INTERACTIVE ONLINE LEARNING MODULES FOR ENGINEERING STUDENTS BASED ON JITT AND PI

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ABSTRACT

At German universities of applied sciences, the composition of first-year engineering students is very heterogeneous (some have completed vocational training, schooling dates back many years). At our university, the first semester Physics course lays the technical and methodological foundations for engineering studies. It should have been converted to activating teaching in summer 2020.

Important goals associated with this change should also be incorporated online: Arousing curiosity, experiencing a positive error culture, and providing confirmation. Considering local circumstances, we decided on the following implementation based on JiTT and PI: Each week was dedicated to one topic. For each, students received a reading assignment, associated learning objectives, and a test including a mandatory open question. Subsequently, students worked on learning modules containing videos (explanations, experiments), interactive questions, tasks, PhET simulations etc. In a weekly recitation, tasks and remaining questions were discussed.

The biggest advantage for students was the constant availability of content. This mitigated bandwidth problems, supported exam preparations, and allowed balancing family, work, corona and study life. Advantages for instructors included a more structured presentation, the possibility to introduce additional materials, and the (necessary) individual contact to students through feedback on the open questions.

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Problems included a high workload for instructors, the need for more instructors to be well-versed with the content, and heightened challenges for shifting from traditional to activating teaching.

Taking into account all constraints, this implementation of online teaching is the best option for students. In the future, the learning modules can support students with different personal needs.

1 INTRODUCTION

At our university, the first semester Physics course lays technical and methodological foundations for engineering studies. The course was redesigned and should have been converted to activating teaching methods in the summer semester of 2020 (15-week teaching period).

The new physics I course has 5 credits and on average 5 teaching units of 45 min per week (90 min lecture every week, biweekly 90 min exercise class and 90 min tutorial, and three 180 min lab courses (two during Corona)). Lectures should have been transformed to Just-in-Time Teaching (JiTT) and peer instruction (PI).

Due to the Coronavirus and the problems involved, the concept was adapted. Our mission was to meet the goals we had relating to the new teaching concepts, offering the best possible online teaching under the given circumstances as well as to consider all restraining social, legal, organizational and technical conditions. The course was held with the adapted concept for three consecutive semesters (summer 2020, winter 2020/2021, summer 2021).

The remaining paper is structured as follows. In section 2 some background on the constraints, the teaching methods and the evaluation is given. This is followed by a description of the adapted concept and its implementation in section 3. In section 4 the experience of students based on the evaluation and instructors is presented. The paper concludes with a discussion of the concept, key findings, and an outlook.

2 BACKGROUND

2.1 German Higher Education System, Local and Legal Situation

The German Higher Education System consists of universities and universities of applied sciences. More people are allowed to study in the latter ones since not only "Abitur" (high school degree) but also work experience, a good vocational degree and others qualify for a study programme. Therefore, the composition of first-year engineering students is very heterogeneous. Some of the students have already completed vocational training, some are having little knowledge of physics and maths since schooling dates back many years, some have children, some difficulties with the German language, and some came directly from high school and therefore are having difficulties to work / learn self-dependent, to organize themselves and to study continuously. A lot of students have to work while studying since they are too old for financial support from the government.

Social bonding has been very difficult for first semester students since 2020. Our university is in a smaller town and a lot of students live in larger cities within a radius of approximately 50 km. For the online semesters a lot of students stayed in their home towns much further away. Student organizations to help and welcome students were basically non-existent.

The summer semester of 2020 lasted from April to July 2020. It was held online only and no teaching in the university was allowed. The winter semester 2020/21 lasted

for 15 weeks and for a few weeks at least some teaching in presence was possible. The summer semester 2021 was again online only.

ILIAS, Stud.IP and BigBlueButton were used for online teaching. The use of software was very constrained due to data protection laws and their interpretation by the university as well as the demands from students. A lot of software tools were not allowed, including ZOOM. Therefore, the software BigBlueButton (BBB) had to be used but ran very unstable. Students and lecturers suffered from severe problems with internet connections. Hence, the university ordered that no one should turn on their videos and students should not speak but rather ask questions via chat. Stud.IP and the learning management system ILIAS were implemented a long time ago.

Further constraints exist due to insurance. At home students are not insured through the university and instructors might have to take the full responsibility in case of injury for instance while performing a physics experiment.

2.2 Activating and Online Teaching

Blended Learning: Peer Instruction and Just-in-Time Teaching

Peer Instruction replaces part of the frontal teaching by small-group discussions on conceptual questions and helps to counter declining participation in classes. In many cases students understand explanations by other students i.e., their peers, better than the recitation by the instructor. Students demonstrate a better conceptual learning, especially when students have less background knowledge [1].

With Just-in-Time Teaching [2] students are encouraged to prepare for class in order to make optimal use of the in-class time. Preparation can consist of reading assignments, videos and many more. Students should use learning strategies which fit to their personal preferences, background and previous knowledge. Subsequently, they should ask remaining questions or write down their most important learning outcomes. Teachers can identify learning difficulties and address them during class.

Flipped Instruction and Online Learning

Flipped instruction uses the in-class time for active learning and interactions with students. The respective content is reviewed beforehand. Instructors serve as consultants. In-class time may consist of answering questions, peer instruction, mini lectures and many more [3].

Online learning is very different to being taught in class. A key ingredient is communication with and between students as well as a continuous (online) presence and commitment by the instructor [4]. Due to the rapid shift to online due to Covid-19 transition should not be complicated further by technology [5]. Existing learning management systems with which the students are familiar should be adapted instead of introducing new tools.

2.3 Data Collection

The data used for this paper is based on written and oral anonymous feedback from the students. In the middle of the semesters, questionnaires with the following open questions were given to the students (translated from German).

- What I like about the Physics I module
- What I do not like
- I have the following suggestions for improvement
- What else I wanted to say

Students were also encouraged to continuously give feedback during the semester and once more after the exams were written and graded.

3 ONLINE / HYBRID TEACHING CONCEPT AND IMPLEMENTATION

3.1 Priorities and Main Objectives

In the summer semester 2020 the Physics I course should have been shifted from traditional teaching to Just-in-Time teaching and Peer Instruction. It was adapted to the online situation, keeping the most important goals from the original concept. So we put an emphasize on activation of students, letting them think through the content, arousing curiosity, letting them experience a positive error culture, and providing confirmation.

We also set priorities for the shift to online teaching. Transition should be as easy as possible by reducing the technical and organizational hurdles. Students should connect and communicate with each other. Also, we wanted to be present and approachable for them even though much of the teaching was online and asynchronous. Students should be flexible in when they worked through the content due to the unknown general conditions (jobs, closed kindergartens, bad internet connections, infection, relatives in need). Last but not least, a clear structure of the content should help them to understand and follow the module.

Considering those priorities and the local and legal circumstances mentioned above, we decided on the following implementation.

3.2 Implementation

Each week was dedicated to one topic (e.g., “Kinematics of Translation”, “Kinematics of Rotation”, “Dynamics of Liquids and Gasses”). For each topic, students received a reading assignment, associated learning objectives, and a test (quiz) including a

mandatory open question (Fig. 1). In this question students were asked to phrase out the problems they still had with the topic or, when no problems came up, to state their two greatest learning outcomes. They were encouraged to name examples they

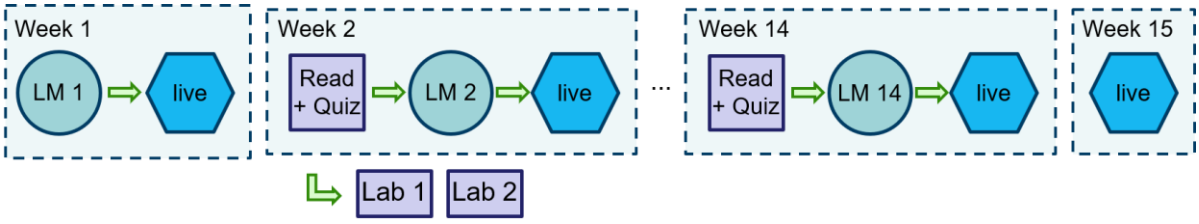

Fig. 1. Flow chart of the schedule for the semester. Read+Quiz - reading assignment and test, LM - learning module, live - live session (online or in person), Lab - lab course.

knew from their daily lives, previous careers, or hobbies. Every student received an individual answer to their questions and statements.

Subsequently, students worked on learning modules in ILIAS. Time for working through the modules was reserved in their weekly schedule but students were free to study them at any other time up to the respective live session. The learning modules contained videos that either explained special aspects in more detail, like topics that were difficult to understand, or the derivation of formulae, experiments, or additional information. Every module started with a welcome video where the lecturer could be seen and gave motivation for the topic as well as an overview. All other videos were either self-recorded or taken from the internet, mainly science channels and other universities. Over time we implemented our own YouTube channel to mitigate bandwidths problems. Students can choose the video quality on YouTube.

The modules contained interactive study control and comprehension questions meaning that students got feedback when giving incomplete, wrong or correct answers. PhET interactive simulations (https://phet.colorado.edu/) with specific tasks and questions to investigate were included as well as tasks to calculate and interpret physical problems. Hints were given for tasks in form of drop-down menus. In this way students could work on the tasks and get help, when needed.

In the learning modules we laid an emphasis on a good and clear structure, on easy handling for the students, on the optical appearance of the content and that the lecturer also brought in her personality. We wanted to show the students that we care for them and are interested in their thinking, ideas and knowledge.

Once a week a lecturer and students met either online in a video conference for 90 min or, when allowed, in person. There, some of the open questions were discussed when the problem affected more students and / or could not be answered in writing (e.g., feedback to open question). Calculation tasks were discussed together. Experiments were shown when possible. In addition, chat was available on Stud.IP the whole time where students could ask questions and receive answers from the lecturers or other students.

During the semester we tried to promote group development since we found this relevant not only for deeper understanding but also extremely important for motivation, perseverance and psychological well-being of the students. We asked them to upload short videos about themselves in the beginning of the semester and we encouraged students to work through the learning modules in small groups of two or three people and discuss the topics multiple times during the semester.

4 EXPERIENCE WITH THE NEW CONCEPT AND FEEDBACK

4.1 Students

Advantages

The biggest advantage for students was the constant availability of the multimedia and interactive content with semi-individual feedback and thought-provoking impulses. This mitigated bandwidth problems, supported exam preparation, and

allowed balancing family, work, corona and study life. Especially bandwidth problems, problems with our BigBlueButton servers and closed kindergartens and schools made it hard for students to participate in synchronous meetings.

Students with a big gap between their school knowledge and the standard requirements on prior knowledge for studying highly benefited. They valued, that they could go through the modules at their own speed.

Students liked and were motivated by the individual answers they got on their open questions in the quizzes. They said, that their interest was aroused for physics more than they could have thought.

Here are some quotes from the evaluation (translated from German):

- “By working on my own on the lecture at ILIAS, I have the opportunity to combine it with work better and at my own pace.”
- “The possibility of being able to look through the online units again later.”
- “That all questions, no matter how stupid, are answered; that everything is clearly presented.”
- “Physics is more fun than I expected!”

Difficulties and Problems

Because a lecturer is generally not restricted to a 90 min lecture slot, the learning modules easily get too laborious for students. Some had the feeling they were left alone with the content and requested traditional lectures. Not only the online teaching was new, but also the idea of activating teaching as well as really understanding the content and not only learning “recipes”. It was difficult for students to imagine an exam that tested understanding, even though we continuously confirmed / repeated that we would ask questions that tested understanding.

Connecting students has shown to be very difficult. We attempted to motivate them by uploading welcome videos of themselves as mentioned above, to use the chat and / or the forum in Stud.IP, and to meet in small groups online in BigBlueButton rooms that we created and go through the learning modules in those small groups.

We asked them to turn on their videos in online meetings, but we were very much limited by the capacity of BigBlueButton. Only few students turned on their videos at least in the beginning. Even participating in the online sessions with a microphone was rare. The most convincing explanations were

- the request by the university to turn off videos and microphones in BBB meetings,
- the shortage on equipment and no motivation to buy it,
- data protection considerations that weighted higher for some students than a good learning environment,
- demotivation due to the general situation (lockdowns, little social and public life, insecurity, all exams are "free trials", so bad marks are deleted)
- distraction.

Here are some quotes from the evaluation (translated from German):

- “Too much to read. The videos are not optimized and cause problems if the internet reception is poor.”
- “That you cannot continue in the online units if you have not answered a question or answered it incorrectly.”
- “It is more difficult to acquire the knowledge yourself with the reading assignment than if it is explained by someone.”

Solutions

We reacted to the feedback in the following ways.

- Lots of videos
  It is much easier for students to follow important ideas in explanations or mathematical derivations, if they are explained and shown to them rather than when they are in writing.
- Videos on YouTube with subtitles
  Students had huge bandwidth problems and therefore wished the videos to be uploaded on YouTube. The text to the videos was uploaded in ILIAS so that in a printed pdf file the content was accessible. A huge advantage is, that the learning modules are now even better accessible for handicapped persons.
- Clear distinction between necessary and additional content
  The workload was too high for the students. Therefore, we checked if the content presented was really necessary or only helpful and additional. Helpful and additional content was put in drop-down menus.
- Hints for the tasks
  The tasks were quite similar to those from the last years. Nevertheless, due to the open esteeming communication with the students they brought up problems that had probably always been there. One was that if they did not have an ansatz for a task, they could not do anything on their own. Therefore, they wished for hints for that case. We implemented staged hints on the ansatz and the path of the solution for almost every task.

This way we could not only defuse this burdensome situation for the students but in the end got very positive feedback (translated from German):

“Thank you very much for your effort and the aforementioned euphoria for physics. That made the start of my studies and especially the Corona situation much easier. Incidentally, my interest in physics has definitely been awakened.”

4.2 Instructors

Advantages

Especially for a lecturer in her / his first year the learning modules offer a more structured presentation and the security that students are aware of this structure. Learning modules offer the possibility to introduce a lot of additional material. This is not possible during a lecture. Students can pick the topics they want and get more informed about their areas of interest. The lecturer had more time to think about the points she / he wanted to make in the course. This was quite good in our case, since

the author held a Physics I course in general for the first time, for the first time used JiTT and PI, and for the first time online.

The (necessary) individual contact to students through feedback on the open questions not only motivates students but connects the lecturer more with the students. We are convinced that teaching can be better and better organizational solutions can be found (especially during the Coronavirus pandemic where everything changes quite often) when the lecturer is aware of the character and background of the students in her / his course.

We learned much more ourselves. Due to the individual contact / the one-to-one communication channel students were very motivated to share their knowledge and interesting and funny examples with us e.g., a marble music instrument (dynamics of rotation), science slammers, an ice cream safe (thermodynamics, linear expansion), pressure in fire hydrant systems, or a leaning tower not too far away from our university. Additionally, the fit to other modules could be improved since students reported overlaps and gaps.

The restrictions due to the Coronavirus pandemic also hit our lecturers (quarantine or quarantine of children, own infection, bandwidth problems at home). Therefore, asynchronous teaching helped us to secure the teaching and prevented course cancelations.

Difficulties and Problems

Creating the learning modules came with a very high workload for instructors, even though a student helped to implement the modules into ILIAS. Too much content was put in the learning modules at first. This was because there is no direct feedback on how long students worked within the learning modules.

For the weekly meetings the instructors had to be well-versed with the content. Usually only one person has to have such a deep knowledge which is the one giving the lectures and answering the open questions in the quizzes. Exercise classes usually can also be held by new employees shortly after finishing their study programme. In typical traditional exercise classes “only” tasks will be discussed with the students. In our setup, students may ask any question and require deeper explanations as well as spontaneous answers in the weekly meetings. This was very difficult for our new colleagues that just completed or were in the final stages of their master programmes. Also, a good communication between the colleagues involved was necessary so that problems could be addressed immediately.

Online teaching and especially teaching with learning modules and a weekly meeting heightened the challenges for shifting from traditional to activating teaching. Of course, we encountered all problems that generally come with a shift from traditional to activating teaching with JiTT and PI in a first semester studying programme. Students are used to exact recipes and listen-only lectures. They want to know correct answers immediately, want to do what the teacher says (vs. learn from the reading assignments and have an influence on the content of the weekly sessions through their feedback), and are very frightened of the exams.

Solutions

The content, students' questions and the process of the live sessions should be discussed beforehand with all participating lecturers. Hence, all instructors are well-prepared and informed. Also, with the now more stable internet access and video conference software and the existing learning modules, more synchronous online sessions can be provided in addition. However, these synchronous online sessions are only a stopgap solution. If possible, an attempt should be made to hold them in presence. Our experience is that face-to-face sessions have a positive effect on group dynamics, learning motivation, attention and understanding.

5 DISCUSSION AND OUTLOOK

5.1 Summary and Key Findings

In this paper we presented a transition from traditional to activating, online teaching for an introductory physics course. We discussed the local circumstances and constraints. A detailed description of the implementation with weekly learning modules followed.

We realised that these weekly learning modules require a much stricter planning compared to offline teaching (strictly distinguish between necessary, additional and "just" interesting content). First semester students hardly know anyone and have no learning groups which makes the transition into online study life very hard. Hence, it was important to give individual feedback to the quizzes in order to open a communication channel to the students. Discussing the problems set by the instructors in the weekly sessions helped mitigating the reduced contact between students. Students could be kept motivated to stay on track, for instance by showing experiments in the weekly sessions.

5.2 Conclusion and Outlook

Taking into account all local and legal constraints, this implementation of online teaching might be the best option for our students. In the future, the learning modules can be used to support students with different personal needs in addition to the lectures. This is especially helpful for motivated students with bigger problems (little knowledge, only rarely familiar with the German language), for students that start late into the semester (up to 6 weeks late out of 15 weeks), and for all students for the exam preparation.

The effort to create the learning modules was very high for the lecturers but we hope, that it was and is worth it. Students will profit from the online modules in the upcoming years for the reasons mentioned above. Since we always searched for additional content to motivate the students, we ourselves probably learned much more, than we would have with a "simple" online lecture.

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