Online Teaching of Project-based Learning Courses - Issues, Challenges and Outcomes

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Abstract

This paper aims to share the experiences during online teaching of two different project-based learning courses at Hamburg University of Technology (TUHH) during the COVID-19 (Corona) pandemic 2020. The success of project-based learning courses relies on how freely and openly students can discuss their task-oriented problems in small teams. The most effort-intensive part of the online teaching of project-based learning is to enhance collaboration among students. This paper highlights the challenges we faced, how we overcame some of these challenges, and our lessons learned. Additionally, the results from a student survey conducted during the semester show the students' feedback on online teaching.

Keywords

Project-based Learning (PBL) — Task-oriented Exercises — Online Tools — Virtual Collaboration

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1. Introduction

"If we teach today as we taught yesterday, we rob our children of tomorrow" *by John Dewey.*

Classic teaching concepts and methods practiced at universities are becoming less relevant for students due to the availability of much of the information on the Internet.

Hamburg University of Technology (TUHH) implements problem and Project-Based Learning (PBL) [1, 2] in courses that award more European Credit Transfer and Accumulation System (ECTS) credits. Thus, in Master courses the teaching objectives are more on the scientific methods and on transferring and applying them than on memorizing facts. In short, PBL courses focus on group oriented problem solving and are organized to achieve the following four outcomes [3, 4, 5]:

1. **Theoretical Knowledge:** Students obtain all the basic concepts like in traditional teaching, but are motivated more due to task oriented teaching.
2. **Capabilities:** Students are able to try out the concepts learned using relevant tools and platforms, apply them to real-life problems and practice problem solving in teams.
3. **Social Competence:** Students are able to acquire expert knowledge in groups, present the results to each other and a wider public, discuss solutions as well as different approaches, learn to act and communicate in teams and develop key competencies for their profession as engineers.
4. **Autonomy:** Students are able to work self-reliantly. They are able to tackle problems they come across by themselves and show that they continuously question results.

In this paper, we share our experiences of teaching two different PBL courses at TUHH, Simulation and Modelling of Communication Networks (SimCN) at the Institute of Communication Networks (ComNets) and Introduction to Information Technology (IntroIT) at the Institute of Technical Education and University Didactics (ITBH). Both were forced to be done online due to the COVID-19 pandemic.

Simulation and Modelling of Communication Networks (SimCN) aims to provide the basic concepts of discrete

event simulation (random number generation, stochastics, simulation models, analysis of results and wireless networks) and is designed with eight practical exercises, which have to be done in small teams as a PBL module. The course is offered by the Institute of Communication Networks (ComNets) for computer science and electrical engineering Master students. The students obtain a hands-on experience of using a network simulator during a 14-week (4h/week) period (single semester). For the final task, two students work together as a team to model a complete network scenario and analyze the results. The final examination is held in a colloquium format where the team presents and discusses their results. As the students come from different disciplines and different universities, some do not have the required knowledge (e.g., Transmission Control Protocol/Internet Protocol (TCP/IP) stack) to understand the lecture contents or sufficient knowledge of C++ programming to work with the simulator.

Though the participation is optional, it is extremely difficult to pass the final examination without attending all the exercises. As tutors, our challenge is to support students with heterogeneous capabilities and to encourage them to contribute to all the exercises. More information on our lecture contents and exercises can be found in [6].

Introduction to Information Technology (IntroIT) covers two semesters and is held annually for Bachelor students at the Institute of Technical Education and University Didactics (ITBH). Students in the course will become vocational school teachers and come from various technical backgrounds and vocations, but are not all familiar with computer science. Thus, the challenge is to inspire them as well as to relate computer science topics to their vocational backgrounds. This course aims to provide a fundamental understanding of the World Wide Web (WWW) and the technologies, protocols and concepts involved. The course is also project-based and has hands-on tasks in every session. At the beginning, students pick a topic for a project website that they implement in groups until the end of the semester. Architecture and concepts of the WWW as well as non-technical topics like Open Educational Resources (OER) and privacy on the web are also taught during the course. At the end, students take an oral examination based on their project. More information on design, methods and content can be found in the accompanying OER online script [7].

The most exciting part of online teaching of a PBL course is to achieve the last two outcomes, viz., **social competence** and **autonomy** with virtual collaboration. A PBL course is not designed to be conducted online to the best of our knowledge.

This paper discusses all the work we have done to achieve the best possible outcome of online teaching of a PBL course. We first elaborate the tools used and the design of lectures and exercises, which were adapted to the COVID-19 pandemic situation. Afterwards we discuss challenges and some solutions that evolved in both courses. Before we conclude with lessons learned, we discuss students' feedback from the SimCN course.

2. Organisation

We discuss here all the tools used to facilitate the virtual collaboration and all the adaptations done to both courses to be conducted online.

2.1 Tools used

To support our online teaching activities, we used a variety of software tools. While many tools have already been used previously, we had to add some new ones to overcome the challenges of pure online teaching.

Since many years, *Stud.IP* [8] is used to organize most teaching activities at our university. Besides being the place where students register for the courses, it offers features to provide the lecture slides, link to the lecture recordings and exercise material, make announcements and organize the forming of groups.

To create the lecture recordings, we used *Open Broadcaster Software (OBS)* [9]. This tool allowed us to record a screencast of the lecture slides and embed a camera feed that shows the lecturer as picture-in-picture. The final videos for SimCN were then uploaded to the *Mediasite* [10] server of our university, which allows the students to stream the lectures on-demand, but prevents them from downloading the video files. The videos for IntroIT are hosted freely accessible on *Vimeo* [11].

In SimCN, *Etherpad* [12] was used for real-time collaboration scenarios as it enables real-time editing of a single text document by multiple people. In the course IntroIT, an instance of *CodiMD* [13] was used. It is similar to Etherpad but supports the use of Markdown for text formatting.

We encouraged our students to use *GitLab* [14] to work collaboratively with their teammates. This gives the students a centralized place to store their code version controlled using *Git* [15]. For the tutors, this also has the advantage that they can checkout their code and try to reproduce problems if students ask for help.

To create the exercise material for SimCN, we used *Bookdown* [16]. All texts were written in *R Markdown* [17] and stored in a Git repository in our GitLab, which provides us a workflow with issue tracking, merge requests and reviewing. On every change, the R Markdown is automatically compiled into Hypertext Markup Language (HTML) and Portable Document Format (PDF) and uploaded to a web server via a GitLab Continuous Integration / Continuous Delivery (CI/CD) pipeline.

For the development of the accompanying OER script for IntroIT, the static site generator *Hugo* [18] was used in combination with the theme *Hugo Learn* [19]. The script is also hosted on GitLab for the students to fork it when they become teachers themselves. The script is built in a similar GitLab CI/CD process as described above and deployed to a publicly accessible web server of our university. Attention has been paid to a responsive design of the website for a good mobile user experience.

As the main communication channel for our courses, we used *Mattermost* [20], which is an open source alternative to *Slack* [21]. Mattermost allows to create group chats as well as to communicate with individual members via direct messages.

All previously mentioned services are hosted on-premise by the computing center of our university. However, with the beginning of the COVID-19 pandemic in March 2020, they were faced with the challenge of providing a video conferencing solution to a large number of users within a short time frame. While a self-hosted system would have been preferred by many parties, a smooth online teaching experience had to be guaranteed for both, students and teachers. Therefore, the executives of our university made the decision to buy *Zoom* [22] licenses. Despite the discussions about privacy and security, we did not have any major technical problems while using Zoom. Only the large number of configuration options and the artificial limitations created by the licensing model required some time to get used to. As a free and open source alternative to Zoom, *Jitsi* [23] was used for video conference scenarios in IntroIT. It should be said that quality and reliability of Jitsi were good when most of the participants switched off their video transmission.

During our interactive sessions in SimCN, we used *TurningPoint* [24] for online on-demand surveys. This allowed us to get anonymous online feedback from the entire class and was used to conduct the survey that is presented in Section 4.

2.2 SimCN: Lecture and Exercises

The lecture period in the morning was organized for one hour of discussion with the students instead of two hours of teaching as in the earlier semesters. We decided to use the flipped classroom concept in which the lecture slides/videos are available to the students to learn on their own. Then the students meet the lecturer later to have a discussion. Lecture videos were recorded every week and students were able to access them at least two days before the discussion, so that they had enough time to listen to the lecture videos and prepare their questions, which they could ask to the lecturer directly during the discussion. The lecture recordings were limited to have a duration between 10 and 15 minutes. Etherpad was used by the students to type the questions during the discussion anonymously as shown in Figure 1. It was a challenging task to split the lecture slides for each video recording and add some questions as an assignment to the students to stimulate a discussion. During the discussion, students were then asked about their assignments if they had done it or if there is anything to be discussed that also helps to keep students on track for each lecture.

After one hour of lecture/discussion in the morning, two hours of exercise session started where students could discuss their results from the previous exercise and started working on the current one. There were three exercise sessions done in parallel, dividing the students into three groups.

Last year, the students had to form teams of two on the first exercise day in a physical room. This semester, we used Stud.IP to let students mention their preferences for the teammate together with the operating system they use. The operating system they use helped us differentiate three groups. Two tutors were involved with each group in their online exercise session.

There were eight exercises prepared for the students. While most exercises consisted of a task and questions and could be answered in any fashion, Exercise 7 had different requirements: Students were asked to record their results to the exercise in a video with a length of maximum 10 minutes and give feedback on two videos from the other teams. Exercise 7 was specifically designed to enhance the collaboration among teams and groups.

The video submission as well as the feedback form were then uploaded to a GitLab repository created only for Exercise 7. As stated above, we created the exercise material using Bookdown so that the students could view the HTML version directly in their browser or download the PDF version for offline use. The CI/CD workflow allowed us to refine and extend the material at any time based on our own findings and student feedback.

After the teams and groups were decided, a GitLab repository was created for each team. By this, it was easy for the tutors to keep track of students' work each week and easy for students to have their version control by the commits. Also, having the remote control option in Zoom was usually a big help for the tutors to answer questions and solve problems faced by the students during the exercise sessions.

Besides the exercise sessions, students always had the opportunity to ask questions on Mattermost. For this purpose we created different channels that contained either all participants of the course (common channel) or only the members of a team and their assigned tutors (private channel). Students were encouraged to ask general questions in the common channel so that they could be answered by any of the available tutors or even another student who knows the answer, which sometimes led to nice discussions between the students. The private channels were mainly used for team specific communication among the members of a team and their assigned tutors. Figure 2 shows a screenshot of how the GitLab repositories and the Mattermost communication were organized. As we also use Mattermost as the main communication channel at ComNets, this gave the tutors a unified platform for communicating with colleges and students. We also connected Mattermost with our GitLab instance, so whenever a student pushed to their team's Git repository, a notification in the corresponding private channel was triggered.

2.3 IntroIT: Lecture and Exercises

In advance of the first session, a short survey was conducted among the students that mainly was intended to gather information about their web developer experience, the technical equipment they had and the general conditions of their home office situation. The results showed that some students expected not to have a quiet place to study and participate in a

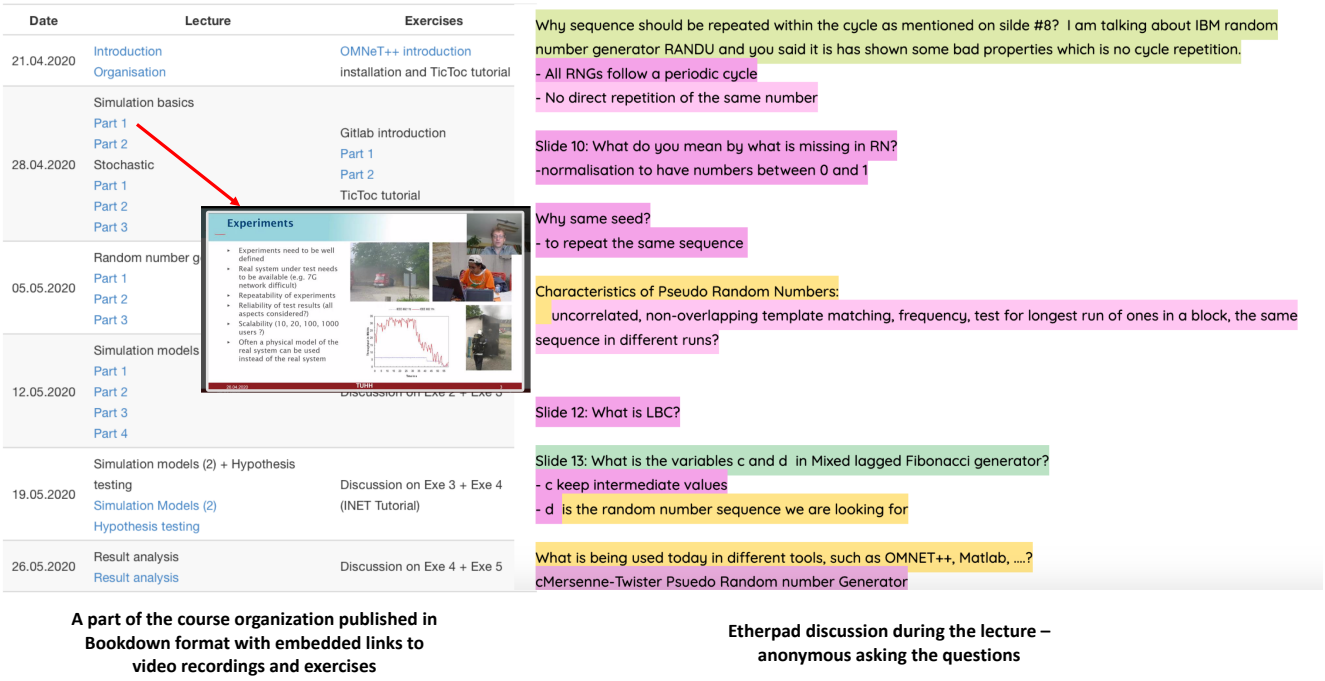

Figure 1. Virtual collaboration during the SimCN lecture

lecture. Some also expected not to have the equipment and bandwidth to participate in video conferences. In order to avoid a bad start for some of the students due to these expectations, it was decided to start the lecture with text-based chat in Mattermost and not have a video plenum as the default.

Much of the time of the first lectures was used to introduce the students to the tools used for communication and collaboration. Only Free/Libre Open Source Software (FLOSS) is introduced to the students to complete their tasks, like *FileZilla* [25], *VSCodium* [26] and the *Chromium* browser [27]. It is crucial for the course concept that the software used is FLOSS and runs on every operating system. Hopefully this will help to reduce social inequalities and digital gaps when the students later engage themselves in teaching. To help the students in getting used to those tools, videos on best practices with Mattermost [28] and VSCodium [29] were produced. A first exercise was to post screenshots in Mattermost and learn how to comment other students' postings, be verbose when describing errors and experiences and be polite when giving criticism. A second task was to form project groups and find a topic for a website project to build along with the lectures.

Jitsi was introduced in the third session as a means to communicate within the groups, but not used for a video plenum until the eighth session. Instead, following the values of autonomy and social competence, students should meet each other without the initiative of the teacher and make the experience that they can exercise the same rights as the teacher. Jitsi supports this as it only needs a shared Uniform Resource Locator (URL) and a browser to start a video conference. In addition to that, Jitsi is also used as the place to get support from the teacher of the course, when Mattermost does not seem to be the tool of choice. Here the intention is that the students are in control of the room and invite the teacher. Beginning with session eight, students can use Jitsi to show the state of their project to the class.

In order to introduce the students to modern ways of collaboration on software and texts, GitLab was introduced. For every student a GitLab subgroup in the course group was prepared that was private to the public. The students were maintainers in their groups and could create GitLab projects themselves and decide who they want to invite to their group. As only some of the students had the experience and knowledge to work with GitLab in the usual way (clone, commit, push, pull, merge, etc.) the tool was at first only used for uploading and downloading files from week to week in the browser. More advanced concepts were introduced later when the students themselves demanded more efficient ways of collaboration on code.

Besides the goal to leave no one behind in the communication with the various tools, weekly exercises on web technologies had to be done and uploaded the day before the next lecture. It was first intended to discuss the exercises in the lectures, but the students reported a heavy workload from all their courses in the semester and demanded to start with the exercises already in the lecture time (2.5 hours). Thus, the concept was changed: In the lectures small tasks were given that prepared the students for the weekly exercise. They had to post their interim results in Mattermost, ask their questions and help each other whenever possible. The role of the teacher was to moderate and facilitate their learning, provide further information for their individual interests and discuss their project ideas in smaller groups using Mattermost or Jitsi.

It turned out that the asynchronous communication in Mattermost gave everybody the chance to speak when necessary as no one had to raise a hand. Students were encouraged to use public channels in Mattermost so that the others could learn from the questions and answers, but they could also chat in direct messages with the teacher and their team mates.

3. Challenges and some solutions

Solving a given task as a team is one of the main objectives of a PBL course. This requires getting to know each other properly to have a good discussion, which was not a challenge when we met students physically once a week. Over the duration of our online courses, we faced several challenges regarding activating and encouraging students to participate in discussions. In this section, we discuss general, lecture-related and exercise-related challenges based on our own experiences. As these experiences are the same for SimCN and IntroIT, we do not differentiate between the two courses.

General Challenges mainly originated from social as well as technical aspects. While most of today's students have some form of laptop capable of video and audio conferencing, suitable low-noise and calm working environments cannot be taken as granted. This fact is especially true during a worldwide pandemic, as most of the population is advised to stay home and the average number of people at home is increased. Since the operation of child-care facilities, elderly-care homes or other assisted living facilitates can be impeded or even completely stopped, the obligation of care is shifted to relatives or friends. Such a shift can further complicate the availability of students to take part in live discussions. Together with bad Internet connectivity, participating in online voice discussions can be strongly discouraging or in some cases impossible for students. Individual technical infrastructure plays a key role for the success of course thought online. Students are free to work and attend lectures remotely from all over the world and consequentially, the availability of fast Internet was heterogeneous and in some cases insufficient. Students' hardware setups were further set apart by the capability to stream sufficiently good video streams as well as proper audio. From our experience it cannot be guaranteed that each student uses headphones, decreasing voice communication quality even further because of echos and feedback loops. In some cases these preconditions resulted in people falling into each other words, as well as situations where we were not able to understand the students' questions. For such extreme cases, we had to fallback to chat based communication.

Synchronous live communication is not always possible due to social as well as technical issues.

Challenges in Online Lecture Discussions stemmed from our objective of enabling as many students as possible to learn and acquire deep knowledge about the course content. The video recording of lecture topics established a base knowledge for the students enabling them to engage in live discussions with peers and lecturers. Even if students are not able to attend live sessions, the recordings can most likely be accessed by every participant due to today's widespread of multi-media devices capable of streaming video content. However, the integral part of flipped classroom methods, discussions and information exchange in a live environment, becomes complicated in online teaching for two reasons. The first reason being the general challenges of technical and social aspects presented in the previous paragraph.

Secondly, it is cumbersome and in some cases impossible to provide recordings of live discussions later for students which are not able to attend. Since General Data Protection Regulation (GDPR) [30] considerations are not suspended during online classes, live recordings would require a legal and written agreement of students to waive rights to allow the recording to be made public. While legally possible, this is not desirable and fails the moment a single student does rightfully not agree. This leaves students which are already disadvantaged by the online environment even further behind. Unfortunately, we were not able to solve this problem satisfying both ends of the trade-off between individual data protection rights and online teaching.

Finally, if we assume neither of the before mentioned obstacles are present, we have to assume that students were simply too afraid to ask questions. Having their name highlighted and maybe even their video feed maximized in the conference client can cause anxiety and unpleasant environments. Together with a lack of direct eye contact, the lecturer is often left alone in the set of speaking participants and has the tough task of creating any kind of discussion.

Lecture discussions cannot be put online due to General Data Protection Regulation (GDPR) and engaging shy students for lecture discussions is tedious.

Challenges in Online Exercise Discussions are multifold and were similar to the challenges in physical exercise discussions. While tutors can lead into an exercise and explain what is to be expected from the students, solution approaches and discussions have to include active participation of students. In contrast to physical meetings however, students' participation may be reduced by social or technical aspects, which further complicates the tutor's job of activating students. Where a directed question in a classroom setting has to be addressed by the questioned student, online teaching allows the student to remain silent more easily. The tutor is left wondering if the student has technical problems, is not at his/her/their computer or simply tries to avoid the question. The resulting waiting game can significantly affect the flow of information and discussion during an exercise.

In our exercises we noticed a highly heterogeneous participation of students. While a small group of individuals were very active and constantly wanted to present their approaches,

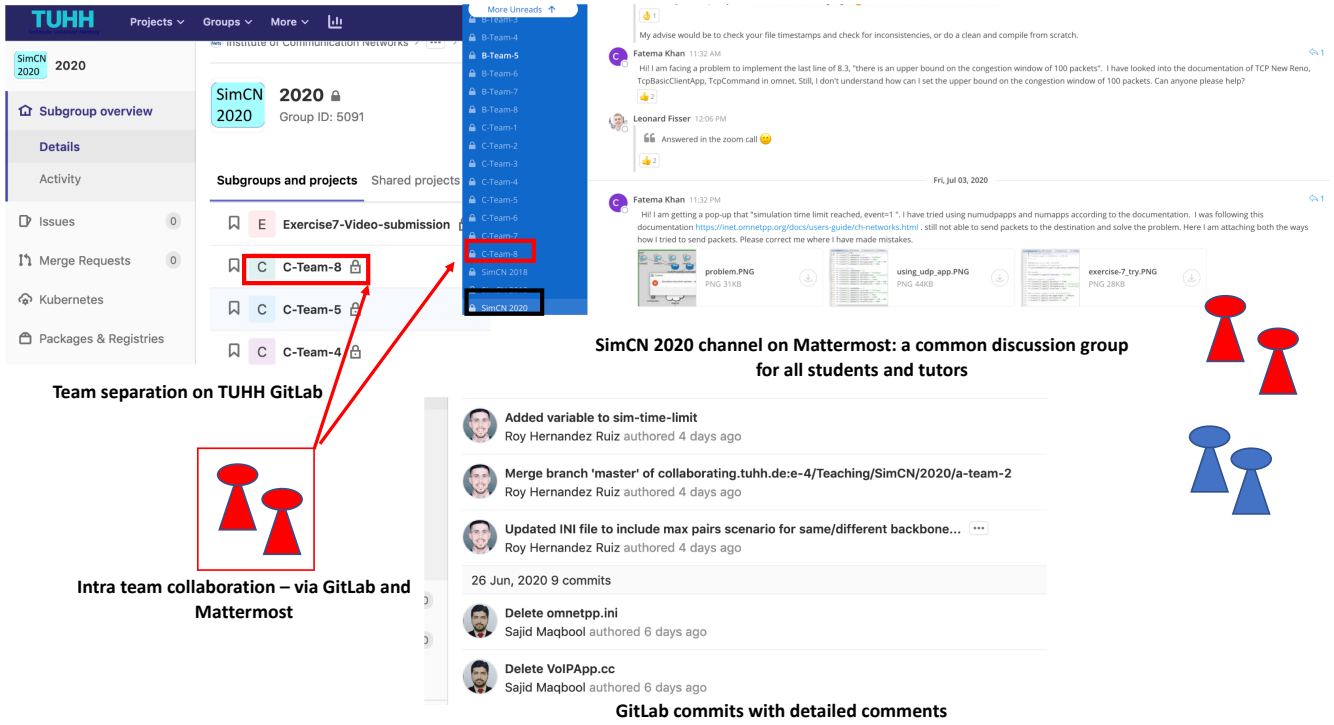

Figure 2. Virtual collaboration within and across teams in SimCN

asked for help or needed further information on the task, a large portion of the students showed no active participation at all. The tutor is left with a tough environment and has to find a way to activate the silent students. Addressing silent students directly resulted in the before mentioned problem of no reaction and was not effective. Instead, we asked two groups of students (one active, one rather inactive) after the exercise concluded to prepare a small informal presentation on their solutions to the current exercise for the next meeting. We made very clear that the quality of their presentation would at no point be graded and considered in their final grade. Both groups were invited and contacted in a small group chat and we asked both groups to stay in touch, exchange their results and prepare a joint presentation over the week. We intended to strengthen inter-team communication and encourage the silent group to be more proactive. For each week both addressed groups prepared at least initial solution approaches which was a really positive success. While the more silent group started the exercise meeting and showed their first initial steps and solutions, the already active group was able to cover the remaining tasks and complete the exercise discussion. The direct chat-based request for a short presentation encouraged both groups to at least shortly take part in the discussion.

The described approach also had an additional side effect: we were able to identify tasks at which students were stuck and might need help. In a physical format, tutors are free to visit a team during the exercise and directly see if and where students are struggling by looking at their computer. This is no longer possible in an online setting, where the tutor cannot simply walk over to the students and ask about their status. The short presentations forced students to take the initiative and gave the tutor valuable insights in the groups' performance and future focus points which had to be addressed in more detail. We also noticed that several student groups kept up their exchange of information even though they were not asked to present any results. Communication between teams started to facilitate for each exercise and questions were jointly formulated during the week and asked in unison during the exercise.

Finally, we want to address the effectiveness of chat based discussion tools like Mattermost. Since no physical meeting took place over the complete course duration we had to make sure to keep in good touch with the students to pick up problematic topics or tasks where students struggled in order to address these topics in the next meeting in a more public settings. To increase communication between students and tutors we tried to increase our presence on the messaging boards significantly. Students could ask questions and would most of the time receive advice within minutes to hours. This even held true for weekends or late hours where student activity peaked. While this definitely helped students with their projects, it created two problems. First, the workload of tutors was increased significantly in contrast to simple physical meetings and few questions during the week. Second, after a while students started to ask questions without putting enough research effort in themselves. This further increased workload due to mundane questions which could have been answered by a quick online search and led to frustration on the side of the students as the tutors limited their answers to vague suggestions (in order to encourage students to research more intensively before they ask tutors).

The main paradigm changes from knowing the students' status via direct contact in a physical classroom to activating students using different approaches.

Master level courses at our university include students from several different origins and cultures. This often comes with differences in the lecturer/tutor student relationship. Students may fear to be belittled or not taken for full if they ask many questions and may fear that the final evaluation will be negatively affected. While we tried to convey an open atmosphere for discussions and encouraged everyone to freely ask questions, the necessary trust in the course organizer is hard to build over the span of a single semester. Such openness is even harder in a pure online environment where facial and tonal expressions are compressed and altered by video and audio codecs. Luckily, most of the students attending the course took part in a similar course the preceding semester and were therefore already comfortable with discussing topics with the team of tutors.

Enable students and tutors to have open and free discussions in an online project-based course.

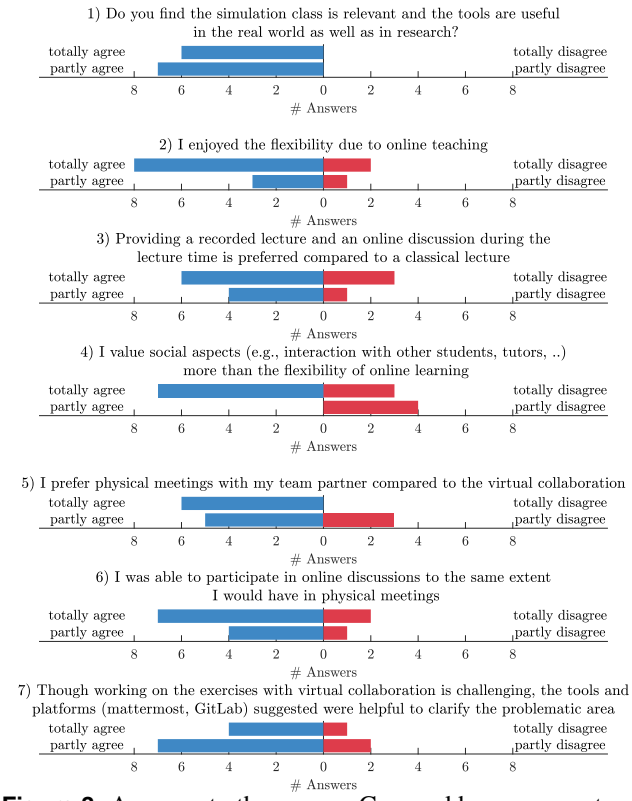

Figure 3. Answers to the survey. Grouped by agreement (blue) and disagreement (red) and number of students choosing an option on the horizontal axis.

4. Students feedback

In addition to analyze the learnings we had while conducting the lectures and exercises it is also important to see how our students experienced this new situation. Therefore we conducted a survey among the SimCN students of which the results are presented in this section.

While we usually ask students for their feedback at the end of the semester so that we can see how the course was received and to identify opportunities to improve the teaching, this year it was of much higher importance because of the big changes we had to make both in the lecture format as well as the exercises as described above. To be able to share the results of the survey here, we did not wait for the end of the semester this year, but conducted the survey online after a lecture. It had eleven questions of which seven were about the lecture in general and their experience on how it was conducted this year (the other questions regarded specific content of the preceding lecture). In total there were 14 students answering with only one student abstaining at one question. Each question was written as a statement to which the students could answer to which extend they agree (totally agree, partly agree, partly disagree, totally disagree), could choose to give no answer or state that they haven't attended the course. The results are displayed in Figure 3 as bar charts with agreeing statements in blue and disagreeing statements in red and the length of the bar representing the number of students choosing an option. In the first question we queried how the students rated the relevance of the course in general. Here all students agree or at least partially agree that the lecture is relevant. Next we asked whether students enjoyed the flexibility due to online teaching. While the results show that the majority of students rather agree, one student partially and two students totally disagree. Going deeper in this direction we asked whether students prefer the flipped classroom structure with prerecorded lectures and an online plenum to ask questions to a classical lecture. The results are comparable to the previous question with only one more student disagreeing with the statement. To get an insight in the reasons for preferring one or the other form of lecture, we asked whether students value the social experience of a physical lecture more than the flexibility offered by an online lecture. For this question the students are split evenly between the two options, but the students who value the social aspects more have a stronger opinion about there choice and everyone answered with "totally agree". As described earlier this course also entails a big share of self organized work among the students which had to be performed virtually this year as well. As we are also interested whether students liked the virtual collaboration or would rather work together in person, our next question captured this aspect. Most of the students state that they prefer to meet physically and only three student state differently. For the next question we asked the students to compare their participation to how they usually participate in

physical lectures and exercises. Half of the students answered that they could participate to the same degree with further four students at least partially agreeing and three students either partially or totally disagreeing. The last question reflected the students opinion about the tools we used to facilitate online learning. Again eleven out of 14 students rate the tools as rather helpful and three students state the opposite. For this question the level of agreement is weaker than for the others with the majority of students stating that they only partially agree with the statement that the tools were helpful.

5. Lessons learned

All the tools used in both PBL courses, except Zoom, Vimeo and TurningPoint, are hosted and maintained by TUHH. Plenty of these tools provided by the university are open source (e.g., Stud.IP, GitLab, Mattermost, Etherpad, Jitsi), while certain ones are proprietary (Mediasite). All employees and students are able to use these tools using their university account. The use of these tools through a single account made working easier for both, students and teachers. The maintenance of these tools including backups are done by the computing center of our university taking away the administrative burden from us.

Access to heterogeneous tools and platforms with a single account with minor to none maintenance.

We have tried out the flipped class room concept for the lectures during the pandemic. As students are not keen watching lecture recordings more than 10 to 15 minutes, the original slides we had for 120 minutes lectures (of SimCN course) had to be restructured to make smaller concept-based stand-alone lecture recordings. However, we still believe that stand-alone lecture recordings should have been done in such a way that the whole concept could have been understood on its own without much support from other recordings. This will be the best way to cater to students with a variety of knowledge-levels and also to let them grasp the different concepts like playing with building bricks.

Lecture recordings should be broken into small independent concept focused pieces.

The decision to reduce the lecture time in SimCN course and to use lecture time for exercises in IntroIT course made it necessary to produce video content and accompanying online script chapters in advance. This increased the preparation time for each session significantly.

Pre-production of videos is helpful but very time-consuming.

During the courses more and more students attended the video sessions in Zoom or Jitsi without turning on their cameras. This ”black tile experience” left teachers unclear about the presence and active participation of the students. As for a video conference, not seeing each other’s faces is a bit weird and discourages the tutor as he/she talks to a black wall. This wouldn’t be the case for a telephone conference where one would not expect to *see* anybody. With this little tweak to one’s attitude a ”black tile” video plenum can be taken as a telephone conference with the enhancement of being able to share a screen. Otherwise, all that remains is to think about measures to force students to show their faces. But this does not follow the values of PBL.

The ”black tile experience” in Zoom or Jitsi can be discouraging for teachers.

It is our utmost responsibility to cater our online teaching for all the students, especially during a pandemic. We have to adhere to current copyright and GDPR rules as most of our material is publicly available. This hinders us from providing the recordings of lecturer-student discussions for the benefit of the other students who were not able to attend due to technical/social related issues. This matter is not a problem for physical lectures as attending a lecture is considered the responsibility of the student.

Relaxing of copyright and data protection laws for online teaching.

Even though we expected to conduct the exercise discussions in smaller groups over Zoom with their videos on, we later realized that students do not always prefer this option due to various reasons. The chat allows students to express themselves freely. Though facial and tonal expressions are unavailable, students collaborate openly as well as privately using chats. The flow of the communication is generally asynchronous and can also be traced later in time.

Asynchronous chat based communication is more preferred by students than synchronous audio/video communication.

As tutors, we find that online teaching for a PBL course is more effort intensive compared to meeting students physically. In physical meetings, tutors and students meet once a week with less support via emails and chat based discussions. We have noticed that the chat based discussions increased enormously during the virtual collaboration. We know that in earlier years, team members met physically to complete the exercises and were able to solve problems together. During this semester, the students discussed their problems directly

on the common channel in which they receive the reply from another student or a tutor immediately. Furthermore, the students also sometimes expected that the tutors are also available for immediate support. This was very critical as students tend to complete their work closer to the deadline. Though we are willing to support the students, this was not the intention of a PBL course, as this tempts students to ask questions without trying on their own and without discussions among team members. Later, we as tutors had to limit our time in answering.

Virtual collaboration is not the same as operating a 24/7 support hotline.

Tutors were involved in solving problems related to personal computers of students. This is very challenging in a virtual setup. Posting screenshots and sharing screens in Zoom or Jitsi helped in solving individual problems. Complex problems like merge conflicts in Git are easier to explain and solve in the same room given the students are new to these tools. Further, the remote control option in Zoom helped tutors to directly access students' computers for further debugging.

Screen sharing, posting images and remote control options are crucial for debugging and solving complex problems.

We had to use some tricks and spend more effort in engaging non-active students in both, lectures and exercises, to fulfill the last two outcomes of PBL, viz., **social competence** and **autonomy** with virtual collaborations. They are, embedding some questions inside our lecture recordings to be prepared for the next lecture discussion, letting them use tools like Etherpad to ask questions anonymously, giving priority to non-active teams to present results and preparing one exercise (Exercise 7 in SimCN course as discussed in Section 2.2) completely for students to share their own feedback among the group.

Encouraging collaboration among students, lecturers and tutors is effort-intensive.

We used a large range of tools to conduct a PBL course online. If students are new to a PBL course, getting to know students first is very important to have a good student-teacher relationship for later discussions. As we have done in IntroIT course, getting to know students preferences and their knowledge-level and afterwards change the schedule (e.g., extra time allocated to learn tools, not to use videos, introduction among students-teachers, etc.) to address those gaps is important. Even for bigger groups of students, this should be done by splitting to multiple smaller groups of PBL.

Extra time is needed to get to know each other as well as the collaborative tools used.

As we see from the answers to our survey, students are open to the new form of teaching and generally show a positive attitude towards the changes. While students express that they miss the social aspects of teaching and being able to work together in a room, they value the flexibility of online teaching and rate the tools used for asynchronous communication as helpful. This feedback is important to be kept in mind for the future even when lectures and exercises are held in person again.

Students value certain aspects of online teaching compared to a classical lecture.

6. Conclusion

Online teaching of PBL courses can be a paradigm shift of responsibilities from students to teachers. It involves making sure everybody is able to access the materials online, deploy online tools to involve students without any face-to-face meetings and to make sure students keep up with the lecture contents. These challenges are present more than ever during a pandemic, where no alternative is available. Lacking any face-to-face meetings is considered by us to be the most difficult part of this online teaching because it hinders open and free discussions among students and teachers. In order to achieve our teaching goals of a PBL course, especially the last two outcomes, viz., **social competence** and **autonomy**, with virtual collaboration involves an extra effort and more preparation time.

However, even in spite of an ongoing pandemic and major reconstruction of the way we organize our courses, we are content with our achievements. The overwhelming level of engagement and enthusiasm from students as well as teachers to find practical solutions to new problems was very interesting and helped us improve our ability to collaborate virtually significantly. These skills are very important for us now that research efforts and working environments become more and more international, but they are even more important for the students. Facing difficult environments, different situations, and a challenging task, everyone involved had to adapt and learn new things, which we consider the most important social skill.

In summary, the lecture part of the PBL can be done with virtual collaboration, but task oriented exercises in smaller groups should at least be done as a hybrid solution with several physical meetings to help students and tutors to get to know each other properly.

We should not forget the fact that online teaching is beneficial during or beyond a pandemic. The online teaching makes it possible for students as well as teachers who belong

to high-risk categories to keep on classes during a pandemic. In general, any student, who cannot always physically attend the classes due to caring for children or sick parents at home is benefited from online teaching.

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