, basic aspects of the lab course are presented. This includes the scientific field, the industrial application of AGVs and a basic introduction to methods required to tackle the lab. Supplementary literature references give clues for independent research. During the semester, teachers remain passive. Questions will be answered as needed in consultations and/or OPAL forums (learning platform OPAL, see https://bildungsportal.sachsen.de/opal/).

Transparent, practical evaluation criteria are provided as benchmarks to assess the quality of the students' solutions. These serve primarily to reflect the groups' own performance but also the competition between the groups and thus to encourage improvements. Students gave feedback that the mutual comparison in the informal competition for the best solution is seen as an enrichment.

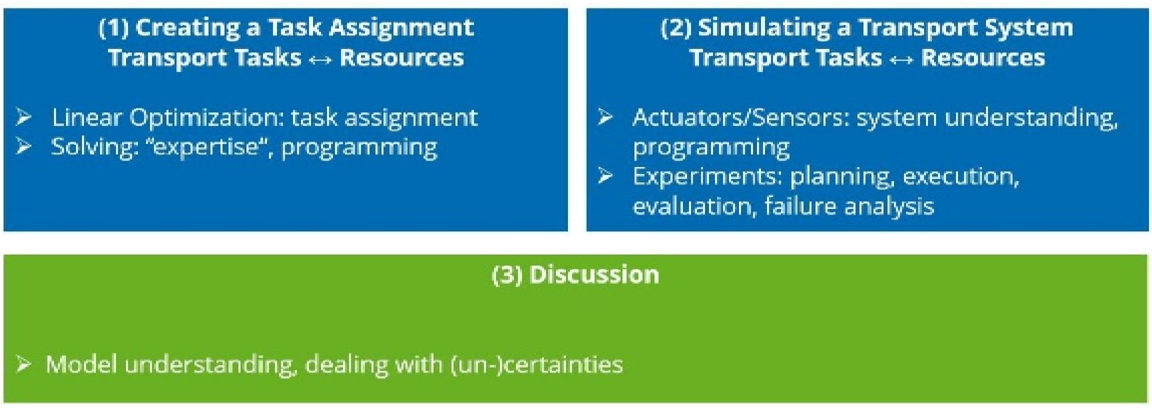

Figure 3: Overview of subtasks (1) to (3) and their contents.

A final report serves as the basis for examination. It should document the procedure and results in a comprehensible form. Due to the high degree of freedom in processing the tasks, the applied approaches have to be discussed self-critically. Potential for improvement identified during the semester should be focused on in the report and thus contribute to the student's process of gaining knowledge.
In a joint final lecture, the solutions and achieved results are discussed. The chair will provide an insight into current developments in industrial applications and research to demonstrate the transferability of the approaches developed by the students and outline development possibilities.

4. Developments in the Corona pandemic

In its history, the "Logistics Lab" was affected by two major developments. On the one hand, the event developed from an elective (for general qualification) to a regular course as part of a module. This led to an increase in participants from about 10 to 60 per semester. In addition, the Corona pandemic, and in particular the demand to avoid face-to-face teaching, forced established concepts to be questioned. In the following, the three stages of development of the "Logistics Lab" are shown.

Initial: The on-site lab course

Initially, the lab course was held as a block course with fixed laboratory working hours. The task was the development of a logistics system with robotic vehicles made from numerous individual Lego parts (cf. Figure 4) to perform transport and storage tasks (e.g., storage of items on a shelf). The focus was thus on the realization of basic functions, with relatively low requirements in terms of system control.
The format was characterized by an intensive exchange between all participants, which was highly appreciated by the students. At the same time, the supervision effort was relatively high for a few participants.
It was found that the students generally spent too much time setting up the system and managing faults. It was therefore concluded that the use of less complex systems with a focus on individual intralogistics components seems more appropriate to meet the set of teaching objectives.

Figure 4: Experiment/model setup of the on-site course: robotic vehicles and intralogistics components.

Revision 1: online and asynchronous

Due to an expected increase in the number of participants and the Corona restrictions, a redesign of the lab course was necessary while maintaining the intended learning objectives.
Basically, the course was adapted so that students were able to complete tasks in group work without the need to be on-site. Experiments were rethought to be carried out using a single robotic vehicle, and necessary parts were handed out at the beginning of the semester (see Figure 5). Instead of complex Lego setups in the chair's own laboratory, the focus shifted to planning the use of the vehicles—which also enhanced the content of the practical course: operational planning is not trivial, requires system-thinking, and thus a high degree of creativity as well as the ability to implement own ideas in terms of programming.

Figure 5: Hand out to perform experiments: components (left) and assembled robot vehicle (right).

To provide flexibility, after an initial lesson, fixed dates during the semester were avoided, which allowed individual time management. The groups were thus able to work independently and asynchronously. The learning platform OPAL and especially the associated forum for the course played a central role in terms of supervising the students, answering and documenting questions, and exchanging

intermediate results. Contrary to expectations, the offer of the chair to use the facilities of the university for processing as needed has not been used so far.
The application of the revised concept was accompanied by a considerable increase in efficiency in supervision, especially because presence at fixed times on-site in the laboratory was no longer necessary. To the benefit of both sides, it was now possible for students to work independently. Furthermore, distance learning students were also able to participate in the lab course. The effects of these measures, i.e. an overview and a classification of the results achieved in the practical course, are given in Section 5.

Revision 2: hybrid with final event in the laboratory

Despite the advantages mentioned above, the online concept shown in the paragraphs before revealed two crucial disadvantages: first, it rather remained unclear that the subdivision into subtasks (cf. Figure 3) not only served for structuring but intentionally targeted the understanding of interacting entities in intralogistics systems. The learning outcome and the teachable content were limited to the individual sub-aspects. On the other hand, the general concept of the course offered a platform for collaborative work and thus an opportunity to exchange interdisciplinary. However, the spatial and temporal separation prevented the generation of possible novel value.
To overcome the disadvantages mentioned above, the online concept was combined with elements of classroom teaching again. A hybrid initial lesson, in presence and parallel online, serves to convey the basics and organizational topics, to get to know each other, to find groups, and to hand out course material. These points were previously characterized by considerable efforts, primarily due to the anonymity of the communication channels used (e.g., web conferences). With a closing lecture in hybrid, on the one hand, a new learning experience is created, and on the other hand, the achievements obtained are appreciated. The solutions developed by the groups will interact in a jointly experiment, be analyzed, and discussed regarding their functionality. The focus will be on the live evaluation of the data. The experiment will be online video streamed.
In detail, a transport system with several vehicles will be set up, and transport orders will be executed in a test environment. For this purpose, the students integrate their robot vehicles and developed software components into a joint system and complete experiments, such as the processing of an operational plan. The goal is to test the control approaches developed during the semester and to comprehensively evaluate the system's performance.
A wireless network is being set up for recording and processing the required data. This is to enable the exact logging of the processing of transport orders, even when several vehicles are used. For this purpose, the laboratory will not be equipped with "conventional" radio technology but with a solution based on light waves, so-called Visual Light Communication (VLC, see Section 6). So, in addition to the pure functionality, state-of-the-art technologies and techniques are used, and a high degree of actuality is conveyed.

Comparison and critical evaluation of the developed teaching concept

In the following, the three development stages of the "Logistics Lab" Initial (I), Revision 1 (R1) and Revision 2 (R2) are summarized and compared.

Format:

- I) Block lab course on-site
- R1) Online and asynchronous
- R2) Hybrid

Number of participants:

- I) Up to twelve students
- R1) Up to sixty students
- R2) Up to sixty students

Role of teachers:

- I) Active supervision of the entire lab course.
- R1) Primarily passive accompaniment, e.g. through consultations.
- R2) Primarily passive accompaniment, e.g. through consultations, and active accompaniment when conducting the joint experiments.

Equipment used:

- I) Logistics system with various components

- R1) Single robot vehicle
- R2) Single robot vehicles are combined across groups using a communication network to form a joint system.

Location of experiment execution/processing:

- I) In the laboratory
- R1) Outside the university
- R2) By arrangement in the laboratory, preferably outside the university, with joint completion in the laboratory.

Examination:

- I) Report
- R1) Report
- R2) Report

The three teaching concepts have in common that students are faced with goals to achieve without providing specific ways of solving them. The objective is to complete the tasks independently within the groups. The focus is on generating solutions that meet the specified requirements in terms of functionality. The quality of the solutions achieved (e.g., duration of the processing of all transport requests) is of secondary importance.

5. Analysis Revision 1

The asynchronous online format of the lab course in Revision 1 requires a high degree of self-reliance from the students. In addition to the organization of the group work, methods for processing the tasks have to be chosen and implemented. In the following, selected analyses of the submitted results/reports are presented to discuss the quality of the results and methodological deficits.

The analysis covers three semester periods and in total 35 groups, each with approximately three students. Of these, 29 groups submitted a report at the end of the semester.

Subtask 1 of the "Logistics Lab" is challenging: An algorithm to solve the optimization problem of task-to-vehicle assignment (resource planning) must be developed, implemented, and tested independently. Apart from two groups, all groups were able to present valid (in the sense of meeting all given restrictions) results.

Students are asked to independently design and discuss multiple approaches, if necessary, using "engineering expertise". Figure 6 uses a boxplot to show how many (different) approaches were investigated by each group.

Most of the groups describe one or two approaches. Usually, there is a basic approach and an optimized version. Groups that only present one solution method typically do an intensive analysis in advance. In some cases, three or more approaches are presented to increase the quality of the solution.

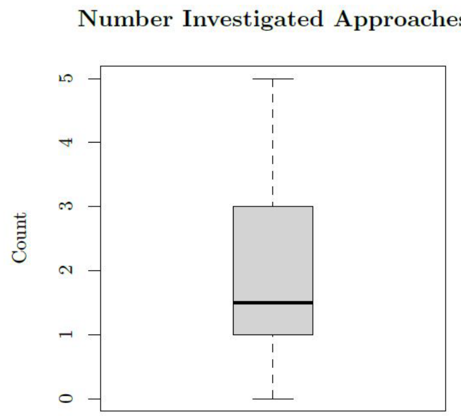

Figure 6: Number of described approaches for solution generation.

An adequate solution is characterized by vehicles traveling as little as possible in an unloaded state ("empty runs"). This basic principle was recognized by the majority of the groups. So, students intuitively came up with heuristic solution strategies, which are typically used in practice.

In parallel, some groups use meta-strategies (e.g., simulated annealing), which are common for solving optimization problems and tend to provide a better solution quality in terms of efficient operational plans—but at the price of higher computational efforts.

Rarely, exact solution strategies (to provide optimal solutions) were applied. Students obviously recognized that these approaches are unsuitable, as the given problem size results in high computation times.

The analysis of the discussions in the reports regarding the approaches used reveals that, compared to a predefined solution path, students delved into the topics. This can be seen in the solution quality: Figure 7 shows the achieved objective function values of the groups in relation to the provided reference solutions. The so-called Makespan was evaluated, i.e. the time span in which all transport tasks were completed and vehicles returned to their specified parking positions. Results for scenarios with one, three, and five transport vehicles are shown.

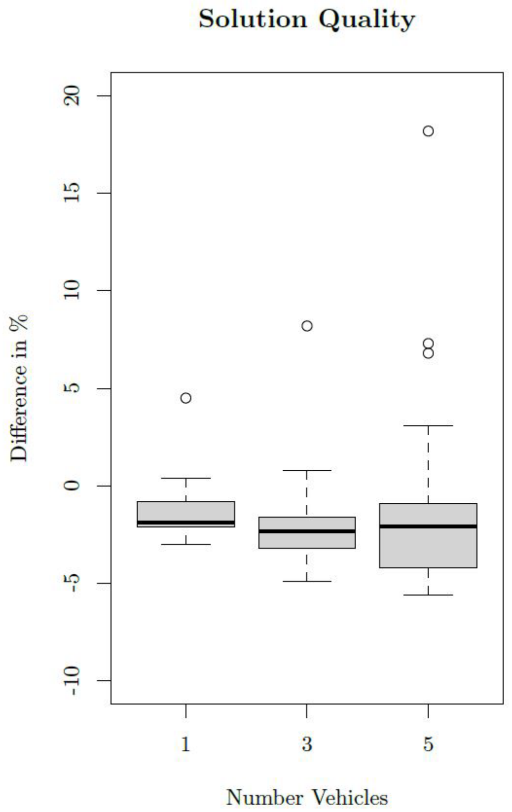

Figure 7: Achieved solution quality measured in percentage deviation from the (provided) reference solution depending on the number of robot vehicles to be considered. Negative values outperform the reference value.

The majority of groups outperformed the reference solutions, that is, the generated operational plans can be processed more quickly. On average, an improvement of 1.5 %, in some cases even up to 6 %, was achieved compared to the reference values. The range of deviation from the specified reference value increases with the problem size (increasing number of vehicles).

The evaluation also shows that solution methods that provide good results for a specific scenario (e.g., one vehicle) are not necessarily advantageous for other scenarios. Most of the students recognized that operational planning is a challenging task lacking a superior solution method, both in theory and in practice.

In summary, students' solution approaches reflect previous research activities regarding the control of automated guided vehicles in terms of diversity and the solution quality achieved (cf. [8], [9]).

For generating the operational plans, no prerequisites are given, i.e., whether and which programming environments to be used. So, students have to apply skills they already have from former courses. From the reports, it becomes clear that initial solutions mostly base on basic considerations and/or created manually. Afterward, software support was used. Even though Java and C# are primarily taught in basic mechanical engineering courses, Python is the dominant programming language applied in this course (67 %, see Figure 8). Software tools such as Matlab and Excel are also used.

Overall, the groups managed to generate operational plans automatically using a self-created program and test them for validity using a provided script.

The solutions or operational plans generated in subtask 1 must be critically discussed in the remaining subtasks regarding their applicability and transferability for controlling real systems, considering experiments with a robot vehicle.

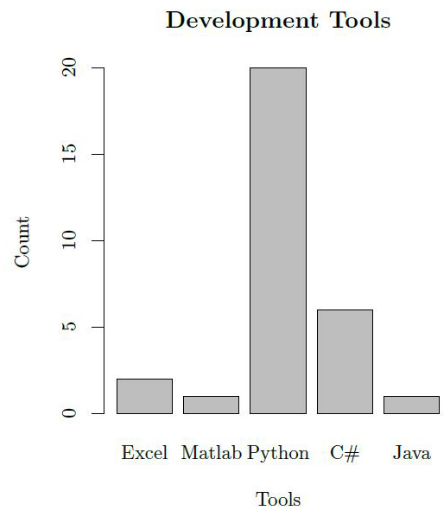

Figure 8: Overview of the frequency of programming languages used for generating operational plans (n = 30).

So far, all participating groups have succeeded in programming the robot vehicles. There were differences in the experimental design and the statistical evaluation of the performed experiments. In particular, the determined number of repetitions of the experiments in most of the cases happened unsystematically, i.e., less according to aspects of statistically valid experimental design than according to pragmatic aspects (cf. Table 1). Most groups determined 10 experiments, or "as a precaution", a particularly high number (> 20). To sum up, there is a methodological deficit.

In subtask 3, all groups succeeded in assessing the transferability of the solutions or the underlying processes to practical applications. For this purpose, the given assumptions were critically discussed. The fact that stochastic travel times are particularly problematic for sequence planning (assuming static values) was usually unrecognized. Looking back and critically questioning the concept of the "Logistics Lab", one reason can be the separation of tasks and, as a result, a lack of perception of an automated guided vehicle system as a dynamic system.

Table 1: Experimental design of protocols—observed frequency of the number of experiment repetitions performed.

Experiment repetitions	Observed frequency in the reports
1	2
3	2
4	1
5	4
7	1
8	1
10	12
20	4
23	1
30	1

For the evaluation, a protocol, or report on the work performed and algorithms implemented, has to be prepared by the students. Again, students are faced with the greatest possible flexibility, with the aim of teaching them to appropriately determine form and scope for summarizing their results.

29 groups submitted a text-based report, often showing more than 30 pages. Two groups submitted presentation slides. Suitable forms of representation, such as pseudocodes and/or UML diagrams, are regularly used to describe the algorithms. Overall, however, descriptions are often too detailed. It is a challenge for the majority of the groups structuring their ideas and present them in a comprehensible form. This deficit should be counteracted in the future by supplementary materials, e.g. based on a "best practice" for a similar task, for self-study.

Regarding the way of organization, the course is characterized by a high degree of autonomy among the groups. Questions concerning the content and organization are answered primarily via the OPAL forum. The majority of the participating groups contributed by sharing interim results, which also allowed them to assess their work. Additionally, available online consultations by the chair are, on the whole, neglected.

As a result, the tasks given to the students are suitable for achieving the learning objectives set. Remarkably, the deficiencies of the work are primarily in interdisciplinary competencies, such as experimental design and documentation. To tackle this, supplementary materials are provided, and shortcomings of past semesters are discussed. In addition, students are asked to present an interim report in a joint lesson in the middle of the semester to allow for constructive advice.

6. Visual Light Communication

As mentioned in the previous chapters, VLC technology (VLC: Visual Light Communication) will be used in the "Logistics Lab" to establish a data network. VLC is a technology based on modulated visible light that takes on the role of a transmission medium for communication. The signal is emitted by a light source (e.g., LED) and received by a photodetector (cf. [10] and Figure 9).

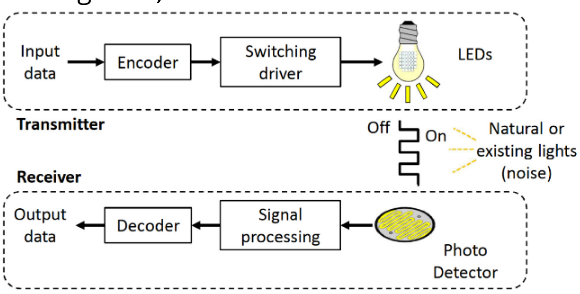

Figure 9: VLC working principle [8].

VLC promises numerous advantages (cf. [11], [12]), including minimal latency and interference for transmission of high data rates with

low-energy consumption, especially when existing radio-based networks are already highly utilized or their operation is prohibited. Since light, unlike radio waves, cannot pass through walls, the technology promises high data security. In addition to its role as a communication network, VLC can also be used to localize objects.
These properties promise applications in production and logistics, which students are taught accordingly.
In particular, application possibilities for communication in AGVs are currently being investigated (cf. [13]-[15] and Figure 10). Potentially, the technology can also be used for localizing AGVs (cf. [16]).
In practice, the use of VLC leads to several challenges. For example, there must be a line of sight between the transmitter and receiver. Artificial light sources or solar radiation may also cause interference. This means that there are uncertainties about VLC that need to be investigated.

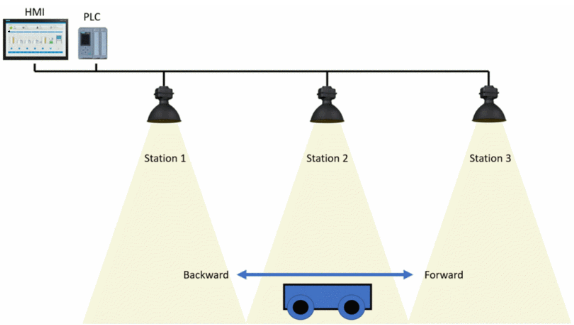

Figure 10: Application of the VLC technology for communication with an AGV (from [15]).

The VLC technology is introduced and critically discussed within the "Logistics Lab". At this point, the course shows a high degree of practical relevance. This is especially true as it is implicitly communicated that logistical systems and their material flows can only be efficiently controlled and realized if associated data and information flows are available and handled appropriately, too.

7. Summary

The "Logistics Lab" course is characterized by constant development. The focus was and still is on digitization, on the one hand to meet the requirements of an increase in the number of students and the associated supervision and organizational effort, and on the other hand, to enhance the teaching content and concepts.
The lab course will be offered as a hybrid course, which allows students to develop solutions independently in small groups and then test them in large group and joint experiments. In this context, a data network with VLC technology will be set up. This allows vehicles to be tracked, system performance to be analyzed, and finally optimized—e.g., by adapting transport plans.
To motivate the students, the gamification approach and its idea of playful competition through disclosure and discussion of key performance indicators are used. This has proven to be successful, following positive student responses and increased solution quality.

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Concurrent Engineering Software Tools – A Trade-Off for efficient Learning in Blended Teaching Scenarios

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Abstract

Concurrent engineering is an approach to the development of complex systems that is characterised by direct communication between the disciplines involved. Key to this approach is the access to the most current design data by all participants at all times. This can be done via a dedicated software solution, for which both commercial and open-source software tools are available. How these tools influence the outcome of the class itself, has been discussed extensively in a separate publication.
This contribution presents the experience that we gathered with different concurrent engineering software tools. The aim of this contribution is to offer other teachers and students some guideline for selecting a concurrent engineering software solution and implementing it in course work, in a way that using the tool itself does not become the central learning challenge of the course. The results might be of interest beyond university courses, as some requirements, like short times to get familiar with the software or certain interface requirements, also apply to other environments in research and development.

Concurrent Engineering ist ein Ansatz zur Entwicklung komplexer Systeme, der sich durch direkte Kommunikation zwischen den beteiligten Disziplinen auszeichnet. Der Schlüssel zu diesem Ansatz ist der Zugang zu den aktuellsten Konstruktionsdaten für alle Beteiligten zu jeder Zeit. Dies kann über eine spezielle Softwarelösung erfolgen, für die sowohl kommerzielle als auch Open-Source-Softwaretools zur Verfügung stehen. Wie diese Werkzeuge das Ergebnis des Kurses selbst beeinflussen, wurde in einer separaten Veröffentlichung ausführlich erörtert.
In diesem Beitrag werden die Erfahrungen vorgestellt, die wir mit verschiedenen Softwaretools für das Concurrent Engineering gesammelt haben. Ziel dieses Beitrags ist es, anderen Lehrenden und Studierenden einen Leitfaden für die Auswahl einer Softwarelösung für das Concurrent Engineering und deren Implementierung in die Lehrveranstaltung an die Hand zu geben, und zwar so, dass die Verwendung des Tools selbst nicht zur zentralen Lernherausforderung der Lehrveranstaltung wird. Die Ergebnisse könnten auch jenseits von Universitätskursen von Interesse sein, da einige Anforderungen, wie z.B. kurze Einarbeitungszeiten in die Software oder bestimmte Schnittstellenanforderungen, auch für andere Umgebungen in Forschung und Entwicklung gelten.

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Acronyms / Abbreviations

CDF	*Concurrent Design Facility*
CDP	*Concurrent Design Platform*
CE	*Concurrent Engineering*
DLR	*German Space Agency*
ECSS	*European Corporation for Space Standardisation*
ESA	*European Space Agency*
EWM	*Engineering Workflow Manager*
IBM	*International Business Machines Corporation*
MBSE	*Model Based Systems Engineering*
OCDT	*Open Concurrent Design Tool*
TUD	*Technische Universität Dresden*

1. Introduction

Concurrent engineering (CE) is an approach to the development of space systems and mission. It is characterised by the direct communication between subsystems and parallel working of the involved disciplines. Learning this interaction and understanding how the different subsystems are connected to each other (i.e. which interfaces there are and which in- and outputs have to be transmitted) might be just as important for students as learning about the individual specialised disciplines (e.g. propulsion, thermal, communication). At Technische Universität Dresden (TUD), students can learn this process by participation in student projects like the development of CubeSat missions or the development of experimental sounding rockets rocket. Furthermore, for engineering students in aerospace, there is also a dedicated course to introduce them to the CE philosophy [1] .

The CE process implementation is usually done with a dedicated infrastructure, which involves hard- and software. The latter is nowadays represented by a multitude of tools, including commercial and open-source solutions. This contribution presents our experience with a selection of the available software tools. The aim of this contribution is to offer other teachers and students some guideline for selecting a concurrent engineering software solution and implementing it in course work, in a way that using the tool itself does not become the central learning challenge of the course.

A detailed overview of the educational aspects of the non-centralized course structure have been discussed extensively in a previous publication [1]. There, advantages and challenges of the course structure but also feedback provided by the participants of the study itself are discussed and evaluated. However, technical considerations of the used tools itself are mostly neglected.

This technical focus shall be discussed in more detail in this contribution. Therefore, following a summary of the software requirements in section 3, the tools will be described in section 4. The actual trade-off will be executed in section 5, before concluding the paper in section 6. Yet before, section 2 will present the educational framework of this analysis.

2. Educational Framework

The course "Spacecraft Design" is embedded in the specialisation module Space Systems Engineering of the diploma programme Mechanical Engineering, specialisation Aerospace Engineering, and now regularly takes place in the 8th semester. This course is one of two courses of the aforementioned module and is completed by a written report for examination. [1]

The students have already acquired detailed knowledge of the design of space systems in courses such as "Energy Systems for Spacecraft" or "Space Propulsion". The course combines the students' knowledge from all previous courses and showcases the high complexity and dependency of vastly different aspects when designing a space mission. The overall learning objectives of the course can be summarised as follows:

- By establishing criteria, weighting them and performing a trade-off, students can comparatively evaluate concepts for space missions to find the solution approach with the highest probability of success.
- By practically applying and combining the knowledge gained in the previous courses, students will be able to conceptualise space missions to develop an overall system to solve a specific engineering problem.

- By getting to know their characteristics as well as advantages and disadvantages, the students know different strategies and models for the development of technical systems and are able to classify and assess them in order to apply them in a targeted and justified manner.

At the beginning of the course, the characteristics as well as advantages and disadvantages of design processes are taught. Special focus is put on concurrent engineering. In addition, an introduction to the utilised CE software is given. The remaining time is used to carry out a concurrent engineering process for the conceptual design of a space system (e.g. a Mars probe, a Moon rover, or a sounding rocket). For this purpose, a mission objective is issued by the teachers, who then assume the role of the customer/client for the rest of the course. The mission is first discussed by the students and initial solution concepts are postulated, which are then evaluated. The students inscribe themselves for different roles/disciplines. Each discipline develops the corresponding subsystem (e.g. for energy supply or communication) or carries out the tasks belonging to the corresponding role (e.g. cost or risk analysis).

Until 2020, the course was held as a block course in a computer lab on three complete days, spread over a period of eight days. Afterwards, the course was transferred into a remote virtual format, which became necessary due to the restrictions associated with the COVID-19 pandemic. The core of the restructuring was the stretching of the course over the entire semester. The portfolio of utilised methods included screencasts to teach the basics at the beginning of the course, shifting the actual elaboration to self-study, and regular live consultations with short presentations by the students. With lower restrictions in the past semester, the course was adapted to a blended teaching version of this course, combining aspects from both previous versions: The course is still stretched over the entire semester, which allows a better focus of the students to the task at hand, be it the exchange of information during meetings, or the development of the responsible subsystem in between the meetings. For the introduction of the course, the available digital course material was utilized, but the consultation meetings were held in person at the institute, allowing for a much-improved room for open discussions to push the state of the design.

3. Basic Software Requirements

Designing any system with a certain complexity is usually not a straightforward process. This is particularly the case for space missions, due to the subsystem experts that may often be very disconnected from each other, both in terms of perspective and physical space. Therefore, a design process requires thorough and rigorous documentation. Appropriate software tools shall support data exchange and guarantee data consistency for everyone. Furthermore, it shall guarantee that the correct information is shared by a standardized definition of objects in the tool, since different subsystems may have vastly different ways of expressing their particular information.

In our course, the students shall experience the concurrent design approach in a first-hand manner, to learn the advantages and strengths, but also get to know limitations and challenges. For this, they shall get to know specific tools that may support a concurrent engineering approach and understand, how this can influence the approach on designing itself. The technical results of the design task itself is only of secondary relevance.

Consequently, the aspects to evaluate possible tools may vary significantly to any industrial or research-oriented approach. For instance, good accessibility and easy implementation of the tool are important, as we may not have a dedicated facility available and in times of remote teaching, students have to have access to the tool from their own personal computer. Since the tool itself is only one part of the course and utilisation of the tool shall not become the main learning challenge, it should be quite intuitive and not require extensive teaching and learning in order to get started. The fact needs to be respected that the students are neither experienced in the design approach itself, nor experts in the subsystem they will represent during the study, making it stressful to tackle too many unknown aspects at once.

Since the technical result of the study is only of secondary importance, the level of details of any information stored may not be decisive, same with the level of complexity, as it is not expected to have too many finalized interconnections between the subsystems. Rather, the system should feature possibilities to define direct relationships between parameters that can be automatically computed, since this can highly benefit the design approach.

4. Concurrent Engineering Tools

Numerous tools to aid the concurrent design process are available. The tools tested here were chosen due to previous experience with them from workshops, projects or similar usage. This list is not meant to be a complete overview of all software tools that could be utilised, but represents the tools that we actually investigated both theoretically (IBM Rhapsody and OCDT) and practically (Rhea CDP and Valispace). Note that further tools are being used in concurrent design facilities (CDF), such as the Virtual Satellite [2] tool used at the German space agency (DLR) or the tool Poseidon developed by NASA [3].

Valispace

Valispace is a German-Portuguese start-up [4] that uses a browser-based web-interface to access a central database (so-called single source of truth) in which the actual design is stored and advanced. Depending on the chosen license, this can be either a cloud-based database or a distribution on a local server. The database can be accessed by any user at any time from any browser system, which guarantees wide compatibility and low software requirements. However, this can also be a challenge due to the wide range of available browser types and active browser versions.

The major goal of Valispace is the development of a design tool to allow “real time collaboration inside and across teams, even with suppliers and customers”[4]. It is designed to support any level of design ranging from early concept studies “through detailed design up to testing and documentation” [4], including a livid requirement engineering.

The design itself is based in a so-called product tree, which is a hierarchic representation of components and subcomponents with its representing parameters (so called Valis) that define the component (see Figure 1).

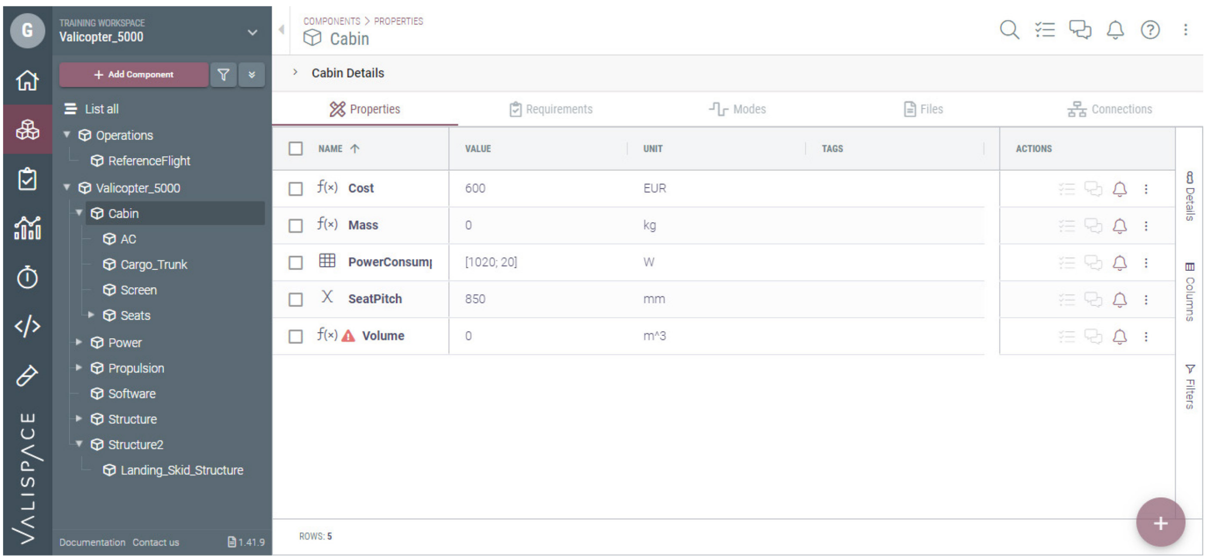

Fig. 1: Screenshot of the Web-Interface of Valispace in the "Components" Section. On the left-hand side, the product tree with the implemented components and their hierarchic structure is shown. On the central and right-hand side, Valis (details) to the selected Component ("Cabin") are shown. [5]

Valis can be dependent of each other, allowing automated calculations as well as budgets over different layers of the component structure. This allows, for instance, quick and easy parametric studies when varying single parameters.

Furthermore, Valispace allows the implementation of alternatives of components that can be conveniently switched in between, for instance implementing different engines in a rocket. In addition to that, modes can be defined allowing the definition of the system at different states of the mission, for instance following the multistage behaviour of a rocket during ascent. Any change by any user will automatically be updated to anyone else accessing the database, allowing close-to real time changes in the model and exchange of data.

Valispace also has implemented numerous quality-of-life-features, including a complete unit implementation, that is able to handle and interchange many different unit systems, also including non-SI-units. Furthermore, a history graph for any parameter allows to follow the evolution of the parameter value over time. Datasets can be implemented to allow for defined interpolation of input values. Also, a general network of interactions between parameters can be plotted.

Many more features have been implemented in Valispace that revolve around the product tree and allow for a more convenient design procedure. All these features are able to link to a certain component or parameter in the product tree, so that it can always be up to date. For instance, the Analysis tool, in which data can be prepared in a document style, including automatically updated tables, graphs and budget lists that can be implemented in reports. There is also a simulation tool that allows for more complex calculations with multiple output parameters. Finally, there is an extensive tool to manage requirements, which can be automatically checked with multiple expressions against parameters of the product tree. Test necessities, procedures, protocols and results can be easily requested and stored accordingly.

Although featuring all these capabilities, Valispace strives to be lean in its user interface and intuitive to understand and use. Short introductions to the tool proved to be sufficient for students to get a grip of its functionality and start designing. The tutorial, that is available at the website [6], allows to get started in a rather short time. This allows for easy and convenient access for any user, which may be in particular beneficial for the unexperienced user.

Rhea CDP

The Concurrent Design Platform (CDP) by Rhea [7] is a detailed design tool with high focus on implementation of space standards like the ECSS-E-TM-10-25A [8]. Here, we want to share our experience with mainly the CDP3.12 as well as the CDP4 version. However, please note that the tool has since been developed further and seen several releases, and is now available under the name “Comet”.

CDP is a standalone program that has to be installed first. It may require a certain Excel Version for some functionalities. In addition to that, a server routing may be necessary to open up a dedicated central database for the design itself. Some knowledge about server setup may be required. However, one can easily connect to any project one has access to, once everything is set up accordingly.

One unique aspect of the tool is the design procedure, which avoids real time changes in favour of a discrete approach of forwarding changes. If a user adds a parameter or changes the value of any existing parameter, these changes are stored in a dedicated routine. Although any user may see indications that changes have been done to a certain parameter, these are not activated right away. A user with a higher level of authority, for instance the team leader of the study, has to manually publish these changes so that it may be live in the actual design. Although this may seem like a highly inconvenient feature at first, it significantly reduces the continuous noise of changes occurring in the earliest design phases. This lowers the risk of potential performance issues of the tool, since it does not require permanent updating. Also, a very high number of additions and changes may only be expected during the initial phase, in which fast publishing may neglect any problems occurring. In later stages of a design, changes mainly update initial values, in which the exact value may not be critical for other components, as long as they are connected accordingly. In any case, this design procedure requires additional tasks and communication, which can negatively affect the development process, particularly in a setting with students that are first-time users of the software.

In addition to this discrete publishing approach, another level of setpoints can be used, being iterations. Here, a user with higher level of authority may set an iteration setpoint that basically copies the current design and freezes its status. These iteration setpoints may be used to analyse the evolution of certain parameters over the course of the study to analyse certain converging behaviour of the design.

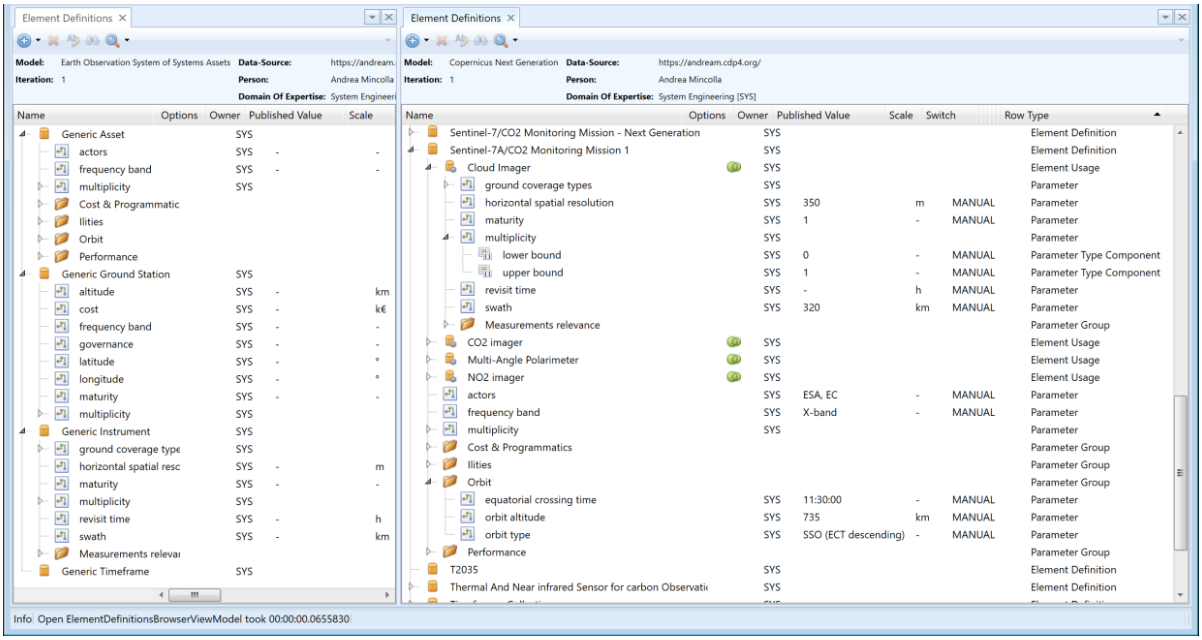

Fig. 2: Working Space inside the Rhea CDP. Shown is the element definition workspace in the tree-list decomposition view for the Model Catalogue (left) and the Study Model (right). [9]

The design itself is stored in a product tree that consists of components and subcomponents with dedicated parameters. Latter are defined in large detail. Furthermore, a strict ownership is established that defines who will be able to adjust a certain parameter, depending on who created it, respectively how it was defined initially. These aspects can make it very difficult for a new user to quickly get into creating objects and generating content. However, once getting used to this technique and understanding the important aspects, it is easy to very clearly define all aspects of any parameter, which makes it easier to later bundle different parameters all over the product tree into detailed budgets and overviews. This is further supported by a model catalogue, which allows the reuse of predefined components over multiple studies.

Although the CDP can be used for any concurrent design approach, it has a defined focus on space mission design. This stems from the implementation of various space standards like the ECSS-E-TM-10-25A [8]. In this standard, best practices for software aided design of space missions are comprised, defining nomenclature as well as data storage in order to enable compatibility between different tools.

Finally, the CDP has an interface to Excel, allowing the implementation of more complex calculations into the design. Therefore, the entire product tree will be exported and linked to an Excel file, which can be updated in both directions to publish changes accordingly. Complex budget calculations, pre-defined graphics as well as calculations can be conducted and exchanged respectively.

IBM Rhapsody

From the tools discussed in this paper, IBM Rhapsody [10] may be the one with the fewest correlations to space mission design, as it is developed as a general model-based system engineering (MBSE) tool for any application. Still, it provides many interesting features to enable the concurrent design approach. In our evaluation, SysML is used as modelling language.

Rhapsody itself is a standalone programme to be installed on one's device, which references itself to a file either on the computer or on a cloud. In order to enable concurrent engineering in a team of multiple users, additional software is required, e.g. the Engineering Workflow Manager (EWM), which can be set up to allow somewhat simultaneous work at the project. However, no actual real-time changes are shared but rather parts of the model are changed by the user in a local copy and afterwards uploaded to the common stream of data for everyone to see. From the university perspective, Rhapsody might be very interesting due to its educational support for educators and students. It is part of the academia initiative by IBM, making it highly accessible for educational purposes.

The general idea of Rhapsody is to have different types of views onto one central model, where each view is optimized for different aspects of specification of the model. The central model itself can again be represented in a product tree, allowing an easy hierarchic structure of the major components. The different views, also called diagrams, focus, for example, on the structure of the subsystems, the definition and connection of requirements, the interaction with users, the definition of states of the system, the definition of actions and data exchanged in the system and so on. Consequently, an initially simple hierarchic structure of a model gets multiple layers of complexity, but the different diagrams keep it comprehensible.

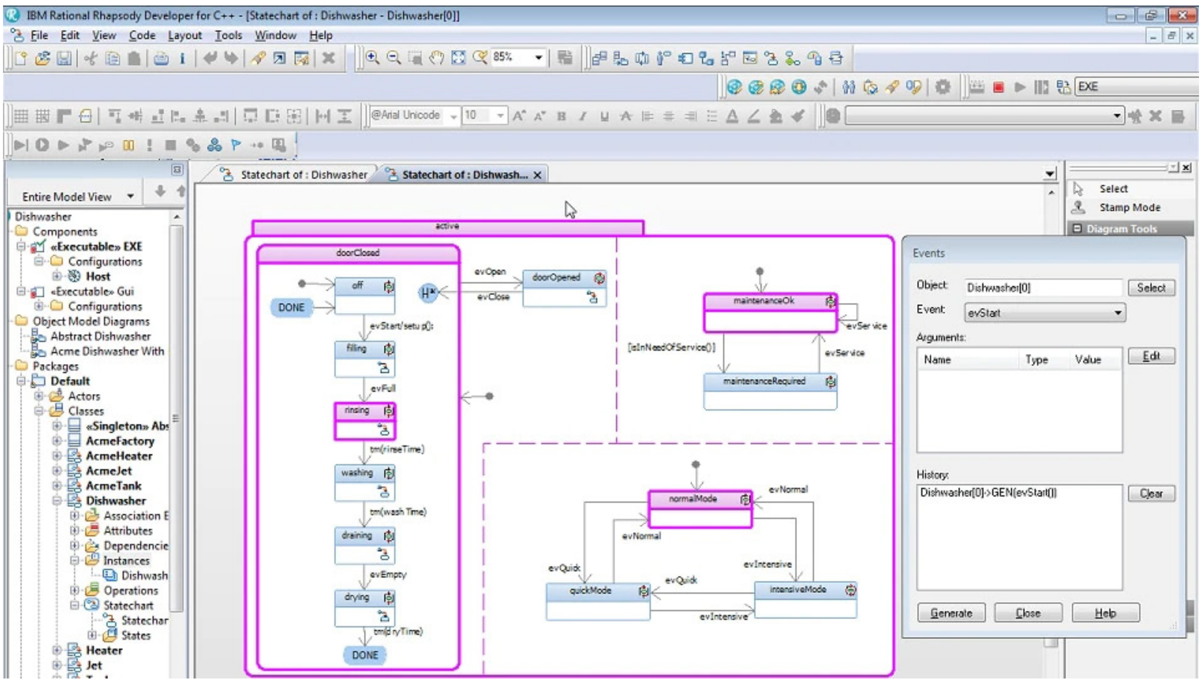

Fig. 3: Screenshot for IBM Rhapsody, showing the tree structured Model View (left) as well as the visual representation of different states of a system (Dishwasher) in an Diagram (central). [11]

Since the focus of Rhapsody is not on the guidance of calculations and therefore the implementation of parametric studies, but rather on the best possible modelized representation of the design, the user has the possibility/task to define any data up to the highest level of detail.

For anyone new to the programme and its implementation, this may very well be overwhelming, which can be, to the authors' experience, a significant hurdle for anyone starting to model in order to exchange data. On the other hand, since much of the setup of data may be multiple layers bellow the initial level of the diagrams, this can make it much easier for any spectator to get the general grasp of the structure and functionality of the model in a top layer view.

Since the possible approaches to modelling a system and all the options for the appearance are vastly different, guidelines have been defined for related topics to establish conventions of naming and structure as well as to guide the eye by similar layout and appearance. For instance, for space mission related topics, the "ESA SysMLProfile" guideline has been defined by the European Space Agency (ESA) [12]. This compendium is a guideline for instance how to structure the model and how to navigate in-between, or which colour code to use, which makes it easier to access multiple projects once you are generally familiar to the appearance.

Overall, Rhapsody is very complex and it may have limited support to guide the mathematical computation of a design task. However, its strength lies in the representation of an actual complex engineering model, down to the very detail, while the different diagrams of the model allow for a quick and easy overview of the system. This way, the modelling may be very complex, but the information that can be stored is extensive. At the same time, the highest levels of the model may be very visually appealing and intuitive, to get a great overview of the model design.

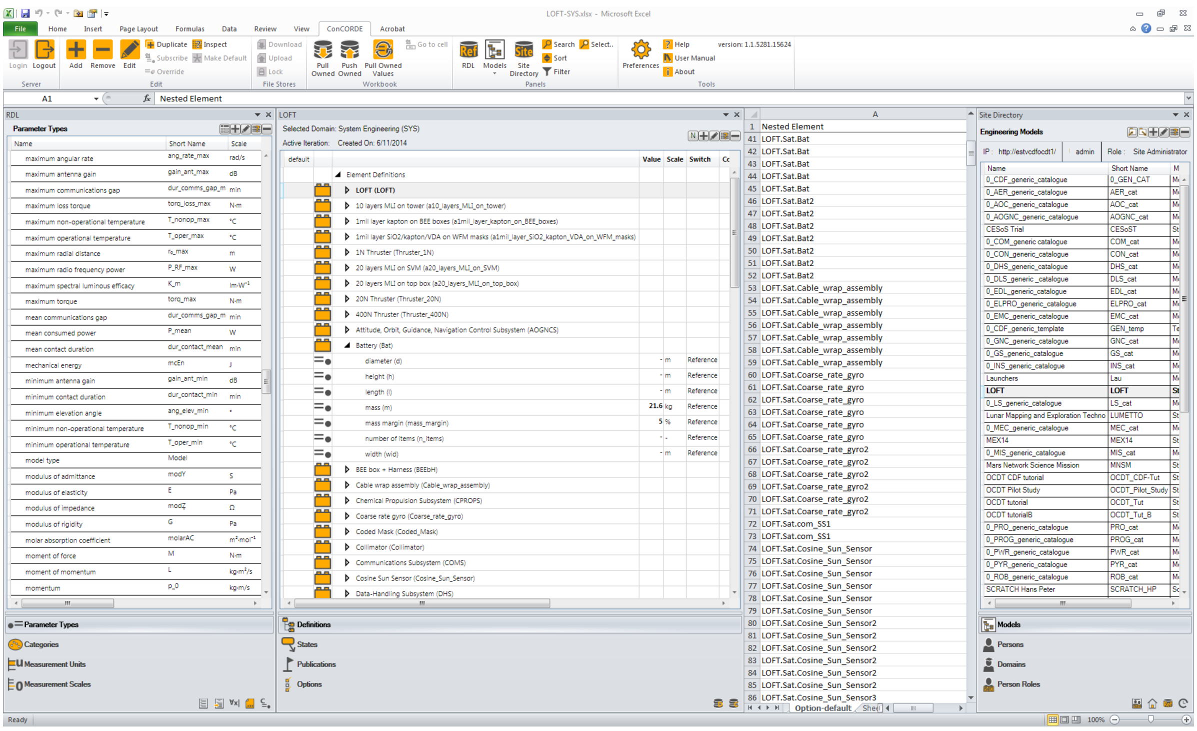

Fig. 4: Screenshot of the ESA OCDT implementation. [14]

ESA OCDT

Used in the CDF of ESA, the Open Concurrent Design Tool (OCDT) is a client/server software package that was developed for ESA. It shares most commonalities with Rhea's CDP. As CDP, it implements a standard semantic data model based on ECSS-E-TM-10-25. However, OCDT is openly distributed under an ESA community open source software licence, which allows qualified community members not only the usage of the software, but also its further development. The centre of this community is the OCDT website[13] with a plethora of information, on which this section is based.

The database, which is stored on a server, is accessed via an OCDT client, which is based on the Microsoft software Excel. Therefore, analyses and calculations can be done directly in Excel, that utilises various spreadsheets that can be added to the workbook as needed. Thus, the work is done locally and the data is then shared via the OCDT interface.

This exchange of information is not done automatically and therefore not instantaneously.

Parameters need to be “pushed” to the database by their creator, who is responsible to keep it up to date. Users who wish to use this parameter need to subscribe to it, which defines the interrelations inside the model. Afterwards, they still need to pull the parameter to their local Excel interface. Moreover, like in Rhea’s CDP, the team leader or system engineer needs to publish data sets after checking the values for consistency.

Apart from that, users are free to create elements/components and attach parameters to them. Those parameters can have advanced characteristics, such as state or option dependencies. Former are used to model system modes or mission phases. Latter are used to model different system options, e.g. to compare an electrical with a chemical propulsion solution and the system effects thereof.

Users who are familiar with Excel, will find a relatively easy entrance to OCDT. Apart from that, the common advantages and disadvantages of Excel apply. The open source character of the software can surely be seen beneficial in terms of accessibility, particularly in the frame of teaching, where the potential disadvantage of relying on community support might not play a big role. Another advantage lies in the fact that this software is used by ESA, which can motivate students to engage more with the software.

Tool Comparison

The tools presented here do have some features in common, but vary in how these are applied. Other Features on the other hand are unique for one or the other tool. One major aspect common for all tools is the representation of the design in a product tree. This hierarchic structure is the baseline for storing the design. For Valispace, OCDT as well as for CDP the use of the product tree is the baseline for understanding the system and is used to navigate through the design to ad or extract information. With Rhapsody on the other hand, the diagrams representing views onto the product tree are a fundamental feature allowing a much more sophisticated understanding of the design of the model. Depending on the design philosophy used for the model as well as personal preferences, many tasks of the work can be achieved only in those diagrams.

Significant for engineering work is the handling of units. In particular for space mission, due to the international character of the industry with its numerous preferences in units as of today and even more so in the past. Although all tools allow a definition of units, Valispace is the only one able to compute with them conveniently. Units of the metric as well as of the imperial system can be added without problem, and once used in formulas are automatically converted. In addition to that, calculations will return error messages if the units are not compatible with in itself. This is great, as it allows the engineer to focus on designing the system, and not care about conversion factors and rules. Although basic unit conversion may be implemented for other tools as well, it is by for not as convenient as with Valispace.

An interesting aspect of the design may be the time resolved evolution of parameters over the course of the study. Valispace has here implemented a historic graph for any Vali, which shows a time resolved development. In the CDP, the evolution of objects may be plotted over several iteration steps. These iteration steps can at the same time also be used as “Save points” of the design, to which one could always could go back, for instance when deciding to go into a different direction with the design or if the design itself may be corrupted. Also, this allows a view onto the design to a certain point in time, which may be beneficial for any review process. A similar feature can be used in the EWM with Rhapsody, where Baselines and Snapshots can be defined. For the OCDT, a version history may be achieved by simply copying the file on the system.

The main objective of our course is to get hands on experience to the concurrent engineering process, so the tools have to compare on how they support this aspect. With Valispace, all users access the same Database, and changes are redirected in real time to any other user accessing the database. Therefore, fast and direct exchange is possible. With CDP, Rhapsody and OCDT, the approach is somewhat more streamlined. While in CDP and OCDT the changes have to be published by a user, in Rhapsody (using EWM) the certain part of the model containing changes has to be uploaded. This upload may generate conflicts that have to be resolved. Even though this approach may be a bit slower, it significantly reduces noise to the user, and allows for an easier performance optimisation of the tool.

File repositories are common for all tools. For Valispace there is also a discussion function connected to Valis itself, including notifications once a Vali is updated, keeping discussion limited to users concerning a certain Vali and saving these discussions for later references.

Analogue tools

All tools presented here have great advantages for particular areas supporting the concurrent design process. However, the tool needs to be intuitive and easy to learn in order to be used by the students in the academic scenario presented. If the software is to complex, students will fall back to familiar alternatives. We observed that students will avoid the software interface and rather share disconnected information by noting it on a common board in the room or facility they are in.

For a course in presence, this may be an option since everyone is working at the same time and means of exchange and communication can be very short. And indeed, we normally started of our courses with a discussion about the general concept idea together on a whiteboard. And even at later stages of the study, this became a pivotal point for the evolution of the design. For general and basic designs, this may be a valid option, since students don't have to get acquainted with a new tool and can focus solely on the design of the respective subsystem they are responsible for and its interaction with other subsystems/disciplines.

However, since the design will get complex by itself in no time, it would quickly get unorganized. In addition to that, for any non-centralized design study over a longer period of time, this cannot be an option.

Nevertheless, we wanted to include this option, as some people might find it favourable in their conditions, where they might have no time to introduce a dedicated software or the means to effectively utilise one. While this option surely has rather narrow limitations, it remains a viable option if the software utilisation itself is not one of the learning objectives. When students of our course avoided the software, we didn't enforce its use. The CD methodology could still be learned well up to a certain model complexity.

5. Trade-Off

The following trade-off will particularly focus on the utilisation of described tools within the scope of course work at universities, as this entails special requirements and boundary conditions, which might not apply to other environments, such as the industrial utilisation of CE. Within this trade-off, we summarise our experience with and assessment of the tools. This means that we didn't conduct this trade-off a priori and then implemented the most promising solution into our course, but we actually tested different options to see what works and what not.

Evaluation Criteria

This section contains the selection of the evaluation criteria for the trade-off with a short description of each criterion to clarify what it represents and how it is assessed. The following criteria will be used:

Usability: A key factor for using a CE software in a course is the time the students need to make use of it, as there is only limited time available. Therefore, the software should be easy to understand in its basics, but not necessarily in its full potential. This includes the availability of freely accessible manuals and tutorials.

Complexity: While enabling very complex models is surely a key aspect for most CE users, it is of secondary concern for the use in an educational framework. However, it is still important to consider. A less complex software could prove beneficial for the course work. However, it would be even better if the software provides complexity, allowing interested students to dig deeper, but not unleashing the full complexity all at once at the new user.

Interface: Aside from the usability and complexity, the design of the user interface also plays an important role, as it defines how the user interacts with the software. While some tools rely on the use of Excel as an interface, other software use browser-based interfaces. While it is clear that the borders to usability and complexity are fluent, this criterion shall put focus on how easily, or better naturally, the user can engage with the software.

Performance: Another criterion is the software's performance. Not only too much complexity or a bad user interface can turn the student away from the screen, also performance issues can. We experienced that, as soon there were problems with the stability of the software or serious latency in the data synchronisation, the acceptance drops. Thus, the software and its implementation in the hardware must ensure not the highest, but flawless performance for a representative user group.

Manageability: This criterion represents the administrational effort for the lecturers, which themselves have limited time and want to put as much focus as possible on the students and their learning processes. Still, they have to set up the software and take care of any troubleshooting along the way. Therefore, this criterion highlights the knowledge that is needed and how much effort it takes to get and keep the software running.

Next to these five criteria (usability, complexity, interface, performance and manageability) the analysis could be extended by further aspects. This could involve the supported interfaces for the implementation of further software solutions (such as design and simulation software). However, we consider this very user-specific and thus did choose not to include it.

Another aspect might be the requirements of the software towards the hardware infrastructure. We didn't include this as the options we consider in this work don't show significant differences that would allow a meaningful differentiation.

Moreover, some might consider available licenses and corresponding prices important. While we agree, we excluded this point as everyone will have their own threshold and prices change frequently.

Lastly, one might consider how widely the different software tools are used within a certain domain. Clearly, learning the utilisation of a more commonly used software would overall have a higher impact on the students than little known software. Nevertheless, this can also change over time and the level of expertise the students can gain on any software solution during the course is rather limited. We also invite the students to check out other tools outside the course to find their own preference.

The five criteria presented are all significant in their very own aspect, which concludes that the failure to fulfil any one of these may have severe influence on the usage by the students participating at the course. Therefore, it was decided to not add any additional weighting factors on these evaluation criteria.

Evaluation

Due to the limited time available during our course, easy accessibility of the functionality of the tool is of significant importance. Since most students are fairly firm with basic Excel operations, it does not take long to get the hang of the OCDT tool. It is easy to start and available on most PCs.

The availability of a browser for Valispace is even more so given to any user, making it very accessible. However, some time to understand the setup of the tool is required to get the principal idea. Still, the tool is kept rather simple and intuitive, and catching the tutorials available will only take a few hours and has proven to be well suited to get started.

For CDP and Rhapsody, additional software has to be installed. Once this one is covered, it may seem to be challenging for beginners to get used to the tools, due to its very detailed options available. With both tools, significant time has to be invested to understand how information is created and connected, to be stored in the model. From our experience, the level of expertise and therefore the level of usage will differ much stronger for the CDP and Rhapsody than for Valispace and OCDT, simply due to the different background and interest of the students. This higher difference makes it more challenging for the tool to be actually used for exchange between the students in the course.

The OCDT, Valispace as well as CDP are designed to aid the design of space related missions. Although other studies may also be conducted, numerous features are implemented to supporting this general field of study, including for instance the handling of units. For new users, this can be quite an important feature to guide the addition of information. Furthermore, a well-known or intuitive interface will also be beneficial for starters.

Guiding the user step by step to add more information is best implemented in Valispace, where only basic information needs to be defined initially, but more detailed parameters can be added at a later point in time. Although updating of parameters is also feasible with CDP and Rhapsody, the user will be confronted with these parameters already at the initial definition of an object, which results into a much slower process of adding information and more hesitance by the students. In particular with Rhapsody, many information has to be added up front, but an experienced user may be able to present this information visually very appealing as well as sorted, using different types of diagrams.

In the description of the tools, we distinguished the functionality of updating the model. Naturally, Excel comes to its limits once a system gets more complex and will consequently take more time to update. Similar challenges have been observed using Valispace, since changing a single parameter can result in the update of a multitude of parameters, which may be resourceful and take more and more time with increasing model complexity.

For the CDP, the model will only be updated by a top-level user. This makes the system more discrete, but also requires less data to be exchanged continuously, improving the performance significantly. For Rhapsody, the aspect for downloading a recent part of the model und uploading it again to the cloud can be a nuisance, in particular when starting from a blank slate and many changes by many different users are to be expected.

From the educators' point of view, the setup of the tools is similar for all options, since respective accounts/access rules have to be added with all of them. However, making use of widely available access points like Excel for the OCDT and a browser for Valispace makes for much more flexibility in planning the courses and allowing the students to work from home. In the end, installing additional software and setting up the respective server for data exchange has always to be respected as a certain time factor.

A basic evaluation of the criteria's is summarized in table 1, which provides a general overview of the viability of these softwares for the requirements discussed initially. For the evaluation, a simple grading system of [++, +, 0, -, --] was used, were [++] represents the best implementation of the criteria, and [--] the worst.

Since the requirements imposed on the tool will drastically influence the results of the evaluation, no summation of our grades is included and the reader is invited to adapt the evaluation to their individual requirements and setting. The grades presented shall be understood as indications for a single semester course at university level.

Tab. 1: Evaluation of software tools for the discussed criterias, based on the requirements imposed by the course structure

	Valispace	**CDP**	**Rhapsody**	**OCDT**
Usability	++	0	--	+
Complexity	+	+	--	0
Interface	++	0	-	+
Performance	-	++	+	+
Manageability	+	+	-	0

6. Conclusion

Multiple tools have been used by the authors to conduct concurrent design studies in a university level course with students. The authors' experience with the software tools is obviously limited, and experienced users may be able to cover many more tasks with the dedicated tools. After all, the authors want to encourage any reader to at least give these tools a try, since they all are very capable and powerful in their very own way. Furthermore, the tools are under constant development, which means that certain aspects may have already changed since their evaluation.

For the course at hand, the software implementation by Valispace is our preferred solution as of right now. The tool grants easy access and requires only a minimum of initial training, which also can be self-taught with the available tutorials, to enable students to work with the tool and start designing. Since the results of our design is not the main priority and the design itself will not get as complex, we can respect possible limitations quite well. Additional tools like time management and the implemented requirement management and the reporting tool are additional benefits for our course. From our experience, the tool provided the best introduction to the general concurrent engineering approach for the students, and resulted in the greatest amount of data shared with such a tool.

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Opportunities of digital teaching in process control: flip the classroom, provide a level playing field, and integrate external experts

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Abstract

After serval periods of remote teaching in the COVID-19 pandemic, many academic institutions are working on concepts to transfer the lessons learned about digital teaching into their didactic concepts. In this paper, we present a didactic concept for courses with student groups of heterogenous educational background. It is based on a self-paced learning phase with self-study materials, a flipped classroom session for interactive problem solving in interdisciplinary student groups, an exercise session for more complex problems, and a student project. An important key feature is that (1) the students can learn according to their educational background in the self-paced learning stage and teach each other in the other parts of the course. Additional features are (2) the maximized share of the student-staff contact time spent on cooperative problem solving and (3) the collaborative development of teaching materials with external experts. The concept was implemented within our course on process control systems. The results are illustrated via the example of a digital teaching module for hybrid semi-parametric modeling.

Nach mehreren Phasen der Fernlehre in der COVID-19-Pandemie arbeiten viele akademische Einrichtungen an Konzepten, um die Erfahrungen mit der digitalen Lehre in ihre didaktischen Konzepte zu übertragen. In diesem Beitrag stellen wir ein didaktisches Konzept für Kurse mit Studierendengruppen mit heterogenem Bildungshintergrund vor. Es basiert auf einer Selbstlernphase mit Selbstlernmaterialien, einer Flipped-Classroom-Sitzung zur interaktiven Problemlösung in interdisziplinären Schülergruppen, einer Übungseinheit für komplexere Probleme und einem Schülerprojekt. Ein wichtiges Hauptmerkmal ist, dass (1) die Studierenden in der Selbstlernphase entsprechend ihrem Bildungshintergrund lernen und sich in den anderen Teilen des Kurses gegenseitig unterrichten können. Weitere Merkmale sind (2) die Maximierung des Anteils der Kontaktzeit zwischen Studierenden und Lehrkräften, der für kooperative Problemlösungen aufgewendet wird, und (3) die gemeinsame Entwicklung von Lehrmaterialien mit externen Experten. Das Konzept wurde in unserer Lehrveranstaltung über Prozessleitsysteme umgesetzt. Die Ergebnisse werden am Beispiel eines digitalen Lehrmoduls zur hybriden semi-parametrischen Modellierung dargestellt.

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1. Introduction

Just as for many other chairs and professorships, the COVID-19 pandemic demanded a transfer of teaching concepts into the digital space from the chair for Process Control Systems (PCS) and the Process Systems Engineering (PSE) group at TU Dresden. Many different lectures, exercises and even practical work of different class sizes (10 to 150 students) had to be transferred into a digital format. To achieve this, various teaching concepts have been adopted in synchronous and asynchronous formats, with videos or life lectures, with questions & answers (Q&A)-based or life exercises, etc. with varying degrees of success. Especially in small sized lectures with up to 30 students an asynchronous flipped classroom approach proved to be a valuable approach providing advantages over the previous conventional teaching style.

The regulatory relaxation of the pandemic related measures then called for a transition of these online concepts into the regular, attendance-based teaching context of our universities based on lectures, exercises and practical work. We also wanted to take further advantage of the digital teaching formats and to continue to use the newly developed teaching materials. Therefore, we chose the lecture "Simulation und Optimierung" (SimOpt, engl.: Simulation and Optimization) in the module "Prozessführungssysteme" (engl.: Process Control Systems) as a use case to continue the development of our teaching concepts. SimOpt is an advanced interdisciplinary lecture consisting of lectures, exercises and a student project, which has to be carried out by the students in interdisciplinary groups of 3-5 students. In the following, the teaching concept and the results of the first implementation steps of our digital fellowship "Digitale, interdisziplinäre Lehre im MINT-Bereich (LIME) - Ausbildung der Ingnieure von Morgen" are presented.

2. Requirements and Concept

The lecture SimOpt aims to achieve two main objectives:

1. Develop advanced skills in process control
2. Develop soft skills for interdisciplinary collaborative work in process control projects

To achieve these goals, the lecture is aimed at students in the study programs "Process Engineering and Natural Materials Technology", "Electrical Engineering", "Mechatronics", "Renewable Energy Systems" and "Information Systems Engineering" as an elective course. In past years, SimOpt did consist of some lectures and exercises to convey knowledge and to provide a level playing field for the heterogeneous group of students. Furthermore, it contained a student project based on rather open project tasks, which was done in interdisciplinary groups of 3-5 students. The student project aimed to simulate a problem-solving task in an industrial environment by providing a real-world monitoring or control problem provided by the Process-to-Order Lab (P2O-Lab) or by an industrial partner. Important key features of the lecture were and will still be

1. its interdisciplinary character,
2. the small sized classes, and
3. its advanced level.

In LIME, we aimed to rethink the way we provide a level playing field for the students, while maintaining the student project. The new concept is based on digital teaching modules, which are used to provide knowledge in a flipped classroom approach. For this purpose, 12 individually digital teaching modules were designed addressing topics like e.g.: the basics of first principles modeling, hybrid semi-parametric modeling, multiple-input-multiple-output control (MIMO) and model-predictive control (MPC). Each digital teaching module consists of one

- a self-paced learning phase with self-study materials, including
    - 1 motivational video
    - 3-5 teaching videos recorded with a lightboard explaining the most important methods and concepts
    - ~10 A4 pages of script providing further content for deeper understanding

- a flipped classroom session consisting of
  - Q&A session
  - 1 problem, which must be solved in interdisciplinary project groups of 3-5 students with help of the lecturer applying MATLAB
- and an exercise session based on
  - 1-2 problems, which must be solved in the interdisciplinary project groups of 3-5 students applying MATLAB

In parallel to the teaching modules, the students work on

- a student project with a complex problem-solving task which spans the entire semester.

Each student group also serves as an interdisciplinary study group. The concept described above does allow to address the three key features of the SimOpt lecture in a convenient manner.

Firstly, the digital teaching modules provide a measure for the interdisciplinary composition of the student group. Students of the study programs "Electrical Engineering", "Mechatronics", etc. can usually be expected to be highly skilled in control design and programming but lack knowledge regarding dynamic modeling of process systems. Meanwhile, "Process Engineering and Natural Materials Technology" students usually have a higher skill level in process modeling but lack knowledge in control theory. The self-learning phase based on the Self-paced learning phase does allow these individual groups of students to focus on their particular learning fields. Furthermore, students can skip content and topics they feel already very familiar with. In the flipped classroom sessions and the exercises, emphasize is put on the application of the knowledge and the interdisciplinary exchange within the project groups. Thus, this teaching style does allow to provide a level-playing field while accounting for the needs of the individual groups of students.

Secondly, the flipped classroom approach allows to make the most of the small sized class. In the past years, it became widely accepted, that flipped classroom concepts provide a great tool to attain mastery for students [1,2]. Lewin et al. [3] argue that students should be allowed "to experiment, get things wrong and understand why". Furthermore, they state that the student-staff contact time should mostly be used to work on problems cooperatively. The staff members should become mentors and motivators. Since this is easier to achieve with a high staff to students' ratio, this suits the SimOpt lecture well. In addition, students begin working together in interdisciplinary project groups early on through the Flipped Classroom approach, start to transfer knowledge within the group, and learn to understand the competency profile of the other students in the group.

Thirdly, the development of digital teaching modules easily allows the integration of new topics from research, which can potentially be provided by external experts. Hence, this provides a suitable framework for an advanced lecture. A pleasant side effect is that this approach does allow to distribute the preparation workload for the teaching materials across institutions if the materials are published as open educational resources (OER) by the contributing partners.

3. Implementation of the Concept in the Digital Fellowship LIME

The chair of PCS and the PSE group is revising the lecture SimOpt in the context of a tandem Digital Fellowship funded by the Sächsisches Staatsministerium für Wissenschaft, Kultur und Tourismus (SMWK). The objectives of this funding program were [4]:

- support the development of digital teaching and learning competencies
- development and testing of innovative teaching and examination methods as well as digital teaching methodologies and tools
- establish Open Educational Resources (OER) in the teaching practice

he provided budget does allow for purchase of additional equipment and materials for our recording environment for the teaching videos. Furthermore, we are able to pay external experts and student workers who support us with the development the teaching materials. For LIME, we did retrofit the Usability for Process Industries (UPI) Lab of the chair of PCS. The lab was already equipped with furniture and recording equipment. Therefore, only little additional equipment was needed like e. g. microphones and bodypacks for the recording. Furthermore, we contacted ten external experts in the field of process control asking for contributions to modeling, process monitoring, process control, etc. to date. The experts were chosen based on their reputation in the related topic. For example, Mr. von Stosch (see [5]) contributed as a highly ranked expert in the field of hybrid semi-parametric modeling for this particular topic in our curriculum. Figure 1 presents an overview on the contributions of external experts to LIME. We received nine answers to our initial contact e-mail. Seven of the experts were in principle interested to contribute to project. Currently, the contribution of three experts is fixed while we are still in negotiation with four additional experts. One expert did not answer to our e-mail, and two did reject to contribute due to the conditions of the contract. Overall, we recognized a reasonable interest in collaborative digital teaching modules. Hence, we believe this concept provides a framework of high potential for collaborative teaching and exchange of teaching materials in the future. The funding of the Digital Fellowship furthermore did allow us to offer a compensation to the external experts. Overall, it can be stated, the compensation did not seem to be the main reason for the experts to decide whether to contribute or reject. The major reason for a rejection was the time, which would have had to be dedicated to the development of teaching materials. Staff members of relevant expertise were paired with the external expert to support them by answering questions about the content and coordinated the formatting of the provided materials with the student workers. The student workers under supervision of the staff

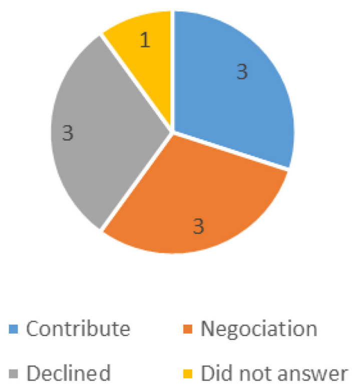

Fig. 1: Contribution of external experts to the digital teaching project LIME-

members were responsible for setting up the recording environment including software tools etc. Furthermore, they did the recording with the staff members or the external experts in our recording environment. Afterwards, they are responsible for the video editing. Furthermore, the staff members, the student workers and the external experts developed problems to be solved in MATLAB. All materialsare created under a Creative Commons license[1] and will be reusable as open educational resources for the TU Dresden, the external experts and other interested institutions or entities.

4. Example - A digital teaching module on hybrid semi-parametric model

This section provides an example for a digital teaching module. For the teaching module on "hybrid semi-parametric modeling", we collaborated with Dr. Moritz von Stosch. Dr. von Stosch provided us with

- a motivational video on hybrid semi-parametric modeling,
- a lightboard sketches, which we adjusted for our purpose,
- a script on hybrid modeling, and
- two exercise task, which we adjusted to apply them within the flipped classroom session and the exercise session.

Figure 2 shows one of the lightboard sketches we derived. On the left side, the sketch shows an open tank system, where water can be fed actively via an input volume flow and is evapo-

[1] https://creativecommons.org

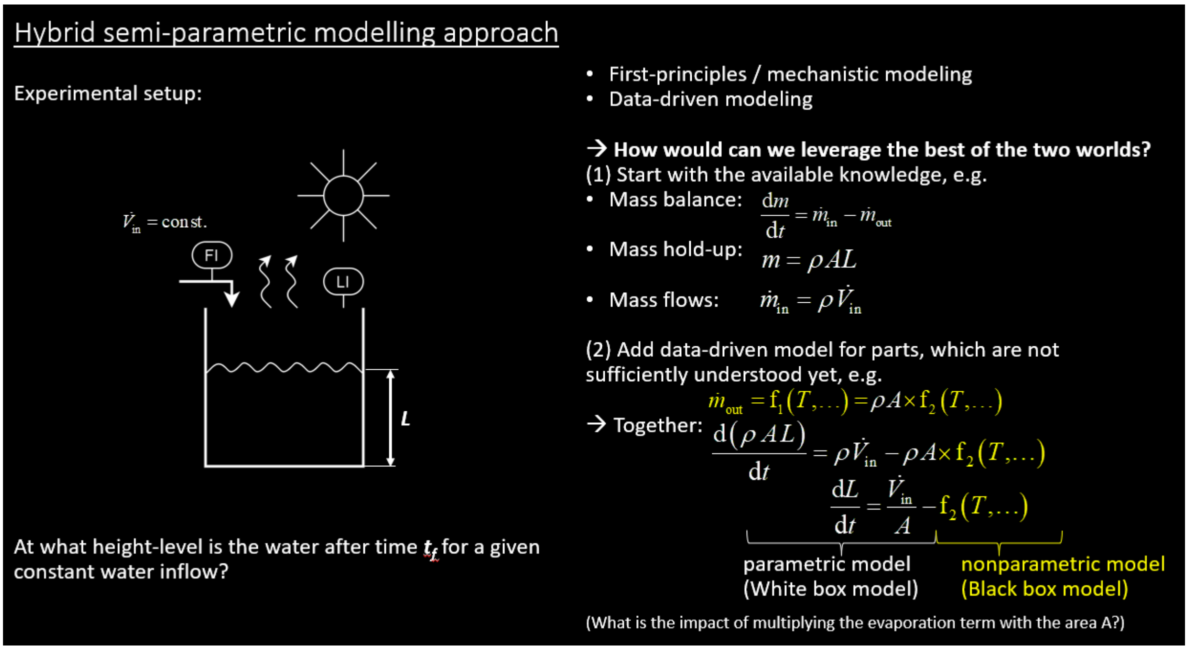

Fig. 2: Example of a lightboard sketch on hybrid semi-parametric modeling

rated by the sun. On the right side, the basic idea of hybrid semi-parametric modeling is presented. Parametric models based on first-principles are combined with non-parametric, data-driven models. Based on the lightboard sketches, we recorded videos with our lightboard.

Figure 3 provides an impression of the style of the videos and provides a link to the example video on YouTube.

For the self-paced learning phase, students were provided with the motivational video, 5 lightboard videos, and the script. These materials were provided via the learning platform OPAL. Figure 4 presents the structure of a teaching module on OPAL.

In the flipped classroom session, firstly a Q&A session was carried out. In the particular Q&A session on hybrid semi-parametric modeling

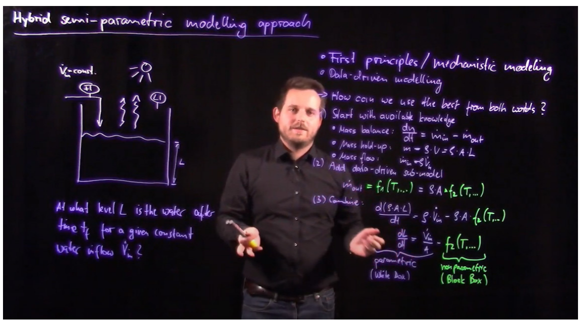

Fig. 3: Screenshot from a lightboard video (see: https://youtu.be/Z8JZm-f1tbQ)

e.g. a question was asked on how parameter identification of hybrid semi-parametric models can be done.

Afterwards, the students were presented with the first problem, which was based on the first exercise task provided by Dr. von Stosch. Via the OPAL platform, the students were provided with a dataset relating different cross-sectional areas, times, and temperatures to the evaporated water volume in open tank systems similar to the system presented in Figure 2. Now, the students were asked to develop a model capturing the behavior described by the dataset. An important feature of the dataset is that it is too small to apply pure non-parametric, data-driven modeling approaches. Furthermore, the amount of available knowledge about the system is too low to develop a parametric, first-principles-based model. These challenges were elaborated in an interactive discussion among students and between lecturer and students as well as through several iterations of trial-and-error. Furthermore, a suitable hybrid semi-parametric model architecture, its implementation, and its validation based on a test dataset were discussed interactively and developed in MATLAB. The result is a nonlinear algebraic equation (NLAE) constructed from parametric and nonparametric model parts.

In the exercise session, the students were presented with a more complex system based on a continuous stirred tank reactor (CSTR). In addition, again they were provided with a training and a test data set. This problem is more complex since the solution envisaged is an ordinary differential equation (ODE) system, developed from the mass balances for the different reacting components. The reaction rate is captured by a non-parametric sub-model. This problem was again processed in the in the interdisciplinary project groups and interactively discussed with the lecturer.

Overall, we were able to significantly reduce the preparation time to integrate this new topic into our curriculum. Furthermore, we produced reusable teaching materials, that will be licensed under creative commons and therefore will be reusable by our external partners as well. Furthermore, we experienced very interactive and hands-on flipped-classroom and exercise sessions with our students.

5. Conclusion

The COVID-19 pandemic accelerated the adoption of new teaching concepts like digital teaching materials (e.g.: lecture videos, etc.) in many universities. The same is true for the chair of PCS and the PSE group at TU Dresden. After adopting multiple different teaching concepts for different lectures, a flipped classroom approach supported by digital teaching materials demonstrated its high potential especially for small to medium sized classes. It allows to maximize the student-staff contact time dedicated to problem-solving instead of an information transfer. Furthermore, it unlocks the integration of contributions by external experts into the lecture program. This is especially interesting for advanced courses, since new digital teaching modules on recent research topics can be developed in collaboration with the external experts. In addition, this approach can mitigate the workload of the teaching staff since the workload can be distributed across different institutions. The overall interest of the experts contacted within the Digital Fellowship LIME into the collaborative development of digital teaching modules has

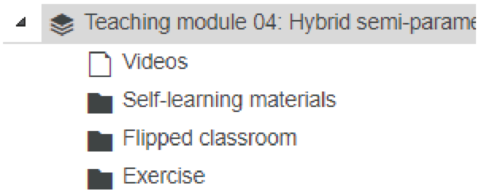

Fig. 4: Structure of a teaching module on the learning platform OPAL

been found to be reasonable. Therefore, we are convinced that the approach of LIME shows potential for a wider adoption. Such collaborative development of teaching materials could be hosted by partnering chairs within universities or by the communities of the particular disciplines. The major reason to reject a contribution to LIME were missing time resources. We expect this issue to be mitigated by the basic concept of collaborative development of teaching materials, but the development of the new concept and the alignment on common topics, structures, and styles make the initial steps challenging. But the experience with the preparation of teaching modules on e.g. hybrid semi-parametric modeling was promising. We were able to significantly reduce the preparation work for a new lecture topic within our group, produced self-paced learning materials that are reusable by us and our partners as well, and experienced very engaged flipped-classroom and exercise sessions with our students.

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Finally, we would like to thank Prof. Brahim Benyahia, Prof. Ali Akbar Safavi, and Dr. Moritz von Stosch for their contribution to the project LIME.

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From the Computer into the Air - The Interdisciplinary Design Project Aerospace Engineering

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Abstract

As part of the Interdisciplinary Design Project Aerospace Engineering, students design unmanned aerial systems (UAS) for search and rescue missions. This includes preliminary design (e.g. aerodynamics), detailed design (e.g. autopilot design) and, so far, simulation-based verification of the overall concept. Now the design is to be brought from the computer into the air. For this purpose, the Chair of Flight Mechanics and Flight Control provides all electronic components (engines, flight computers, etc.). The aircraft structure is to be manufactured by the students themselves. For this purpose, they have a state-of-the-art laser cutter at their disposal, which the professorship received funding for within the framework of the call for proposals for teaching/learning projects of the Faculty of Mechanical Engineering. This allows the fast and efficient cutting of the structural parts in wooden construction. The self-built UAS is evaluated in a flight test.

Im Rahmen des Interdisziplinären Entwurfsprojektes Luft- und Raumfahrttechnik entwerfen Studierende unbemannte Flugsysteme für Such- und Rettungsaufgaben. Dies umfasst den Vorentwurf (z.B. Aerodynamik), Detailentwurf (z.B. Autopilotenentwurf) und, bisher, die simulationsbasierte Verifikation des Gesamtkonzeptes. Nun soll der Entwurf vom Computer in die Luft gebracht werden. Hierfür stellt die Professur für Flugmechanik und Flugregelung sämtliche elektronischen Komponenten (Motoren, Flugrechner, etc.) zur Verfügung. Die Flugzeugstruktur soll von den Studierenden selbst gefertigt werden. Hierfür steht ihnen ein hochmoderner Lasercutter, welchen die Professur im Rahmen der Ausschreibung für Lehr-/Lernprojekte der Fakultät Maschinenwesen gefördert bekommen hat, zur Verfügung. Dieser erlaubt den schnellen und effizienten Zuschnitt der Strukturteile in Holzbauweise. Das selbstgebaute Flugsystem wird im Flugversuch evaluiert.

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1. Introduction

The module "Interdisciplinary Design Project Aerospace Engineering" ran for the first time in the summer semester of 2022 at the Chair of Flight Mechanics and Flight Control, which has been in existence since January 2021. As part of the project, students work in groups of four to design and test a small Unmanned Aerial System (sUAS) specifically for search and rescue missions – an ever-growing field of application for sUAS. The current iteration stage consists of the three core topics of any design project: the preliminary design, the detailed design and the implementation and verification of the concept. The latter, however, is still done purely numerically within a simulation environment. The project demands a high degree of teamwork, self-organization and interdisciplinary thinking from the students. The direct interaction with each other, but also with the lecturers, promotes the development of essential soft skills from which the students can benefit in their later careers. The work and consultation in a small group format makes it possible to closely monitor the learning progress of individuals, to provide targeted support and also to challenge them. A core aspect of the course is a realistic implementation of the design project, which includes reasonable requirements, development of specifications, reviews, progress meetings and presentation of milestones. In the next evolutionary stage of the project, the designs will now be taken from the computer to the air. The students will build their aircraft designs using structural parts manufactured with a laser cutter. The chair provides commercial-off-the-shelf (COTS) electronics components. A final flight test campaign will then verify the flight characteristics of the designs. This will allow students to go through the complete design process of an sUAS and earn the rewards of their work.

2. The current iteration stage

The "Interdisciplinary Design Project Aerospace Engineering" started in the summer semester of 2022: Groups of four students each design a small unmanned aerial system for search and rescue tasks. A fixed-wing configuration was chosen consciously for this purpose because it is the most efficient and most-commonly used configuration for such tasks. It also allows direct, interdisciplinary application of the theory taught in the aerospace course including aircraft design, structural design, flight mechanics, flight dynamics, flight performance, flight control, as well as aerodynamics. Furthermore, sUAS represent one of the major growth markets of the international aerospace industry [1], but receive little attention in the teaching of many universities so far. Thus, the module perfectly prepares students for a potential career path and gives them an edge over competitors from other universities. This specific outlook directly contributes to student motivation and engagement.

Especially in a course based on personal responsibility and self-organized work, it is important to convey a comprehensible story and a realistic scenario. This represents the starting point of the project, in which the teachers act as the company's management and the students embody a team of young development engineers facing their first major project after receiving their degree.

The company management presents a customer's order for an sUAS for a well-defined reference mission (Fig. 1) with imposes performance requirements which differ slightly for each group. Special attention was paid to fair conditions, i.e. no requirement was per-se more difficult than another. However, they were different so that there was no suitable "standard design" for all groups. Based on the given requirements, a defined specification was presented.

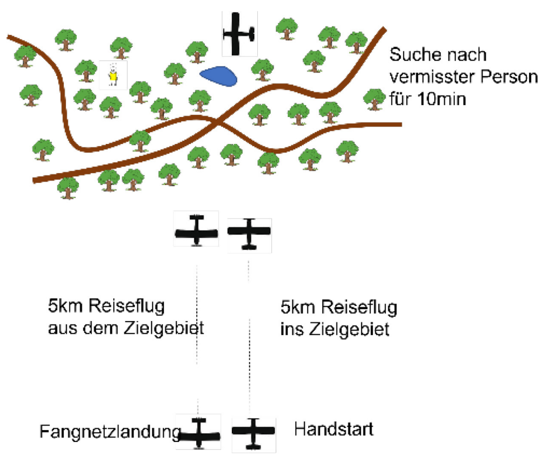

Fig. 1: Example mission of an sUAS

This marks the start of the project, which in its current state consists of three main parts: the preliminary design, the detailed design and the simulation-based verification of the overall concept.

In the preliminary design, students must fundamentally dimension their sUAS based on flight performance and aerodynamic calculations. This includes the selection and evaluation of a suitable airfoil and planform. For the former, the program XFoil [2] is used. This tool is based on a 2-D panel method with superimposed boundary layer calculation and allows the numerical computation of airfoil drag polars as the basis of the overall aircraft velocity polars. These are mandatory for the selection of the propulsion system, batteries and determination of the flight performance. For this purpose, the students are given data of COTS motors and batteries as well as typical assumptions for the preliminary design regarding aerodynamic drag or structural masses of individual aircraft parts. This keeps the focus on the design and the task within a reasonable time frame. All calculations are performed in Matlab [3], one of the most powerful and widely used engineering computation and simulation tools in the industry. The presentation of the results is equivalent to the "Prelimenary Design Review" (PDR) in an industrial project.

Matlab was selected intentionally as the software of choice, as briefly explained below. On the one hand, Matlab is the leading commercial software for numerical simulation and data acquisition as well as their evaluation. A large number of problem-specific libraries, e.g. for system identification, controller design and controller analyses, allow a broad application to engineering problems, which is why it is used by companies such as Airbus in the field of flight mechanics and flight control or by BMW for the modeling of vehicle dynamics and the development of driver assistance systems. Many university spin-offs in the field of sUAS (e.g. Phoenix Wings, Amazilla Aerospace) also use Matlab. The same applies to research institutions such as the German Aerospace Center (DLR). By familiarizing students with this powerful software at an early stage of their career, it makes it easier for them to start their careers later on. In addition, Matlab uses a syntax that is easier to learn compared to Fortran or C. The software is also easy to use. In combination with the large repertoire of tutorials, it offers students a pleasant learning curve. This is especially important since the focus of such a project should not be primarily on learning how to use software, but on problem-based application of previously acquired knowledge. Last but not least, Matlab includes the software Simulink, which is defacto a graphical representation of Matlab code in the form of block diagrams. Simulink is particularly suitable for modeling and analyzing complex nonlinear dynamic systems. Through direct integration with Matlab, as well as a variety of tutorials, an appropriate learning curve for students is also achieved. Simulink becomes essential especially in the later analysis phases.

The next task block involves the detailed design and thus the final dimensioning of the aircraft. The groups must design a fuselage that can accommodate the payload and the necessary equipment. In addition, the tail unit must be designed to guarantee stability and controllability for all envisioned center-of-gravity positions of the aircraft. Furthermore, a well-founded material selection is required. For the later implementation of the aircraft in the simulation environment, the mass distribution and the aerodynamic characteristics of the sUAS must be determined. For this purpose, the students use the program Athena Vortex Lattice (AVL) [4], which calculates the relevant aerodynamic parameters by means of a vortex-lattice method (Fig. 2). AVL provides non-dimensional coefficients that can be fed into the simulation tool.

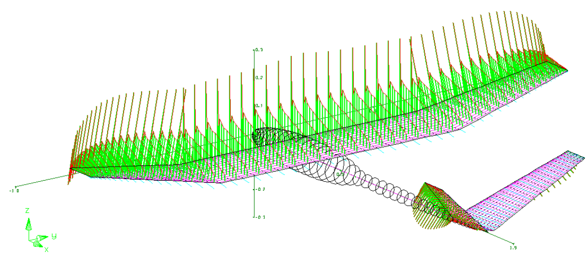

Fig. 2: Example sUAS in AVL

The results achieved to this point represent a major milestone on the way to the project's Critical Design Review (CDR); the final designs are already taking shape (Fig. 3).

Fig. 3: sUAS before the CDR, still without the later V-position of the outer wings (cf. Fig. 6).

Subsequently, the implementation in the modern nonlinear flight simulation environment of the chair based on Matlab/Simulink is carried out. The flight performance data achieved by the nonlinear simulation are compared with the theoretically achievable ones.

In the final section of the project, last incremental changes are made to the design and the flight dynamics of the aircraft are evaluated using common flight test techniques. Based on the knowledge gained in the lecture Flight Mechanics and Fundamentals of Aerodynamics/Aerodynamics and a short recapitulation in System Dynamics, the aircraft's eigenmodes in longitudinal direction (phygoid and angle-of-attack oscillations) and lateral direction (spiral motion, roll motion and Dutch roll) are characterized. Here, methods such as the transient peak ratio [5] are used to identify natural frequencies and damping of the eigenmodes. These are directly related to the aerodynamic design of the aircraft and therefore the results from AVL. These results are compared with common requirements from the so-called "Mil-Specs" [6]. This way, the flight dynamic performance of the aircraft without a controller can be assessed. If this is not sufficient, (minor) aerodynamic modifications have to be made to the design. This part of the project requires a high degree of interdisciplinarity and transfer performance from the students.

This is followed by the design and implementation of the flight controllers for longitudinal and lateral motion. The purpose of the controllers is to further improve the flying and handling qualities of the aircraft, as well as to augment the controllability for the operator. The designs will be limited to classical proportional-integral-derivative (PID) controllers. PID controllers are familiar to students from undergraduate courses, allowing them to rely on existing knowledge. Extensive numerical tests are performed to compare the behavior of the closed-loop and open-loop aircraft. The comparison of the controlled and uncontrolled aircraft is shown in Fig. 4. At the end of the block, a milestone is reached which corresponds to the CDR in an industrial project.

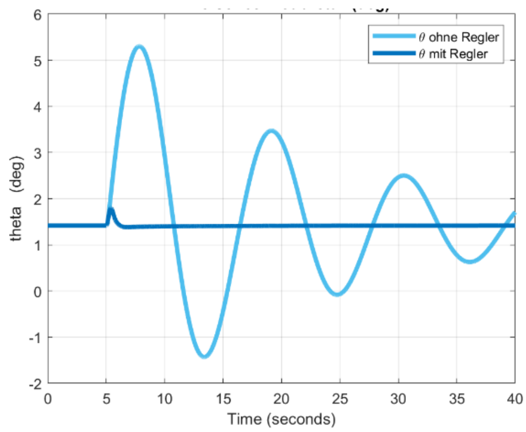

Fig. 4: Time course of the pitching motion after a wind disturbance without and with controller

Students are supported in working through the tasks and milestones in two individual group consultations of 30 min each in every block. This allows the teachers to assess the individual group progress as well as to specifically support students in their scientific development.

With a report and the final presentation after each block, the presentation of results in front of larger groups is trained. A very important skill which is often neglected at universities. Additionally, the active exchange between the groups by means of constructive feedback should be promoted.

3. Student feedback and lessons learned

Although the first iteration of the project is still limited to a purely theoretical and simulation-based implementation, all participants have shown a high level of interest and strong commitment from the very beginning. There was a good and stable participation of the twelve registered students in the lectures in off-peak hours (Tues., 16:40-18:10 and Fri., 7:30-9:00), while the audience for the conventional lectures was slow to find their way back into the lecture halls. This makes the course an important component of the Mechanical Engineering Faculty's back-to-campus strategy.

Particularly the consultations encourage an intensive exchange between teachers and students, which has suffered greatly in times of purely digital teaching. This is essential in the first iteration of a new course, as it allows the teachers to identify the students' interests and abilities, but also deficits in the structure of the course and potential for improvement.

The feedback given was incorporated directly into the course by the lecturers, resulting in a very dynamic and also modern event. For example, the number of reports was significantly reduced towards the end of the lecture period and more compact milestones were formulated, as they are also common in industry. A further "industrialization" of the task blocks and their "milestones" and "deliverables" is planned in the next iterations of the module (Fig. 5).

This adjustment allowed students to spend more time on the design tasks. However, the regular presentations remained. These presentations have received very good feedback and students have welcomed the opportunity to improve their presentation skills in front of a critical professional audience. This was noticeable in a steady increase in presentation quality and hence an improvement in an important soft skill.

Moreover, the presentations are an adequate means to motivate the groups to work continuously and to prevent "high-pressure" work shortly before the submission deadline of the document. This was very positively received by the participants.

The students also found it positive that time-intensive and iterative work, which required coordinated homework, took place at the beginning of the semester. Shorter and especially more practical tasks towards the end of the semester could avoid additional stress before exam time.

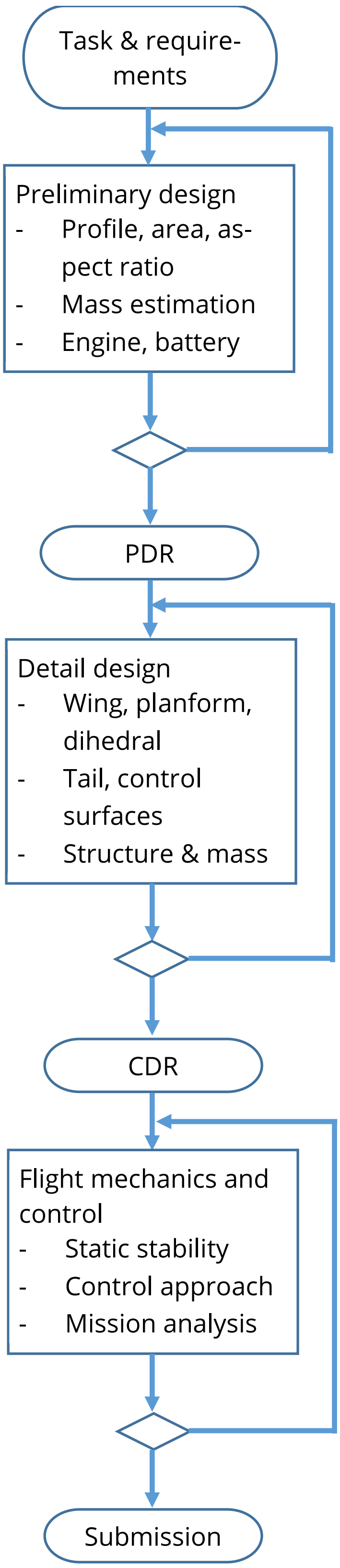

Fig. 5: Flow chart of the project process

Furthermore, the presentations and frequent consultations are very suitable for quickly evaluating the progress of the groups. In this way, risky concepts could be identified, modified accordingly. This way, creativity could be directed efficiently, preventing demotivating and time-consuming mistakes in the process. The success was evident in the designs of all groups, which consistently met or even exceeded all requirements.

Despite the purely theoretical design so far, working on one's own project has a very motivating effect compared to recalculating given academic examples. The highlighting of the different aspects of the design further promotes holistic thinking and understanding of the interactions between the individual disciplines.

Fig. 6: Final design of the group with V-position in the outer wings to improve spiral stability.

Fig. 7: Final design of another group

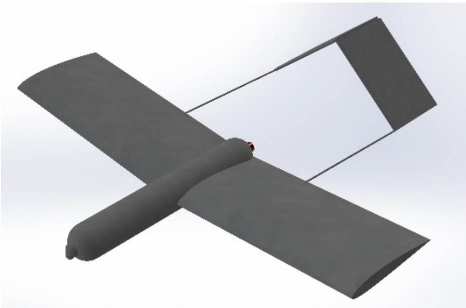

Fig. 8: Final design of the third group

Furthermore, the students have and take significantly more freedom, which promotes creative engineering problem solving. This was evident in clearly different aircraft concepts (Figs. 6, 7, 8).

Moreover, the students welcomed the use and application of various tools. Through lively exchange with the groups, new approaches to the creation of efficient tutorials for self-study were conveyed. The greatest difficulties were encountered by the participants in dealing with Matlab. However, clear progress was observed in all groups over the course of the semester. The interaction in the groups, consisting of participants from different semesters with different interests and abilities, also had a positive effect. This again showed that the whole is more than the sum of its parts and that group work should be an important part of the studies.

An important finding of the first iteration of the design project was its positioning in the curriculum. Scheduled for the eighth semester, it takes place simultaneously with the lecture Flight Dynamics and Flight Control and the module Aircraft Aerodynamics (also provided by FMR). This offers theoretical synergy effects, which unfortunately did not manifest themselves. Since the knowledge imparted in the other two lectures could not be assumed, a dynamic adjustment of the expectation horizon was made on the basis of imparting basic knowledge. A formal shift to the ninth semester could remedy this.

4. Outlook

With the capacities created by the funding within the framework of the teaching project, it will be possible to put the student designs into the air for real, thus allowing all participants to earn the fruits of their hard work.

For this purpose, the Chair of Flight Mechanics and Control plans to procure various components as well as tools for building the drones at its own expense. This includes sets of electric motors of different power, accumulators, servo actuators, flight computers, receivers, transmitters as well as material. The teaching project funding will be used to procure a modern laser cutter, which will enable fast, safe and low-waste production of the individual parts.

Students provide the technical drawings for cutting. Guided by a staff member, they work on the manufacturing process and get feedback on their drawings. After assembling the structure and integrating all components in the chair's UAV lab, students test their own aircraft on a model airfield. Doing so, they will experience the complete, industry-related development cycle of a UAS first-hand and are always actively involved. This ideally prepares the students for employment in the constantly growing commercial UAS market.

Furthermore, it is intended to complement the series of events with wind tunnel measurements on the finished aircraft models. The 3m wind tunnel of the TU Dresden– operated by the chair – has the optimal dimensions for the investigation of objects of this size class (Fig. 9). It will therefore be possible to verify the aerodynamic data obtained with the computational tools and feed them into the simulation environment, whereby the comparability with free flight will improve. For the relatively low forces to be expected regarding the low velocities, a suitable balance still has to be made available. Its construction and calibration will be the subject of a student research project. In addition, particularly the assumptions regarding the efficiency of the propeller, on which the design of the propulsion system is based, still seem quite optimistic. Student work on the measurement of propeller characteristics in the wind tunnel is also planned for this.

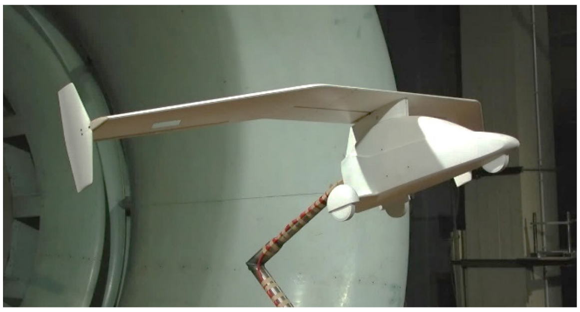

Fig. 9: Model of a tailless aircraft with a wingspan of about 2 m in the wind tunnel of the TU Dresden

Finally, the iterations in the design part are reduced by setting more specific and partly more restrictive reference values and less iterative calculation approaches in order to approximately maintain the time frame of the lecture.

With the overall higher practical component and the motivating prospect of being part of a team that makes an airplane fly, it is expected that the number of participants will increase significantly compared to the first attempt.

Acknowledgement

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Textile finishing as *inverted classroom* with OPALWiki

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Abstract

An inverted classroom method (ICM) in combination with a Wikipedia (wikis) was implemented in the context of second courses in the field of textile finishing. The Wikipedia is part of the OPAL learning platform. The presented teaching-learning concept includes the creation of the wiki based on self-learning assignments as asynchronous learning units, which are presented in a synchronous phase in the course by means of an implementation method chosen by the students themselves. This part corresponds to the ICM. Furthermore, the course content was again entered into OPAL asynchronously as a wiki. As quality assurance methods, both a *peer review process* for the entries and an interim evaluation were carried out.

Im Rahmen zweiter Lehrveranstaltungen im Bereich Textilveredlung wurde eine *inverted classroom*-Methode (ICM) in Kombination mit einem Wikipedia (Wikis) umgesetzt. Das Wikipedia ist Teil der Lernplattform OPAL. Das vorgestellte Lehr-Lern-Konzept beinhaltet die Erstellung des Wikis auf Basis von Selbstlernaufträgen als asynchrone Lerneinheiten, die in einer Synchronphase in der Lehrveranstaltung mittels einer durch die Studierenden selbst gewählten Umsetzungsmethode vorgestellt werden. Dieser Teil entspricht dem ICM. Des Weiteren wurden die Lehrinhalte wiederum asynchron als Wiki ins OPAL eingepflegt. Als Qualitätssicherungsmethoden wurden sowohl ein *peer review*-Prozess für die Einträge als auch eine Zwischenevaluation durchgeführt.

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This article was originally submitted in German.

1. Introduction

In the course of my work as a lecturer in the field of fiber production and the interface design of these, I experienced what it means to familiarize oneself with new topics for a lecture series that was not in one's own previous scientific focus. For example, one of these new topics included textile finishing.

Textile finishing (Fig. 1) has been and continues to be an essential part of the education of textile machinery engineers, and in a sense occupies a frontier area, since it involves both an understanding of the machinery, process concepts, processes, and technologies involved in textile finishing, but also necessarily the chemical background, which, it is to be presumed, would not otherwise be found in the curriculum and module plans of conventional mechanical engineers.

Fig. 1: Textile finishing - dyeing and finishing of textiles © ITM

Accompanying this with the currently very diverse *online learning opportunities that* students were accustomed to, the challenges now arose:

- To open up or expand a field of expertise for myself,
- 'Teaching chemistry' to mechanical engineers,
- To develop an interesting teaching-learning concept for (originally one) course that meets the students' requirements - preferably a hybrid concept.

In the end, it became an *inverted classroom concept* complemented by an OPAL Wikipedia (wiki).

2. Target group of students

The students were mechanical engineers from the 8th semester of the diploma course 'Processing and Textile Mechanical Engineering' with the course 'Machines and Technologies of Textile Finishing' (MTdTV, 3 semester hours per week) as well as students in the 2nd semester of the subject 'Textile Finishing 1' (TV 1, 3 SWS) in the master's course Textile and Ready-made Clothing Technology (MaTK). The prerequisite for attending this course was a basic knowledge of fiber materials, technical textiles and the usual fiber processing procedures, such as surface (weaving, knitting, ...) and yarn formation. Both textile finishing courses were held as a series of lectures in the summer semester (SS), but differed in the distribution of SWS with regard to the lecture (VL) and practical units.

3. Content and implementation of the teaching-learning concept

The original planning concept included the inclusion of one course. However, due to the low number of participants in one course (diploma), I decided to include the second course on textile finishing (master), so that a total of 10 students were involved. Furthermore, there was already a first version of the implementation of this teaching-learning concept in SS 2021, in one of the two courses (MTdTV), whereby challenges still to be solved arose, which were addressed in the current SS 2022.

Basically, the concept was based on an *inverted classroom* (inverted *classroom method* [1-3], ICM), where students present a topic at the beginning of each VL and enter into discussion. The presented topic was then the content of the syllabus or module description, but was not presented by the instructor. In order to make the developed topics sustainable, they were subsequently stored in the form of a wiki in the OPAL learning platform. It became apparent in the summer semester 2021 that there were various difficulties in the implementation, such as a loss of motivation of the students to work out and present the topics even towards the end of the semester, so that I always had one or two emergency slides available despite the presentation of the topic by the students. Furthermore, the quality of the various wiki entries varied significantly: either an entry was not created, too many students had worked on a topic, or only one started a topic but it was not sufficiently illuminated.

<u>Sequence of the teaching-learning concept:</u>

1) Students receive self-study assignment (text, photo, video (VL), ...)
2) Self-learning phase (individual, group, research, ...)
3) Presence phase
   - Collect questions after lecture first
   - Response by the auditorium (*think-pair-share*, active plenary)
   - Deepening/Application
   - Questions (apply what you have learned in a different context = practice task)
   - Group work
   - Lectures
   - Pro & contra groups

Based on the teaching-learning concept and the experiences from SS 2021, supplementary changes to the concept were made for SS 2022:

- In the first VL the concept for the complete LV was explained by the lecturer.
- Specific topics were assigned for each VL, which were elaborated by a student as a self-learning assignment (asynchronous learning unit) and subsequently presented (synchronous learning unit). For each of these topics there was a *reviewer* from the ranks of the students, who took over the *proof-reeding of* the wiki draft (*peer review* process) / editorial responsibility.
- The way of presenting the topics was left to the students, so there were PowerPoint presentations as well as presentations as a normal lecture, using pdfs or in the form of classical blackboard pictures and derived equations (Fig. 3).
- The wiki entries created were also reviewed by the instructor afterwards.

In SS 2021, it became clear that this concept can also be implemented completely digitally. In SS 2022, however, the course TV1 took place completely hybrid, i.e. VL is transmitted via Zoom. The students could therefore also present their topics or ask questions as online *listeners.* Questions about the topic were asked directly by the auditorium to the lecturing student. Example pages for the wiki can be seen in Fig. 2 and Fig. 4.
Another advantage of the wiki (Fig. 2) was that both the students of the MTdTV and TV1 courses could access it. In this way, all students had access to the information and could benefit from the content of the other, thematically similar LV and self-study phases.

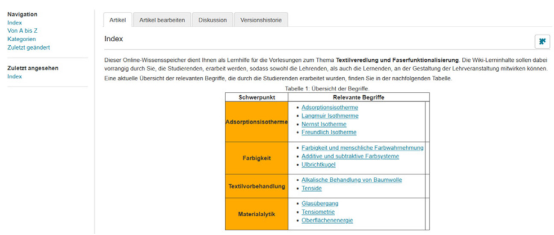


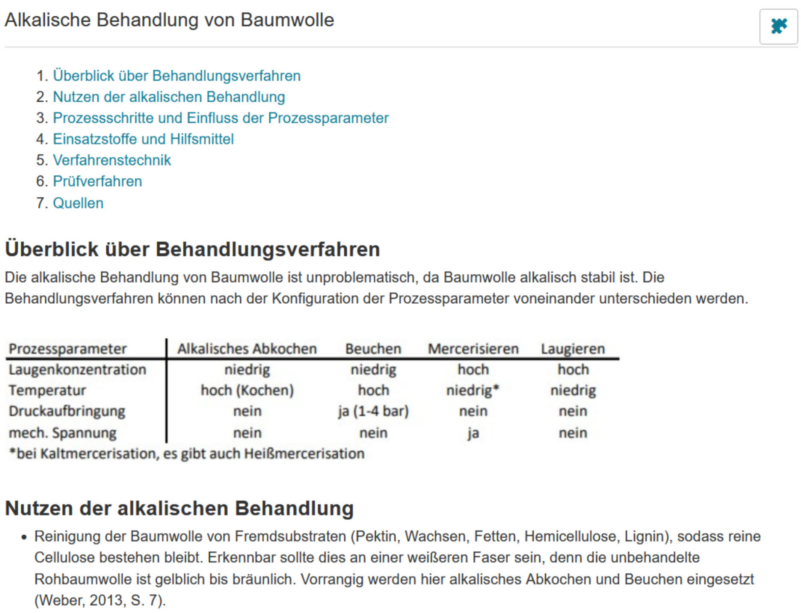
Fig. 2: Home page of the Textile Finishing Wiki, schematic diagram

I think that the wiki is particularly useful for the course TV1, because the exam for this textile finishing lecture takes place together with 'Textile Finishing 2' (TV2) in the winter semester (WS), and the wiki makes it easier for the students to access and repeat the contents of the SS during the self-study phases.

4. Learning objectives

According to the module description, the classically intended learning objectives of this course primarily included the first three taxonomy levels according to Bloom and Anderson and Krathwohl [4-5], i.e. knowledge, application and understanding, whereby the processes and procedures with a textile-chemical focus, use and functional requirements as well as quality assurance (application of measuring technologies and tests as well as fastness analyses) were mainly in the foreground in the textile finishing context. In addition to the 'classical' learning levels mentioned above, which extended to analyzing, linking, judging and creating, further complementary competencies emerged in the course and through the implementation of the teaching-learning concept from the work in the ICM and in the creation of the OPAL Wiki (Fig. 2 and Fig. 3).

These competencies included, for example, the acquisition of knowledge and independent research with the help of technical literature (journals, textbooks, ...), the Internet or alternative sources (videos, YouTube, ...). Furthermore, the acquired knowledge had to be formulated concisely and reduced to the essential statements and described..


Alkalische Behandlung von Baumwolle

1. Überblick über Behandlungsverfahren
2. Nutzen der alkalischen Behandlung
3. Prozessschritte und Einfluss der Prozessparameter
4. Einsatzstoffe und Hilfsmittel
5. Verfahrenstechnik
6. Prüfverfahren
7. Quellen

Überblick über Behandlungsverfahren

Die alkalische Behandlung von Baumwolle ist unproblematisch, da Baumwolle alkalisch stabil ist. Die Behandlungsverfahren können nach der Konfiguration der Prozessparameter voneinander unterschieden werden.

Prozessparameter	Alkalisches Abkochen	Beuchen	Mercerisieren	Laugieren
Laugenkonzentration	niedrig	niedrig	hoch	hoch
Temperatur	hoch (Kochen)	hoch	niedrig*	niedrig
Druckaufbringung	nein	ja (1-4 bar)	nein	nein
mech. Spannung	nein	nein	ja	nein

*bei Kaltmercerisation, es gibt auch Heißmercerisation

Nutzen der alkalischen Behandlung

- Reinigung der Baumwolle von Fremdsubstraten (Pektin, Wachsen, Fetten, Hemicellulose, Lignin), sodass reine Cellulose bestehen bleibt. Erkennbar sollte dies an einer weißeren Faser sein, denn die unbehandelte Rohbaumwolle ist gelblich bis bräunlich. Vorrangig werden hier alkalisches Abkochen und Beuchen eingesetzt (Weber, 2013, S. 7).

Fig.3: Example page 'Alkaline treatment of cotton' from the textile finishing wiki

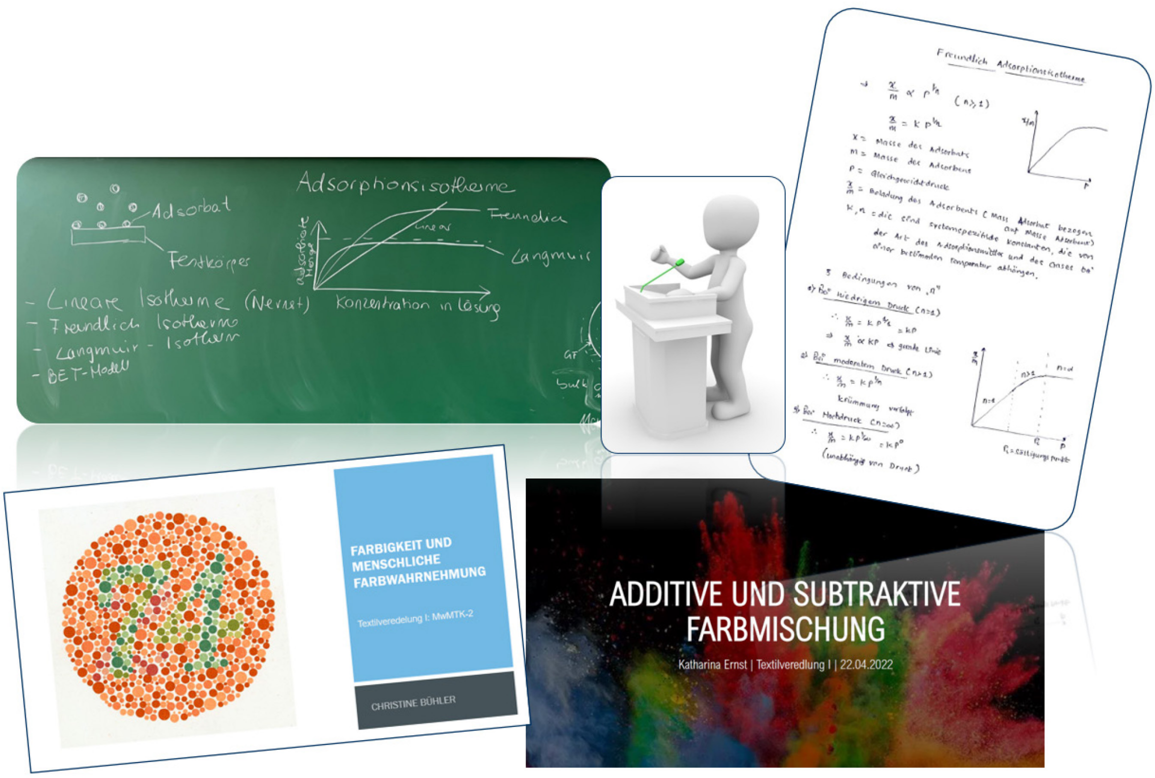


Fig. 4: Presentation variants of wiki topics for face-to-face and hybrid teaching of students.

In the *peer review* process, the students also learned to analyze and evaluate - but in order to do this, the 'controlling' students had to delve into the respective topic as well as compare their own knowledge with the acquired knowledge and also evaluate and assess it. Another advantage of the OPAL Wiki was that the students had to deal with the creation of such an entry (Fig. 4), among other things (*soft ware, soft skills*). The ICM also enabled the students to deal with the development of their own concepts for knowledge transfer, e.g. to work out their own representations of functional principles and facts (Fig. 4)

5. Quality assurance, feedback and evaluation

The quality assurance of the teaching-learning concept was carried out on the one hand by the lecturer in the context of the VL, as a contact person in the ICM. On the other hand, the wiki was secured through the *peer review* process by the students and also by the lecturer. The scheduling of when who was responsible for which ICM/Wiki article and for which *peer review* also resulted in organizational quality assurance.

The method of the 'self-formulated exam question' was also used in one course (MTdTV). At the end of one of the lectures, the students were asked to formulate their own exam questions (2 min, moderation cards) on the lecture that had taken place, which were used to identify levels of understanding (Fig. 5). These, together with the learning success questions, formed a content-related basis for potential exam questions.

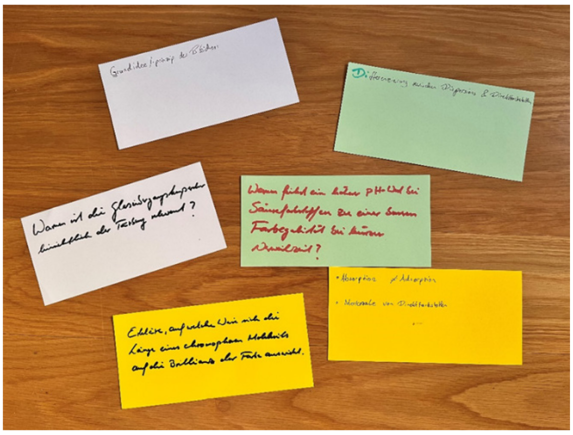


Fig. 5: "Student" exam questions from the course

Furthermore, an interim evaluation of the course took place during the SS, from which feedback on course TV1 and the entire teaching-learning concept ICM and OPAL-Wiki could be obtained:

"Through the inverted classroom, one's own topics and also those of fellow students were perceived and internalized more intensively. It was always an interesting change from the classic lessons."

"- Content of the topic you present you master super, better than in a normal lecture.

- Topics of others often worse, depending on how well the topic was worked up and how well it was presented by the person in question"

"When I had to create a presentation for the group myself, it really helped me professionally in this subject."

The disadvantage perceived by the students of knowing only one's own subject, and those of others worse, was an effect that may well occur with other teaching concepts and methods, so that these should not be regarded as a fundamental disadvantage of ICM.

6. Summary

It had been shown that working out and presenting the individual textile finishing topics was very well received by the students and that the ICM with Wiki was a useful supplement to the lecture. It was also easy for the lecturer to identify comprehension problems that could be addressed during the lecture or in general during the course, and the ICM represented a kind of feedback system.

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