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Online teaching at CTU in Prague aka university under COVID restrictions

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ABSTRACT

Covid-19 related restrictions bring new challenges to all aspects and phases of higher education. At universities, new remote formats are deployed or even developed both for lectures and laboratory exercises. This article addresses new challenges and describes the experience with lessons during the pandemic time at the Department of Measurement of the Czech Technical University in Prague, Faculty of Electrical Engineering. It introduces the best practices exercised using the Home Lab, which helps in distance teaching of practical electronic classes. Home Lab includes two models with functional groups, a Laboratory Experimental Device and System of Measurement Instruments.

The article also shows the possibilities of suitable remote exercises and variants of circuits that can be easily assembled and measured using Software Defined Instrument based on STM microcontrollers. During the pandemic, the home lab model was successfully practically verified during distance learning in three classes, with more than 150 students. The article also presents experience with the teaching of software-oriented courses. At first glance, their transformation can be viewed as straightforward. However, practical realization reveals few remarkable details.

1. Introduction

The COVID-19 pandemic dramatically changed or even temporarily stopped teaching in many universities overnight. This situation was a particular challenge for technical universities with originally plenty of hands-on activities and laboratory exercises, as they had to set up a stable, full-fledged online education system in a concise time, 5 min to twelve. Everything that has taken place so far in the form of direct contact, from the actual lectures, seminars, practical demonstrations, and laboratory exercises, through written tests to oral exams, had to be transformed into digital form, not to mention all the legal and administrative processes behind the implementation of teaching [1–5].

The significant advantage of universities is that the vast majority of them already have extensive experience in providing online education and have a number of tools that can be used for this purpose. The rapid transition from full-time to distance learning, especially if it should last longer, nevertheless requires a reassessment of the concept of teaching organization and the provision of a range of related activities, especially in communication, planning educational activities, and selecting appropriate methods and tools [6,7].

On the other hand, the pandemic brings new challenges for universities:

- Keep the quality: Long time of pandemic - oncoming graduates spent half of their study in the distant form in case of the bachelor program. The master’s degree program situation is even worse - three of four semesters were online. Will these graduates become good engineers? [8,9].
- Social aspects: A big part of university study is to build own network of contacts (classmates, roommates) [10]. How is this traditional process affected in situations when many students spend a big part of their study in parent’s home?
- Staff: Quick transformation is demanding on human resources.
- Tools: Varieties of tools, many free or campus-licensed, are available to help. Therefore, it can be tempting to try to use everything. However, students asked in their regular semester feedback to limit the number of tools, apps, and platforms not to get overwhelmed. If it is possible, only few online tools should be used.
- Privacy: Videoconferencing takes teachers and students into each other’s homes, so it is important to consider privacy. Blurring video background is highly advisable when supported by the tool. In addition, teachers should dress as if they attend the university and expect students to do the same. Online learning is also very suitable opportunity to review digital etiquette.

All these challenges have to be addressed. In this article, the experience from the teaching of laboratory classes and software-oriented classes at the Department of Measurement, Faculty of Electrical Engineering, Czech Technical University of Prague is introduced.

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2. Methods

During the pandemic, all standard teaching units have been changed dramatically [11]. This section focuses mainly on lectures, practical laboratory exercises, and software-oriented courses.

2.1. Lectures

There are many possibilities for how to offer online lectures to students [12,13]. The most important thing is to give the students some options to watch recorded lectures. Many universities offer online lectures and teaching classes, but this never happened before the whole semester/year had to be taught online without any personal contacts or consultation. From our experience and as a result of student surveys, the best way how to offer the lectures is to record the lecture in advance to provide an opportunity to watch the video before the scheduled time, so the students can prepare their questions or topic for discussion. Afterwards, at the originally scheduled lecture time, the lecturer will be available remotely for all participants. The lecture can be recorded in the class when the lecturer uses the whiteboard and is recorded via camera or if there is no possibility to attend the university, a recorded presentation in suitable software, where tools like a pointer, drawing, and other features could be used. Based on a student survey, in this way, students can prepare for the lecture and then discuss all the problems with the lecturer. Another important aspect, especially for students of first-year grade, is the possibility to play the recorded lecture multiple times.

2.2. Seminars/laboratory exercises

Most laboratory exercises and experiments are not suitable for direct transformation to distance learning. From our experience, a quick solution is to make laboratories as a set of short movies where students watch the video, make notes and then send the laboratory report to the lecturer. The pros are the students can watch the video before the class and then consult everything with the lecturer.

The cons of this solution are the minimal student interaction. A better solution is to develop new or modified labs suitable for distance learning.

Another way to solve the substitution of practical laboratories teaching in distance form is to use the Home Lab. It is based on the knowledge that several experiments in the field of basic electronics and sensors correspond to a model with two functional groups. First, the group consists of an experimental laboratory device (LEX), to which the second group consisting of a system of measurement instruments (MIN) is connected. LEX can be, for example, a simple electrical circuit with an RC integrator, a circuit for measurement of static parameters of a transistor, variants of circuits with operational amplifiers, circuits with photodiodes, and phototransistors, or various logic circuits and analogue temperature controllers, Fig. 1.

For such experiments, only basic measurement instruments such as oscilloscope, multimeter, voltage source, and generator are used. For many experiments, these devices may not provide top-class parameters and can often be replaced by improvised device solutions. Alternatively, the design of the experiment can be modified to the improvised devices are sufficient - for example, not to measure the response of the RC integrator with a time constant of 1 us, but to use a circuit with a time constant of 1 ms.

The Department of Measurement of the Czech Technical University in Prague, Faculty of Electrical Engineering, has been developing such improvised measurement instruments for several years. The measurement instruments are based on powerful STM32 microcontrollers. The microcontroller with its peripherals (ADC, DAC, comparators, counters) serves as the front end of the improvised device. Since all functions are software implemented or only with the use of the peripherals on the microcontroller chip without the use of other external circuits, we refer to this solution as Software Defined Instrument (SDI). For availability, a PC with a USB interface, which every student has at home, is used for power supply, SDI control, and display of its results, Fig. 2.

These SDIs have been used at the Department of Measurement for teaching for several years.

It is primarily used for solving individual student projects and in classes focused on practical experience, such as electronics basics courses for students in the first semester or motivational courses for high school students. Thanks to this, there was enough experience with the use of SDI, which could be quickly used in some courses during the COVID-19 distance learning.

The Home Lab model is based on the fact that the student assembles LEX on a solder-less prototyping board (called breadboard) which is part of a supplied set of materials and is assembled according to the instructions. It uses SDI and a PC with USB for the measurement, which also powers the whole experiment. Thanks to the use of a PC, the student can share the screen of its SDI, e.g., oscilloscope (see Fig. 3), with the lecturer remotely to discuss and to present the experiment results or to consult the problem that occurred during the experiment.

It even proved to be an advantage compared to a situation where a student had a real digital oscilloscope, where the screen is difficult to share with the lecturer.

Two versions of the SDI were used for distance teaching. The first version uses a ready-made Nucleo module with the STM32F030RE microcontroller, which implements the functions of an oscilloscope with sampling frequency \( f_s = 4 \text{ MS/s} \), function generator, counter, PWM generator, voltmeter, adjustable voltage source, and logic analyser up to 12 MS/s. The second “low cost” version is used if there is a high risk of damage to a microcontroller in case of a student’s mistake. It is based on a single chip-SDI circuit microcontroller STM32F042F6P6, Fig. 4.

It includes an oscilloscope with sampling frequency \( f_s = 600 \text{ kS/s} \), PWM generator, counter, logic analyser up to 8 MS/s, voltmeter and a simple FFT analyser.

SDI with an Arduino module with an ATmega 328 microcontroller worked as a voltmeter, pulse generator, counter, oscilloscope, data logger has also been tested. However, this module has very limited parameters, and, therefore, it has been used only marginally in our lectures. However, for tasks with low demands on SDI parameters, this can also serve as a solution. During the pandemic, the home lab model was successfully practically verified during distance learning in three
subjects, with a total of more than 150 students. It turned out some students applied borrowed SDI not only for the class but also to verify the results in other individual projects such as a diploma or bachelor thesis. More details about Home Lab can be found on a homepage https://leo.fel.cvut.cz/.

2.3. Programming exercises

Software-oriented teaching online experience is described based on the observations during the Computer Networks course where more than 150 students were enrolled. As a part of the class, students implement several network programming tasks. The general task is transferring the binary file (e.g., picture) between students using the User Datagram Protocol (UDP) protocol. As a rule, one student programs a sender side, and the second student codes a receiver side. The goal of individual tasks is to practice Automatic Repeat Request (ARQ) methods and data protection codes. Programming exercises themselves are suitable for distance learning by nature. However, several problems remained previously unsolved.

Under normal conditions, lessons are held in a computer laboratory. Workstations are connected to the same network, and, thus, computers are directly accessible for incoming UDP connections. Under Covid-19 restrictions, students are located at various places with a various internet connection, and public IP address is unusual. The challenge was how to interconnect students. Deployment of a virtual private network (VPN) technology could be the key. Requirements were as follows: The VPN should be easy to set up, especially on the client (student) side, reliability, and multiplatform client availability since students use all three common platforms (Windows, Linux and macOS). SoftEther VPN Project (https://www.softether.org) was chosen as a quick solution to resume teaching. Time showed it was a good choice, and with some adjustments and server hardware upgrades, it remains a permanent solution. Windows users use SoftEther VPN client with its communication protocol. The rest use L2TP over IPsec supported by various devices and VPN clients. The evolution of network configuration is depicted in Fig. 5.

Another problem was the task evaluation. During normal conditions, evaluating individual tasks consists of demonstrating the program function and a short interview with a lecturer. In this case, we prefer live interaction with a lecturer instead of deployment of some automated system. The idea was to preserve the original style. Fortunately, using modern video conferencing platforms can create conditions close to live evaluation during the class. Beyond standard video calls, screen sharing is required for program demonstration. The interaction (talk) with the teacher is appreciated by students more than during normal conditions.

3. Experience and application

The pandemic at universities affected not only lectures, but above all practical laboratory teaching.
According to the student survey, the best way to lead the lectures online, is to record the lesson and offer it online in advance to students before the scheduled lesson. The students can prepare for the topic and in the time of scheduled lesson, the lesson is lectured again with additional questions from the students.

The rapid need to find an alternative way of practical laboratory teaching has led to the massive use of presented SDI method. E.g. in the winter semester of 2020/21, over 90 sets of equipment with electronic components for homework, including Nucleo F32F303RE as SDI, were lent to students in three of different classes. In the summer semester of 2021 students in a single class received 60 sets of components (breadboard, Wi-Fi module ESP8266, magnetometer, OLED display, microcontroller STM32F042 with module FO-Lab, as in Fig. 4) to practice theoretical knowledge.

The pandemic brought many difficulties and complications to practical laboratory teaching. In solving these problems, it turned out that in some limited topics, focused mainly on courses in basic studies, it is possible to use other methods that can be used as a supplement to standard laboratory teaching, especially in students’ independent homework and in solving their projects.

4. Conclusions

The COVID-19 pandemic continues to spread, and universities around the globe have been forced to switch to online teaching in an effort to help to slow the spread of the disease.

The article showed new challenges related to distant teaching and presented the experience with distant lectures during the pandemic at the Department of Measurement, FEE, CTU in Prague. It describes the methods how to prepare the Lectures and Laboratory classes of practical electronic. Shows practical laboratory experiments using the Home Lab and two possible models with functional groups, a Laboratory Experimental Device and System of Measurement Instruments. The experience with teaching of a software-oriented online course with network programming is also presented. The effectiveness of distance teaching can be illustrated by signs of satisfaction on the part of students as well as by their results, which they achieve with regard to the COVID-19 emergency.

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