Transformation of a traditional face-to-face engineering study program into a digital online program - A case study of Global Production Engineering

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ABSTRACT

The need for Digital Education (DE) in higher education has been growing for the past years, as the landscape of education became more diverse and global. It has become apparent with the COVID-19 pandemic that, in terms of width, DE had been mostly neglected so far. In the past year, the master program Global Production Engineering (GPE) at Technische Universität Berlin has been enhanced by a complete digital track, called GPE-Digital. In order to design this online study program a student survey was conducted and lecturers have been interviewed. The results were analysed and requirements for both lecturers and students were identified. Chances and challenges have been identified and a "tool box" for teaching and learning was developed. It contains a multimedia studio, a learning platform, a cloud platform et cetera. Lecturers are supported to develop and adapt their lecture-concepts and to choose the tools needed, which led to a variance of teaching-concepts. In this paper, after presenting the findings of both the interviews and the survey, the "tool box" is presented and its various possibilities for implementation are shown by the example of four different courses offered at GPE-Digital. These examples contain both synchronous and asynchronous teaching and different approaches of preparing joint sessions and lectures. Finally, based on the courses the benefits and challenges are discussed and rough approaches for exploiting the benefits and tackling the challenges are given.

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1 TEACHING GOES DIGITAL

For more than 20 years distance learning or distance education is well-known [1] and until the beginning of 2020 it had rather a niche existence. However, during the pandemic distance learning experienced a boom like never before [2]. From one day to another many universities had to cope with the challenge of distance learning which was until then – even though the concepts were generally well-known – still rather a subject of research (having some implementations in e.g. evening study programs) than broadly implemented. Within a couple of weeks tools like Zoom, Microsoft Teams and WebEx were in daily use. To put this into numbers: While on December 31st, 2019, 10 million participants joined a Zoom meeting, on March 31st it was 200 million and on April 21 even 300 million people [3]. Suddenly, servers for educational clouds were working on their limits and were needed everywhere [4].

After two years of higher education in a pandemic experiences have been gained by various lecturers, e.g. [5] and [6]. Benefits which have already been identified before the pandemic could be widely confirmed [7]. A key benefit which is enabled by distance learning is an increased flexibility for students and lecturers, when it comes to their location but also in terms of when learning takes place. For synchronous classes only the time zones became an issue. Nevertheless, in terms of class-time distance learning offers further flexibility by offering recorded lectures and exercises.

Considering these and further benefits of distance learning which were experienced during the beginning of the pandemic the decision at the Technische Universität Berlin was made to enhance an existing face-to-face study program by a fully virtual branch. Global Production Engineering (GPE) is a full-time four-semester master program [8]. The curriculum is designed for international graduate students offering modules in the fields of production, management, engineering, new energy technologies and inter-cultural communication. Within this paper, the experiences of implementing a completely digital study program shall be presented and discussed.

2 SURVEY WITH STUDENTS AND INTERVIEWS WITH LECTURERS

As a basis for designing the digital study program a survey with the students of the face-to-face study program whose class took place virtually due to the pandemic was conducted in order to learn about their challenges in virtual classes, but also to learn from their suggestions for the design of digital classes. Furthermore, interviews with lecturers were made in order to figure out their main challenges digitalizing their classes and by that to get an idea of how a completely digital study program should look like in order to enable a smooth learning and teaching environment.

For the student survey 41 students were contacted. The goal of the student survey was to receive a feedback of the first steps of digital teaching and learning but also to have a basis for designing a fully digital study program. The main comments include the students' expectations on the presentation of teaching material, which they expect to go beyond simple voice-over Power-Point presentations, the fact that students find seeing facial expressions and gestures profitable to learning and thus

prefer live interactions with lectures and fellow students in presence, as they are hardly replaceable. However, they find the degree of freedom of asynchronous teaching in terms of learning times to be advantageous, perceive online tools such as quizzes, exams, external videos, Moodle platforms or course forums as an enriching offer that they would like to retain for face-to-face teaching.

A total of eight interviews with lecturers, who are planned to be included in the digital program, were conducted. Each interview took between 60 to 90 minutes. The main subjects during the interviews were the challenges during the digitalization of classes, the software and hardware which was used and its evaluation, experiences with the current learning platform, changes to the teaching concept and the learning goals due to the digitalization, changes in the communication with the students and its evaluation, acceptance of the digital classes based on the feedback that the lecturers received in their classes, overall positive and negative experiences during the digital classes and the transformation process from an lecturers' and students' perspective, changes in the teaching concept if the digitalization would be permanent, support which could be provided by the study program staff to support the lecturers, and hard- and software which could be used within a (teaching) studio.

According to the lecturers, the main challenge during the early phase was the lack of time to actually plan the transition, but to not directly transfer all face-to-face teaching material one-to-one to a virtual environment. Non-professional equipment often led to pragmatic solutions, but not necessarily to satisfying ones. Lectures were either pre-recorded and uploaded on an educational platform or were given online. This led to a massive decrease in interaction, but was realizable in the short period of time. However, exercises in laboratories had either to be postponed, cancelled and another task had to be given or exercises had to be completely changed so that physical attendance was not required. Software-wise mainly PowerPoint, Zoom, Kahoot and Mural were used next to the Moodle platform. The equipment used was rather "classical" hardware: laptop, camera, headset etc. The previously reserved usage of the Moodle-based learning platform changed rapidly. While many lecturers never had used the platform before, it immediately became a backbone of each class. The teaching concept of the lecturers did not really change - mostly because there was not a lot of time for any changes. Also, the learning goals of each class did only change if the exercise was affected. One major drawback which could be experienced by all lecturers was the decrease in communication with the students. At the time of the interviews no exams had been taken so far. Therefore, no statement could be given on how the digital teaching influenced the exam results. Generally, the students did not complain about the digital classes. Due to the pandemic it was accepted. However, the lecturers were told that the students are missing the interaction in class. Generally, the lecturers saw the benefits in terms of flexibility for themselves but also for the students. For a permanent change to digital teaching, the lecturers saw a need for a stronger involvement of the students during class. Further they identified a need for a better hard- and software. The results of this interview led to the design of the studio, which will be presented in the following.

3 IMPLEMENTATION

3.1 Requirements for the digital program

On the basis of the surveys conducted, the educational, didactic and technical needs were worked out and measures were derived to increase the facilitation of learning. After having discovered the drawbacks and problems with the digital education during the pandemic, particular focus was set on three categories: digital technologies, community building and educational concepts.

The technological requirements are to use adequate, modern technologies with high-end quality media, as students are used to a high standard of image- and sound quality. To build a sense of community, both for lecturers and students, a platform for regular and informal exchange is required, while the educational and didactic aspect has to be, while still regular, more formally presented. These requirements are met by developing a didactic and educational toolbox. To ensure a consistent high quality education, guidelines have been established. The toolbox and the quality guidelines are presented in the following section.

3.2 Conception of toolbox and the learning environment

Toolbox: Digitally driven learning and teaching is particularly dependent on the provision of technical equipment. This not only has to meet the requirements of didactics, support the transfer of face-to-face-based teaching concepts to digital representation and be user-friendly and intuitive for the users. The technologies also open up new possibilities for teaching, group work or interaction by new tools that were not available in face-to-face teaching and whose reasonable integration into the teaching concept must be checked individually for each lecture or module.

In order to support the lecturers in the digital implementation, a so-called toolbox was developed, which contains a wide range of technical aids and tools. Especially in the initial phase, each lecturer is advised and supported on the conceptual integration, trained on the application and supported in overcoming technical challenges by a team of 5 experts in digital teaching and film production.

The centre is the Green-Screen Studio (fig. 1 & 2), which enables the removal of the green background both in real time and in post-processing and replacing it with any background such as lecture slides, images, videos or websites (fig. 3 & 4). In this way, depending on the respective thematic focus of the lecture and educational goal, a suitable learning environment can be created in which the lecturer is placed and that gives students the feeling of still being in a classroom. Even the implementation of a virtual 3D environment has also been successfully tested, in which the lecturer walks through a factory, for example, while the background changes according to the perspective. This makes it possible to zoom into machines, view components in detail, hide parts or make them transparent, while the lecturer is in front.

To achieve a high degree of video quality, professional film lights (amaran 100d & swit) are used since insufficient lighting of both foreground and background can create disturbing digital artefacts. Two high-resolution 6K cameras (Black Magic) are

used to record the teaching sessions, while 4K cameras (Brio Logitech) are used for live events. Especially when using green screen technology, cameras with low resolution should be avoided, as they can also produce unwanted artefacts. By means of a streaming software, in this case the Open Source software Open Broadcaster Software (OBS), any image composition can be generated on the computer and inserted as an emulated webcam on all conference tools (Zoom, WebEx, Microsoft Teams, etc.). Sound is provided via a clip-on microphone (RodeLink) whose signal is transmitted to the camera via radio.

To enable the lecturer to share notes in the same way as on a white board or chalkboard, the room has a 55-inch touch screen on which handwriting can be done with a special pen. Written texts can be shared handwritten or converted digitally into machine text. Another 55-inch monitor has been integrated to display the students' video images and a smaller monitor to display the lecture slides for the lecturer. In addition, the lecturers also have a touch screen stand PC and a Wacom board at their disposal, on which manual markings can be created in the slides directly.

An additional input device, an Elgato Stream Deck, was installed to make the operation of the extensive technology more intuitive for the lecturer. On this keyboard, the buttons can be assigned individually with shortcuts and personalized icons. As a result, when changing an application during a live event on the computer, the user does not have to create a complex sequence of clicks on the computer, but can start or stop an application at the push of a button.

The lecturers and students are provided with server-based applications for exchange, provision and communication, such as Zoom, WebEx, Next-Cloud, OnlyOffice and a Moodle learning platform, which are all operated entirely on the university's own servers for reasons of data security and sovereignty. Zoom and WebEx are used as communication software. Every lecturer and student get their own unlimited access and can generate meetings independently. Zoom in particular, with its large range of functions, compatibility, stability and user-friendliness, established itself as the main platform for communication during the COVID-19 pandemic. Functions such as breakout rooms support group work or can enable consultation with the lecturer in digital exams without disturbing other users in their work, also, the platform enables real-time translation of spoken content. At the same time, hiding the own video background or creating a virtual background allows students the greatest possible degree of privacy.

An adaptation of the open Moodle learning environment developed within the university is used as the central learning platform. This learning environment was developed with collaborative learning and teaching methods in mind and allows for the customization of classrooms that can be broken down into weekly or thematic segments. The platform provides a rich portfolio of functions, such as the provision of texts, videos, forums, calendars, glossaries, wikis, surveys, brainstorming tools, learning quizzes or tasks. Learning packages can be created and linked to individual learning progress. Other functions support peer teaching and learning and allow mutual assessment. The individual learning success of each student can be tracked

by the lecturer over the semester and additional support can be provided if required. The platform has proven to be particularly useful for digital exams, as new forms of interactive questioning are possible and tasks can be automatically evaluated according to previous definition or digital exam reviews can be carried out. It must be mentioned that for the creation of content and the use of the range of functions, a basic experience in handling software tools is helpful, if not necessary. Practice has shown that inexperienced users, especially in the initial phase, needed special support from the team. In addition to the Moodle platform, external game-based learning platforms such as Kahoot are used, with which students can carry out location-independent learning quizzes in real time. Similar to a television show, the lecturer moderates the quiz, the students enter their answers via their smartphones, the correct solution is then provided and the individual results are evaluated.

The use of a lot of open source software as well as software provided by the university keep the costs for the technical equipment at a well justifiable level of roughly 12.000 Euro. The biggest cost drivers are the cameras (circa 2500€) and the touch monitor (circa 2000€). Another driver for costs is the large amount of data that needs to be stored and processed. For that, several hard drives (HDD for storage, SSD for production) as well as a computer (Mac Mini M1) for production have been acquired at around 1800€. Some of the equipment, like the touch computer were already available from former projects is be valued just under 2000€.

Fig. 1 & 2. Multi Media Studio and typical recording scenario

Community Building: To nurture a positively experienced learning environment, special attention was paid to the aspect of Digital Community Building. In a first step the students have been given an Introduction Event to the whole program. Furthermore, there are regular meetings for the students to give feedback to the program management and administration. Although high level, the meetings are informal. Besides administrative discussions and organizational difficulties, topics of these meetings are also personal or cultural exchange. Additional Community Building is encouraged through partly synchronous teaching with and without the presence of lecturers, e.g. in form of group assignments. Between the third semester and the students' internship, as well as their Master's Thesis, students are welcomed in Berlin to the optional Spring School. Students can meet in person and also get in touch with both staff and students from similar GPE-programs. Future Community Building measures are digital factory tours and fair visits as well as digital or hybrid attendance at conferences.

Quality Guidelines: To ensure consistent quality at high level, quality guidelines have been established. These are mostly mandatory. Lecturers are given templates for their teaching material. Videos are produced by professionals of the team and are conceptualized to shape the learning environment. The background is designed in the way, so there are not too many distractions, texts are readable easily, the room lecturers are presented in is large enough and many more details are considered. Additionally, lecturers are required to use the learning platforms, calendars and communication channels that are provided to ensure a standardized and consistent learning environment.

3.3 Exemplary Lecture Program

In engineering education, subjects are often divided into a lecture and an exercise or a project. The lecture conveys the theoretical knowledge, which is to be applied in the exercises and projects. [9] Most of the modules used as examples here are split into lecture and exercise. They are courses that are currently offered at GPE-D or planned to be offered in the following semesters.

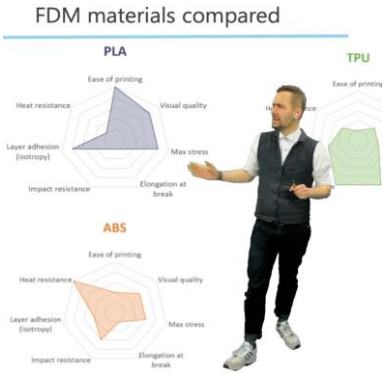

Fig. 3. Live Lecture on Additive Manufacturing

Fig. 4. Pre-recorded Lecture on Digitalization and Industry 4.0

Additive Manufacturing (AM): The module AM is split into lecture and exercise and is very application-oriented. The lecturer has decided, that it is better for his lecture to be able to communicate with the students during the sessions. For this, the green room is used in combination with OBS Studio to place the lecturer into the lecture's slides (fig. 3). This way it is possible to actively show and emphasize arguments and principles of AM. This is transmitted via Zoom, so the students get the impression, that the lecturer is actually standing in front of them. They can ask questions at all times, which enhances this immersion. The lecturer has multiple monitors to observe both his slides and the students in Zoom. The exercise for AM is planned in the Summer School, to teach the students printing strategies, troubleshooting, etc. For students who are not able to join the Summer School, printing via internet is provided. Students have to prepare their print-jobs and can observe via broadcast.

Digitalization and Industry 4.0 (DI4.0) and ***Manufacturing and Factory Planning (MFP):*** The teaching concept of the modules is also split into lecture and exercise. For the lecture professional videos are produced to according to the quality requirements of the program, an example is given in figure 4. Every third lecture is a

live session and includes a Q&A for the pre-recorded topics for DI4.0 and a weekly Q&A including discussions of given homework for MFP; in this manner, facts are already established and discussions can be held at a higher level. The Videos for the lectures are usually not longer than 45 minutes to maintain concentration. The exercises are focused on the students' (former) jobs and held in a seminar-style course. The students are presented an assignment in a live lecture and have to present their work after regular Q&A-Sessions. In the DI4.0 exercise an action plan for the transition of companies to a next level of digitalization is asked, for the MFP exercise the students are assigned the planning of a bike factory. The difficulty as opposed to the presence courses lies in the coordination of time zones and finding common communication platforms.

Lean Management (LM): The module lean management integrates lecture and exercise. The lecture is partly pre-recorded and partly held live to answer possible questions. The lecturer also assigns groups of two or three students to summarize the topic of the last lecture. They are completely free in terms of realization. For instance, some students create small quizzes on "Kahoot". The lectures are complemented by short videos, which are tailored to specific subject areas. In these videos principles of Lean are illustrated by the lecturer standing in a virtual factory. The lecturer is able to move and explain all aspects in detail. The immersion of the lecturer standing in a factory can also be used in a live situation to go into questions.

4 SUMMARY

In this paper insights to the planning and implementation of completely digital track of a study course are given. During the planning phase a survey with students was conducted and interviews with lecturers were made. Both students and lecturers had first experiences in the digitalization of a study course due to the pandemic. The survey conducted with the student has shown, that students would have higher expectations on an online study course compared to the situation experienced during to the pandemic when classes suddenly had to switch from classroom to online teaching. Similar feedback was received by the interviews with the lecturers, who generally where able to switch to online teaching, however practical solutions for exercises and especially hands-on work like in laboratories or student workshops must still had to be found. Furthermore, the possibility of social interaction is still quite limited which should be tackled but cannot be completely solved. In the section of implementation, the (digital) technologies in use as well as aspects of community building, and educational concepts were highlighted. A toolbox, which contains a wide range of technical aids and tools, consisting of was presented. Finally, four digitalized modules using different concepts were presented as an example.

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