Surviving the Unforeseen – Teaching IT and Engineering Students During COVID-19 Outbreak

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***Abstract*—In this Full Paper on Innovative Practise, we sum up our teaching experience during the COVID-19 pandemic. We focus on several courses taught at the Department of Computer Systems. The main technique to cope with COVID-19 restrictions in higher education is to use online teaching solutions. The first step was to make the traditional lectures available online through recordings enabling students to attend lectures as needed. Yet, for several courses, a quick reconfiguration was required for laboratory exercises as COVID restrictions were established in the middle of the study semester. Thereby, an irreplaceable solution was to use remote laboratories. One of the main concerns was how to set up the online environment within days and weeks and not in months. In addition to remote laboratories, we propose an online teaching and custom assessment setup that to the best of our knowledge has not been used before. For example, instead of using Proctorio for online assessment, we propose a two-stage, licence-free, online examination setup. The proof of concept was carried out with more than 200 students.**

***Index Terms*—COVID-19, teaching, online, laboratories, examination**

I. Introduction

Since early spring 2020, countries have limited or even banned public social interactions in public areas. However, for universities, the obligation to remain functioning has not changed. Therefore, new ways to pass on knowledge to students are required. Furthermore, in these confusing times, higher education serves a novel purpose in maintaining stability in society by allowing students to pursue their studies.

For years, higher education has been based on passive lectures; in-class practice lessons and laboratory exercises; and an examination session to sum up everything. The reversed classroom, also known as the flipped classroom teaching method [1], first used in the 1980s, aimed to change student participation in lessons to be more active by changing the roles between the lecturer and the student. It was a novel method then, and now it has reached its peak [2]. Meanwhile, Massive Open Online Courses or MOOCs have gained popularity along with online lectures. However, that was about a decade ago [3]. Different MOOC platforms have been created over the years, mostly with commercial interest in mind, coordinated or partnered with public universities. For example, Stanford University, UC Berkeley, and Harward University offer courses on the Coursera, Udacity, and edX platforms [4].

On the same page with MOOCs, we find online lectures, either provided by MOOCs or by universities directly. As course management has moved widely online, thanks to Google Classroom [5], Moodle [6], and other similar learning management systems (LMS), universities can provide online lectures of comparable quality. Other digital platforms that support online lectures and are also available for Tallinn University of Technology (TalTech), are Echo360 [7] and BigBlueButton (BBB) [8]. Students can attend lectures virtually anywhere and at any time if recordings are available. For lecturers, the main task with online courses (also MOOCs) remains how to maintain students' learning motivation [9]. In our experience, online lectures decrease the students' active participation.

Are MOOCs and online lectures the latest trend in e-learning? Fortunately, not. According to a survey [10] conducted by Office of Academic Affairs at TalTech in May 2020 lecturers listed alongside classical digital platforms several smaller environments, e.g. Padlet, Slack, Maurus, WooClap, Discord, and Nabble useful to engage interaction and playful absorption of learning material in online courses. Moreover, with the rise of digital access, not only lecture materials are available online but also practise and laboratory exercises, under the concept of a remote laboratory or online laboratory [11]. As MOOCs are usually combined on a uniform platform, remote laboratories are mostly a custom solution that requires more work from the lecturer than just uploading a video or lecture slides. Although the concept of remote laboratories has a longer history than MOOCs, starting in the 1990s [12], the topic still provides challenges due to technological advances. Mainly because for the practical lessons, a video feed is not sufficient and a custom interface for interacting with the physical object is required. Students usually have to interact with physical hardware and this is why remote laboratories have to be custom developed. An example of a remote laboratory setup developed before the COVID-19 period by the Department of Computer Systems is presented in [13]. Furthermore, in this paper, we describe the best practices in various hardware and software related courses with remote laboratories as being one of the ways to deal with teaching over the COVID-19 period.

Our efforts towards providing modern ways of teaching and learning belong well beyond the pre-COVID era and have over time provided our department a good set of knowledge and skills for adapting for changing situations. Well before Moodle became available and popular in Estonia, we established a light-weight LMS e-EDU [14], [15]. In [16] we explored new paradigms rising in contemporary teaching and involving engineering students into this process, and in [17] the inclusion of start-up culture in teaching. In addition, we explored hardware programming for freshmen in [18] and developed a custom robot programming kit in [19]. We have studied the use of webcams for learner attention tracking for online courses [9], [20], [21], including MOOCs but also for learning on mobile devices [22]. Over time several interactive learning objects have been developed [23]–[25].

When lectures can be covered by different online lecturing solutions and practical lessons can be handled by remote labs, then examinations must be treated differently. During the first spring of COVID-19, when the university was off limits for graduate students, new ways to assess students were needed. Of course, an online platform might be used to conduct an oral exam when the number of students is relatively small. Even an online chat tool like Microsoft Teams [26], Zoom [27], Discord [28] or Skype [29] would be sufficient.

However, for courses with a large number of students, an alternative solution is needed. Dedicated software like Proctorio [30] – an environment where the student is remotely monitored by a camera when taking an online exam – could be used to perform online assessments. However, in our experience, the system is not foolproof as false negatives for cheating occur. For this reason, students in one course did not like the software at all. Thus, we propose an alternative setup for student assessment using Teams [26], Moodle [6], and Safe Exam Browser [31]. The setup was successfully tested in spring 2021 in a course with more than 200 students.

Therefore, it appears that tools to cope with unexpectedly changing situations in education were already available before the pandemic. However, the challenge is how to adapt to new platforms, remote laboratories, and online examinations in the middle of the study semester. Equally important is maintaining the quality of teaching and the motivation of the students. The latter is especially crucial, as studies suggest that distance education bears a heavy burden on student study motivation and can cause distraction, depression, and stress [32], [33]. One of the methods to counteract the downsides of distance education is to include active learning experiences [34].

This paper is organised as follows. In Section II teaching experiences about study motivation and student attendance in various software and web engineering courses are described. Section III describes the work related to remote laboratories on bachelor level Embedded Systems course. Section IV covers online and simulator-based teaching solutions for automation course. In Section V the setup of a custom online examination platform for a Computers course with a large number of participants is described. Section VII concludes the paper.

II. Courses on Software and Web Engineering

The outbreak of the pandemic influenced the teaching of three software-related courses – Software Engineering (SWE), Web Technologies (WT), and Software Project Management (SPM) – the first two of them taught at the bachelor level for students of different curricula and SPM for masters of the international Computer Systems program. The WT course was mandatory for most of the participants, whereas the SWE and SPM courses were elective. For each of this course, students could get a grade based on continuous assessment or, if they were not satisfied with the result, take an exam. The practical side of the courses contained both individual tasks and teamwork tasks or a project. Table I provides an overview of the course statistics. As the leading lecturers shared the courses, the same concept of online teaching was applied during the COVID-19 pandemic.

TABLE I
Course statistics for the SWE, SPM and WT courses

	# enrolled			**Average Participation [%]**		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**
SWE	11	5	3	69.5%	91.4%	n/a
SPM	n/a	52	20	n/a	79.8%	81.8%
WT	53	60	52	64.6%	65.0%	89.3%

When the sudden lockdown and ban on physical meetings hit in spring 2020, the courses were reaching midterm – the ban was enforced from the eight study week, whereas the courses are of length 16 weeks. As for many of the lecturers, this meant long nights and overwork to get some order into the chaos: a lot was unknown, and organisational-level orders arrived at the last minute. There was no preparation for this new situation. Thus, the first weeks were spent to try out many of the tools and platforms available, e.g., Zoom [27], Microsoft Teams [26], Jitsi [35] – each having its flaws at the time. Also, the option of pre-recorded lectures was studied, but seeing the time effort it consumed from lecturers, it was soon discarded. Finally, it was settled to use either Zoom (having 40-minute restriction) or Teams, and after having a few online classes Teams was chosen due to the limitations and technical problems of Zoom. The decision towards Teams, regardless of its bugs and daily crashes at the time, was also influenced by the fact that the platform was made automatically available to students through university-level agreements with Microsoft.

In terms of courses' organisation, it was decided not to deviate from the initial course plan and have regular weekly meetings according to the time schedule. Therefore, physical meetings were replaced with online real-time meetings taking place at the same time as the physical meetings would have taken place. It was decided as such keeping in mind the students and their need for regularity for their daily lives in the emerged chaos situation. Through discussions with colleagues from our university as well as abroad, it became clear that students from courses, where just recordings were made available or only reading materials or slides were provided, were suffering from a lack of motivation and course participation. Indeed, there was no obligation for students of these courses to be present in online classes, participate in discussions, or perform tasks; all of a sudden, everything was left on their shoulders, and as natural, things started to accumulate. This was a situation that we clearly wanted to avoid. Thus, regular lectures and practices were held according to schedule, only changing the environment in which they were taking place to online. This was a challenge!

Each online meeting started with an obligatory attendance check. As some of the courses were running on a lightweight LMS called e-EDU [14], [15] and not in the Moodle LMS [6], this was achieved through Google Forms and Microsoft Forms, and for the Moodle courses using the Attendance check tool, while the check was equipped with password and changing URL address. Lectures were held using mostly Teams, while practices took advantage of Teams to introduce the practice class, its topic, and tasks, and then in further was used for group or one-on-one (student–lecturer) task defences/discussions according to the order of preregistrations. A great deal of support was gained from the use of the self-hosted Mattermost [36] communication platform, which we had chosen as the communication channel for all the courses already before the pandemics. This made it easy to share all the details to start online lectures or practices, and for students to ask questions privately or in public channels, or request an online meeting to defend their practice tasks.

To keep students motivated to learn and participate, we introduced weekly online quizzes as mini-tests on the topics of the previous lecture and the one before. The quizzes were carried out on the Wooclap [37] platform. These quizzes were well accepted and expected by the students, and if we deliberately missed one on one of the weeks, they immediately asked for it. This gamification aspect of the course turned out to be quite popular and worked well for online lectures.

In the SWE and WT courses previously, the students had to defend their work on-site. As these tasks were about programming, by moving the courses online, we started to use GitLab, where they had to upload all their work and share it with instructors prior to defences. For the SPM course, however, most of the practical tasks were in the form of teamwork, where solutions were usually marked down or drawn on paper by teams during teamwork sessions for later in-class discussion using document scanners. This meant that to move online, we needed to transform tasks into digital form through the concept of task templates to obtain visually comparable results from student teams, but also to find collaborative online drawing environments (e.g., Diagram Software and Flowchart

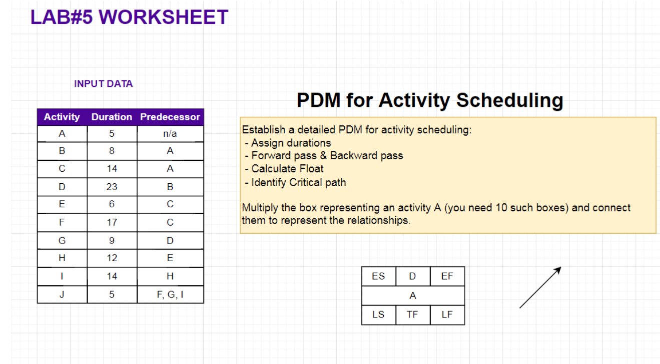

Fig. 1. Example of a digital lab sheet template made for the SPM course.

Maker [38]) that students could use to solve the tasks within the given time limits efficiently. Fig. 1 provides an example of the project scheduling template prepared for the students of the SPM course. The lab sheet with ready-made shapes was made available in the XML-format, whereas to start with the task, students had to upload it to the tool.

The tests and exams for the SWE, SPM, and WT courses were conducted in Moodle as online tests with time and availability restricted. The tests were composed of two parts, having *True/False* statements and open questions, and followed by one-on-one interviews online, not limited to the questions of the test variant but to all the topics of the test set. The students for interviews were randomly selected based on the monitoring during the tests, forming a solid 20%. Each exam ended with an obligatory interview to obtain a grade.

Having learnt the hard lessons of moving the courses to online in spring 2020, then for the next spring 2021, when another lockdown was enforced, we were already well prepared. The procedures were in place, as well as the tools that had evolved and become more stable. For spring 2021 we moved all the courses to the Moodle LMS platform, and began to solely use its Attendance check tool with preset period and password. We also switched from Teams to BigBlueButton [8], as it only required a web browser from students, consumed less resources, and provided the possibility of break-out rooms (a feature that was later made available in Teams as well). The use of break-out rooms allowed to better organise practice labs and teamwork sessions, lecturers could take part of these by switching rooms, but also allowed to have several students defending their practice tasks at the same time. To enforce teamwork and keep teams working on projects efficiently, we introduced a *fair and individualised project teamwork evaluation method* [39] established for the Computer Systems Engineering master's course to the SPM and WT courses as well. We also continued to have online real-time classes and quizzes to keep students motivated and engaged.

We were also interested in seeing whether the COVID-19 restrictions and the move of studies online had an effect on participation. Table I lists the average participation statistics for 2019 (before COVID), 2020 with restrictions enforced of study-week 8, and 2021 when all the three courses were running full time in online mode due to lockdown. Before moving to online course format, the participation in each class was checked on a paper form, where students had to write down their name by hand and sign the row with their details. Heads were counted after the attendance sheet arrived back to lecturers. During the COVID restrictions when teaching was moved to online on Moodle platform, participation was checked using Moodle Attendance check tool for which during the online class a new password was provided each time, and attendance check was restricted in time. In addition, participant list was downloaded from the online platform (e.g., BigBlueButton) for comparison. To analyse the effect of changing studies form physical to online, we look at participation data in two periods: week 2–7 (*period 1*), and 8–15 (*period 2*). We choose to disregard the first study week, as students have not decided their study load at that time, and the last week, as it is usually the end of the course for wrapping up (not quite reflecting the real study process). The segmentation into two parts on week 8 is according to the start week of the COVID restrictions in 2020. For the elective SWE course in 2021 there were only a few participants and the study format was changed to seminar form, so we do not analyse this data, as it would not provide any indication. There is no data for the SPM course in 2019 as the course started running in 2020. For the WT course we have data available for each of the period.

We analyse the data through comparing the average participation level and variance of participation of *period 1* to *period 2* (Fig. 2). For this, we find on a weekly basis (as each course had weekly meetings) the student participation level expressed in percentages (e.g., course SWE, week #3 participation 91%) over the number of students who had a valid declaration for the course, and thus were expected to take part. These participation levels are then averaged for *period 1* and *period 2*, supplemented with variance. The change (Fig. 2) is once again expressed through percentage but now for *period 2* regarding *period 1*. As mostly the participation level during *period 2* is lower, this will also produce negative values to express change trend. For example, the participation level of *period 1* was found to be 77% and for *period 2* only 64%, indicating a change of -18% (e.g., for SWE 2019). We notice that after midterm, as usual, there is a decrease (a negative change) in the course participation, regardless of COVID-restrictions; and yet it appears to be less than with physical meetings (2019 versus 2020 and 2021). This can be either from having participating also the students who otherwise would skip the physical class for various reasons (e.g., work) in the online form, or the students marking themselves present without actual participation. For the SPM course in 2021 we see even an increase in average participation for *period 2*, characterised by lectures blended with teamwork labs in online breakout rooms. Indeed, the student feedback stated that with online classes they saved valuable time that otherwise would have been spent on travelling to the university. The increased variability for all the courses in 2020 represents that the participation was not stable, whereas it seems to normalise for 2021 when all the courses were running online throughout the semester. The negative values of the variance on Fig. 2 represent the negative trend of the change in participation variability, i.e., the participation level variability of *period 1* decreases compared to *period 2*, and thereby represents an increase in stability (less variability in participation levels). Although the three courses and periods are too little to make statistically relevant final conclusions, it sends a signal that the new crisis had an effect on students motivation to participate.

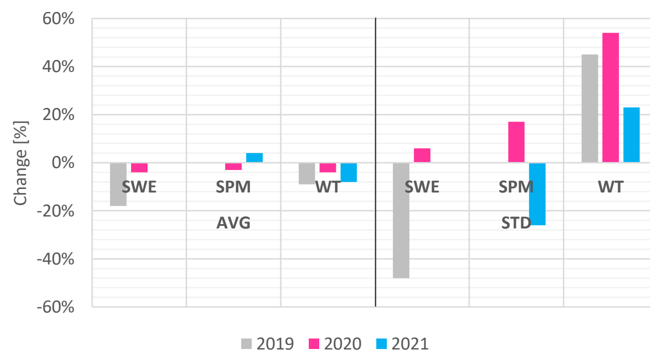

Fig. 2. The changes into average participation level (left) and variance of participation (right) of *period 1* (weeks 2–7) to *period 2* (weeks 8–15).

III. Course Embedded Systems

The master level course Embedded Systems covers a variety of topics in embedded systems over 16 weeks with both double academic lessons for lectures and practical exercises each week. An important part of the studies is practical experience with microcontrollers, in particular the Texas Instruments TM4C123G LaunchPad [40] as depicted in Fig. 3.

Practical exercises start with an introduction to tools and cover simple functionality of microcontrollers, such as blinking the LED in reaction to a button press. To check the controller's functionality, physical access to the board is required. For subsequent labs, the complexity is increasing, and different microcontroller functionalities are studied. Fortunately, in spring 2020 the basics were covered in class before the lockdown period. However, for more complicated exercises, such as setting up a simple real-time operating system, the possibility of using the microcontroller boards was impossible due to the start of the COVID-19 lockdown period.

Unfortunately, the number of students who declared the course exceeded the number of microcontollers that we had for the class. Therefore, it was not possible to lend devices to home use. An alternative solution was required, and naturally remote access in some form seemed the only solution. Remote access to the lab class was set by the university's IT services. Some in-class computers were permanently connected and students could access these PCs remotely through a virtual private network (VPN) connection. They could programme the board and blindly through provided tests check the required functionality. In these practical exercises, physical manipulation of the microcontroller board was not necessary. The only problem remained with the number of students in correlation with the available microcontroller boards. As only seven PCs were permanently available to students but the number of students was eight times higher, the online lab time required scheduling. The chosen solution was to use a Group Choice tool in Moodle. This allowed to establish a semaphore mechanism for the available PCs. The rule was to lock a PC through the Group Choice tool before establishing any remote connection. In order to work with the hardware, a separate remote connection through VPN to the chosen PC had to be made. After being disconnected, the semaphore had to be unlocked so that other students could use the PC. As the semaphore system and remote connection work independently, the students were required to follow the rules and not interfere with computers that were marked as locked by the semaphore system. Technically, an impatient student could have locked out another student's session via the remote connection. However, this was never the case, and the semaphore method worked well.

All communication, along with answers to questions and comments on detected issues, was maintained through the Teams environment. The lectures were held online using BigBlueButton (BBB) via Moodle. Students were active during lecture time and the BBB supported proper teaching well.

IV. Course Intelligent Buildings

The six credit point course Intelligent Buildings is mandatory for the students of Hardware Development and Programming, Robotics and, in a reduced capacity, for Mechatronics curriculum. As the course is a part of special study module and is usually chosen on the last study semester, when all students are engaged with their undergraduate thesis, student participation in the course is modest, usually up to ten students from every curriculum select the course.

Fig. 3. The Embedded Systems course laboratory setup.

The course teaches the necessary skills and know-how to enable students to choose the most optimal smart technology for building in future projects and gives an understanding of the role of building automation systems. In addition to teaching the basics of building automation, the course also advises students on how to continue investigating and practising topics covered in class by introducing them to inexpensive development kits and freely available software tools. For example, students who have access to popular hardware platforms like Raspberry PI could use these additional resources to implement the knowledge gained in this course in real-life practise.

Although the course was already up and running in Moodle with online lectures as well, we still had to find a way to conduct different building automation-themed laboratory exercises during COVID-19 elicited no-contact teaching periods. The solution was to use common practise in the field of automation controllers, where the designed algorithms and programmes on selected series of controllers can be tested with built-in or added simulators without downloading the programme into the controllers. Although the students did not get the actual feedback from working with hardware, they still could at least simulate the algorithms. Finally, three software suites were used. The software suits used to conduct the virtual laboratories were Siemens LOGO! Software [41], KNX Virtual [42], KNX ETS Demo [43], and BACnet BAScontrol Toolset [44]. Fortunately, KNX Virtual software was released as free software less than half a year before the lockdown period began [45]. For the online laboratories, this was a major help. From the BACnet BAScontrol Toolset the Sedona Application Editor (SAE) and BASemulator tools were used as part of online laboratories. The task for the students was to install the software on their computers following the online tutorial from both the software manufacturer and the lecturer, and solve the programming task.

As semesters progressed, the conduction of laboratory exercises was considerably simplified by the remote connection possibilities to the laboratory computer class. Remote access was managed by university IT services. As a result, students had the choice to install the software on their personal computer or use VPN and Windows Remote Desktop Connection (RDC) [46] to access the laboratory class from distance. As RDC takes over the control of the class computer, a scheduler was required to organise the work time for the students. Booking app [47] from Office365 was used as a scheduler as office tools are available on campus. However, any other free scheduler software would have also been suited.

The most important part of the RDC was to give students access to the physical automation controllers available in laboratory class. In addition to simulating the software, students were able to design the controllers web page, test remote access to the controller, override internal variables, etc. The KNX ETS software, available in the laboratory computers, allowed students to monitor the KNX bus and connect via KNX IP routers to physical KNX devices on the educational platform. Fig. 4 presents the workplace with automation equipment for the Intelligent Buildings laboratory.

Fig. 4. A demonstration setup of the Intelligent Buildings laboratory workplace with equipment.

V. Course Computers

The six credit point course Computers is an obligatory course for several curricula including both hard- and software-orientated bachelor programmes. The course covers many entry-level topics related to the principles of digital logic, processor architecture, computer memory architecture, and management. In addition: external devices, like monitors, printers, etc. are covered with some more specialised concepts like programmable logic, ASIC, parallel computing, and fault tolerance. Table II presents the number of students who have registered for the course since the COVID-19 pandemic. The decrease in students who took the course in the spring semester since 2020 is due to the fact that the course was excluded from the Business Information Technology curriculum. Overall, the course has always had a large number of students in each study year.

TABLE II
Number of students in the Computers course

Study Semester	Enrolled Students	Curricula
2019/2020 spring	262	IABB[a], IADB[b], IACB[c]
2020/2021 autumn	83	IAIB[d]
2020/2021 spring	244	IADB[b], IACB[c]
2021/2022 autumn	60	IAIB[d]
2021/2022 spring	195	IADB[b], IACB[c]

[a] Business Information Technology
[b] IT Systems Development
[c] Hardware Development and Programming
[d] Informatics

A. Lectures and Laboratories

The Computers course consists of lectures and laboratory exercises. Since the COVID-19 pandemic, course lectures were held both in-class and online; therefore, a hybrid lecture format was used. Due to the fact that the university has several online lecture platforms available, as well as infrastructure support for online lectures, the transition to hybrid lectures was most seamless. To present the hybrid lectures, the Echo360 [7] platform was chosen. Additionally, to make the course more accessible to students, lectures were also recorded.

Compared to the smooth transition from in-class lectures to hybrid lectures, laboratory exercises required a bit more attention. Each student has to solve several individual exercises to meet the prerequisite for the exam. The exam prerequisite states that a student must obtain at least 11 points out of 20 from the laboratory exercises. There are five individual exercises, with increasing complexity, which each student must solve consecutively. However, it is not required to complete all exercises to obtain the minimum required score for the exam prerequisite. The complexity of laboratory exercises was not in the organisation of the exercises, as all exercises were based on free software simulators, but in the organisation of the lab defence procedure for students. Therefore, the Microsoft Teams platform, available to both staff and students, was used to organise the defence of the laboratories. In collaboration with Moodle Scheduler, the defence of the laboratory exercises was well organised.

B. Examination

The Computers course is a fully integrated Moodle course with exceptions for the laboratory exercise software and chat that is organised using the MS Teams software. Therefore, the examination is also conducted in Moodle. For this, a custom question bank with more than 300 questions has been created over the years to test the students' knowledge. The examination is divided into two parts, with each part taking up to one hour, where the first part consists of 50 multiple choice questions and the second part includes five open questions. As the number of questions in the bank is high and the examination questionnaire is organised to take random questions from the question bank, the chance of two identical versions of the exam is low. Furthermore, prior to COVID-19 the exam took place only at the university under close supervision of the lecturer. Therefore, any chance of effective cheating was almost non-existent.

In the first COVID-19 spring, the spring of 2020, it was forbidden to carry out any teaching-related activities on university premises, with the only exception to students working on their thesis. Therefore, the examination for more than 250 students had to be organised in some other way. Clearly, an online solution seemed to be the most suitable. Although an online oral examination is suitable for a small group of students, it is immediately rendered unsuitable for this course. For example, each student gets a minimum of 15 minutes for the oral exam, instead of the 2 hours used before for the written exam. In this case, the lecturer can grade four students per hour, and it takes more than 65 hours together for the entire examination session. As the time spent on examinations would have added a considerable amount of workload to the lecturer, it was ignored. Therefore, an alternative approach to the organisation of the examinations was required.

One of the alternatives that was considered was a home online exam using Proctorio's online proctoring software [30]. The software aims to safeguard the exam by monitoring student behaviour via camera. However, a feedback survey conducted prior to the examination session showed that several students with previous experience with Proctorio software did not praise the solution. The main reason is that the software can produce false positives when a student looks away from the computer. Also, the software is not freeware and requires a licence fee to be paid per seat. Therefore, the software was not the first choice as the number of students was also high. On the other hand, a fully automatic examination monitoring software could be beneficial for those who can afford it.

Lastly, a custom examination monitoring solution was created that utilised the available resources and suited the needs the best. A two-stage full online home examination kit was developed. The aim was to allow the student to take the exam at home while being monitored by the supervisor. It was also required that several students could attend the exam simultaneously. Additionally, the goal was to fully use the Moodle-based exam structure and questions. Therefore, in Fig. 5 is presented the overview of the examination process based on Moodle with Safe Exam Browser (SEB) [31] and MS Teams messaging software. The SEB software is a kiosk programme that locks the computer by allowing only the preset software to run. In this case, the SEB environment executes a Moodle-based examination questionnaire, which is, as mentioned above, a totally random test generated from the questions in the question bank.

On the left side in Fig. 5 is presented a student at home behind a PC with Moodle login and a suitably placed smartphone with a video chat running the Teams oversight for examination. The appropriate placement of the smartphone means that both the student and the PC screen must be visible. It was suggested that the smartphone be placed on the side or far behind the student. On the right of the figure is presented a supervisor/lecturer that monitors students' activity both in Teams as well as in Moodle. For each exam session, a predefined number of places was created. In our experience, the number of students per exam should not exceed 15 students to keep the lecturer on top of things.

The examination process starts with the supervisor checking the student ID in Teams chat. For this, students present an official document near the smartphone camera to the lecturer to verify identity. Identity verification is also used against the examination registration list. When all students are verified and the examination rules are explained, the supervisor presents the students with the examination password that is needed to start the exam via Moodle test in the SEB environment. The lecturer simultaneously checks the summary of the Moodle test to verify that all registered and present students also begin the exam. The Moodle test check is required to verify that any unregistered student would not start the exam and to confirm that any student taking the exam is not just faking it by allowing a fellow student to take the exam instead.

In our experience, the examination process is quite safe as long as the students position the smartphone according to the requirements. Of course, some students tried to cheat by placing lecture material in their lap or elsewhere, but were quickly caught because their attention was elsewhere than on the monitor. Also, there is a way to cheat the SEB but this means using a virtual machine and is probably caught by the Teams camera. In our case, we did not suspect that any student had cheated this way. Furthermore, to prevent students from cheating by having an additional person in the room, all microphones had to be turned on, except the lecturer. Also, the lecturer could start a conversion with any of the students at any time in exam to verify camera position, etc. If students had to modify anything on the smartphone before answering, this could mean that the student could potentially have a microphone off.

The main restriction of this setup is that SEB is available for MacOS and Windows environments. Linux users had to find another PC with a suitable operating system. Also, when a student does not have a smartphone, the solution is not suitable. However, when students were presented with the proposed setup that required the use of their smartphone, there were no disagreements.

VI. Project Courses

Over the last few years, project courses have been introduced in the Hardware Development and Programming bachelor curriculum. Starting from the first semester with a mandatory half-semester project, each semester includes an option for students to select a project course. In the first half of the studies, electronics, hardware and software-related project courses are offered. In the last semester, more advanced project courses were presented at the system level to students.

The goal of such courses is to give students opportunities to work on real-life close tasks, either individually or in teams. At the beginning of the course, students select a predefined project task or define their own task. The feasibility of each task is discussed, the tasks are divided into subtasks, and the subtasks are scheduled over the 16 weeks of the study semester. Most of the time, the teams work independently but after every two weeks they meet at the classroom for sprints to present their progress with projects, what has been done during the last two weeks, what are plans for the coming weeks, plus discussions.

Before 2020, it was easy to organise the sprints, but from the moment the university was closed, we had to find solutions on how to continue. For biweekly sprints, the solution was obvious: meetings were organised virtually using Teams [26]. Demonstration videos were also recorded for sprint presentations earlier, too; now it was important to make sure that the meetings and presentation could be organised online. Another challenge for the students was how to work as a team but at the same time minimise physical contacts as much as possible. Depending on the project task, the students divided their tasks mostly successfully, although in a few cases the initial task had to be modified to take the restrictions into account.

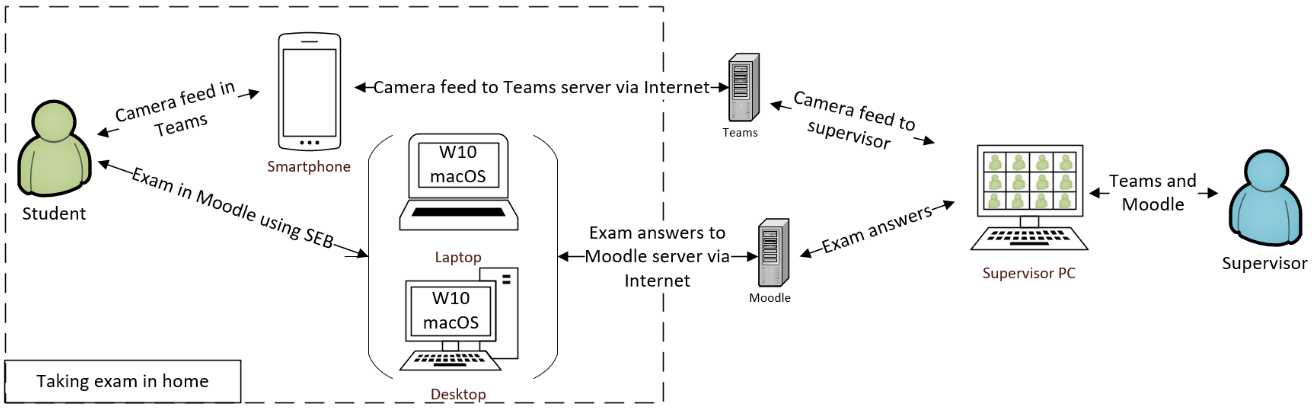

Fig. 5. On-line examination setup in Computers.

In fall 2021 and spring 2022, the project courses were organised in hybrid mode because it was still important to minimise physical contact. However, in the last weeks of the spring semester, the sprint meetings have been organised as usual – students came to the meetings and presented their progress. In general, these courses did not suffer much when running in virtual or hybrid mode; the presentations had to be prepared and presented anyway, although some extra minutes were wasted now and then because of technical problems. The feedback from the students was also positive: they were able to work on practical tasks and received useful feedback after presentations.

VII. Conclusions

In this paper, we present the teaching experience through the COVID-19 pandemic during the lockdown period over the last two years. As the first lockdown was introduced in spring 2020 in the middle of the study semester, a rapid reorganisation of several courses was necessary to maintain a satisfactory level of teaching quality. Therefore, online lectures, remote laboratories, and even online examinations were required. As spring 2020 was of the essence, we present the initial solutions that were improved for several courses for the study year 2021. The adjustments for teaching are covered by the following courses: Software Engineering, Web Technologies, Software Project Management, Embedded Systems, Intelligent Buildings, Computers and project-based courses for undergraduate students.

To sum up our teaching experience during the pandemic period and at the beginning of it, we focus on three teaching components: lectures, hands-on laboratories, and examination. First, for a period of time, student access to the university was prohibited; therefore, any and all forms of teaching had to be resolved without physical contact. For each course discussed in this paper, an online lecture solution was the obvious choice. Some of the courses were offered as in-class and online even before the pandemic period and some needed to be adjusted. For example, the project courses described in Section VI, did not have drawbacks during the lockdown period at all, as the biweekly meeting took place online. Section II, which describes software and web engineering courses, focuses on reorganising lectures, including gamification, blended team-working labs with breakout rooms, and mandatory attendance check for online lectures with successful implementation. The introduced measures indicate an increase in course participation.

The main contribution of this paper focuses on the laboratories, mainly developing remote laboratory solutions in the middle of the semester. In Section III, describing the Embedded Systems course, a remote access lab was set up to allow students to access the lab remotely. The task became more complicated by the fact that during the pandemic semester more students than ever had chosen the course. Therefore, a trust-based scheduling system was established that manifested itself as a semaphore for remote laboratory access and proved to be sufficient to overcome the pandemic period. The Intelligent Buildings course, described in Section IV, had similar problems with laboratory exercises as the Embedded Systems course. This means that programming a physical hardware device was required. Fortunately, one of the software suites used in the laboratories was made freely available just before the lockdown period, allowing one to substitute the physical hardware with a simulation-based exercise. However, for other lab exercises, access to the lab was still required. Similarly to the Embedded Systems course, remote access through VPN and Remote Desktop Connection and the scheduling app enabled students to complete the labs.

The novelty in online examinations, covered by the Computers course, is described in Section V. Instead of using the available Proctorio online assessment tool, a custom setup was created that included Moodle Learning Management Systems, Safe Exam Browser, and Microsoft Teams. The Proctorio environment was not used due to the negative feedback from the students prior to the examination period. Although an oral examination via Microsoft Teams or similar video conferencing and meeting tool could be used for a small number of students, the case for the Computer course was to assess hundreds of students within the two- to three-week lasting examination period.

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