Advances in Engineering Education

FALL 2020 VOLUME 8 NUMBER 4

The Labs May Be Closed, but Experiments Must Go on: Innovations to Teaching Mechanical Measurements 1 During the COVID-19 Pandemic

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ABSTRACT

This article describes how the Sichuan University - Pittsburgh Institute has embraced new methods and new technologies to ensure high-quality laboratory teaching during the COVID-19 pandemic. Taking Mechanical Measurements 1 course as an example, this paper introduces two lab projects that were successfully transferred into online experiments through remote-control platform and virtual simulation software, as well as three lab projects which were transformed into "pocket labs" where cheap and easy-access equipment was mailed to enable students to conduct experiments at home. Meanwhile, video demos, online Q&A sessions, feedback collection were employed to deliver a realistic lab experience to students.

Key words: Experimental teaching, Online experiment, Pocket lab, COVID-19 pandemic

INTRODUCTION

In response to the Coronavirus Disease 2019 (COVID-19) pandemic, academic institutions around the world began migrating in-classroom lectures to online teaching as a way of implementing social distancing requirements (Zhou, et al. 2020). As a result, online educational platforms faced incredible new challenges for courses that they were not designed for, especially, laboratory sessions. Some challenges for offering lab-based courses include but are not limited to student attention management, barriers to communication, and inaccessibility to the lab equipment (Roytman and Shah 2020). With very little time to prepare, the Sichuan University - Pittsburgh Institute (SCUPI) explored possible solutions to ensure the continuity of experimental teaching.

The course, Mechanical Measurements 1, which is offered to junior students, is the first course in a sequence pertaining to engineering laboratory measurements. It aims at developing the students' understanding about lab safety, experiment procedures, data analysis techniques, and gaining hands-on experience with common laboratory tools like power supplies, oscilloscopes, circuit boards, data acquisition units, strain gauges, etc. This course consists of 15 lectures and 5 lab sessions.

SCUPI's online teaching platform, Blackboard and the web-based online conferencing system, BigBlueButton, allowed for the delivery of lecture sessions with relative ease (Huang et al. 2019). The lecture materials were stored on Blackboard and actual lectures were delivered through the BigBlueButton system. However, it was necessary to redesign lab sessions to guarantee teaching quality and achieve learning outcomes. To this end, the SCUPI lab teaching team successfully implemented two methods to teach the experiment portions of this course: first, we created "online experiments" where the real instruments were accessed remotely via specially designated software (Rohrig and Jochheim 1999); and second, we prepared "pocket labs" (Klinger T, Madritsch 2015) where lab equipment was mailed to the students. This required close coordination among members of the teaching team (see Figure 1 for team roles and responsibilities).

The teaching team			
	Instructor	Lab engineer	Teaching assistant
Job functions	Give lectures	Introduce lab safety	Provide online guidance
	Prepare lab handouts and pre-lab assignments	Develop lab projects	Produce tutorial videos
	Develop lab projects	Train teaching assistant	Grade reports
	Prepare exams	Purchase and mail equipment	

Figure 1. The members and job functions of the teaching team.

METHODS

Online Experiment

"Lab 1: Introduction to Instrumentation and Data Acquisition" and "Lab 2: Characteristics of Passive and Active Filters" are two laboratory experiments closely related to circuits. By introducing a remote-control platform (ELF-BOX3) and simulation software (Breadboard_Sim), the teaching team successfully transformed the above projects into "online experiments".

ELF-BOX3 is a remote-control platform that supports students to use real components and instruments deployed in other places via personal computers. With the help of this platform, students can build experimental circuits online, remotely control the oscilloscope and function generator, and observe the signal through the camera simultaneously, as shown in Figure 2 and Figure 3.

Breadboard_Sim is an open source virtual breadboard. Through this software, students can learn the characteristics of breadboards and use a virtual breadboard to wire and build electrical circuits, as shown in Figure 4.

Pocket Lab

For the other three experimental projects, the teaching team optimized the experiments' contents and evaluation methods, and mailed inexpensive and easy-access objects to enable students to carry out

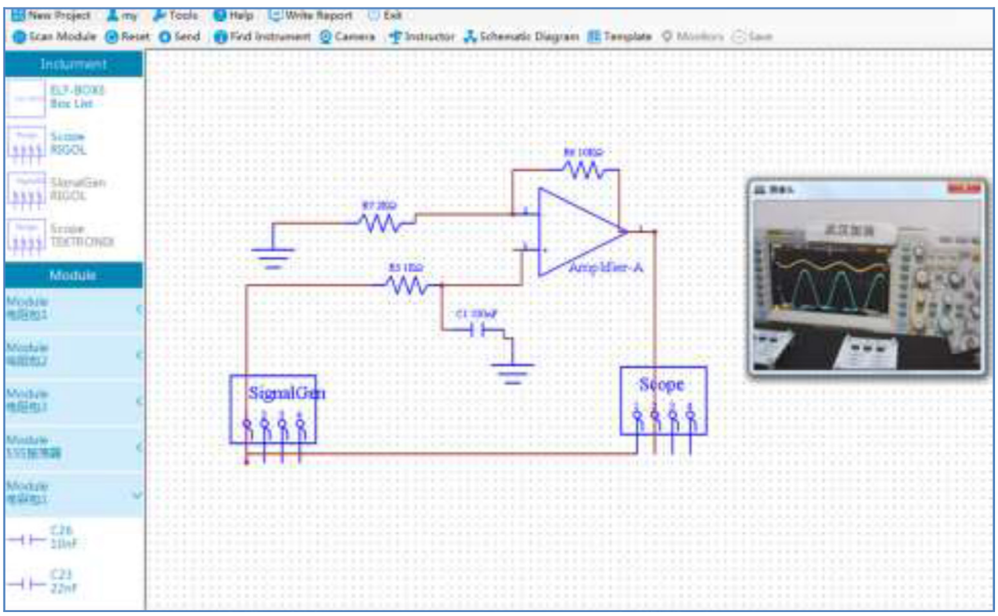

Figure 2. Circuit signal measurement on ELF-BOX3 platform.

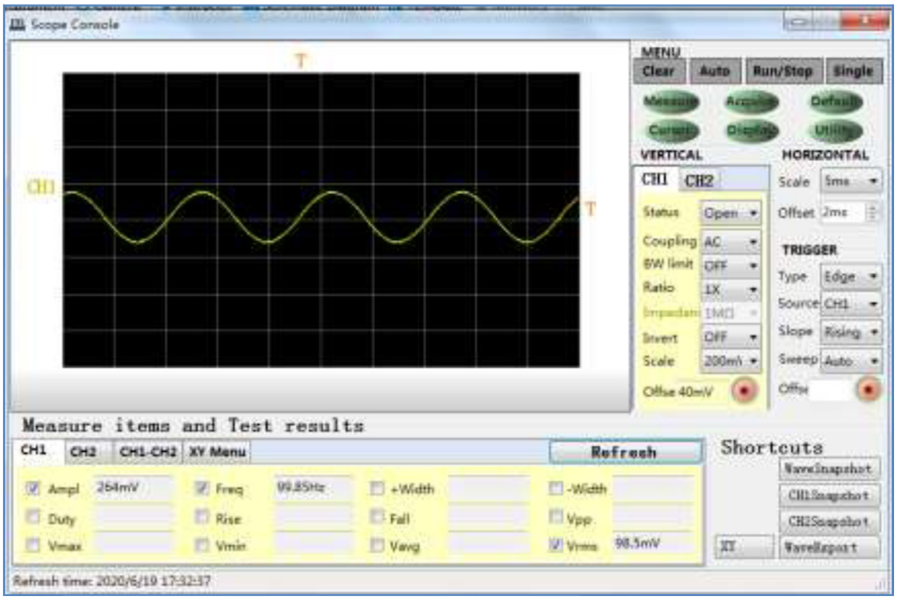

Figure 3. Interface of oscilloscope on ELF-BOX3 platform.

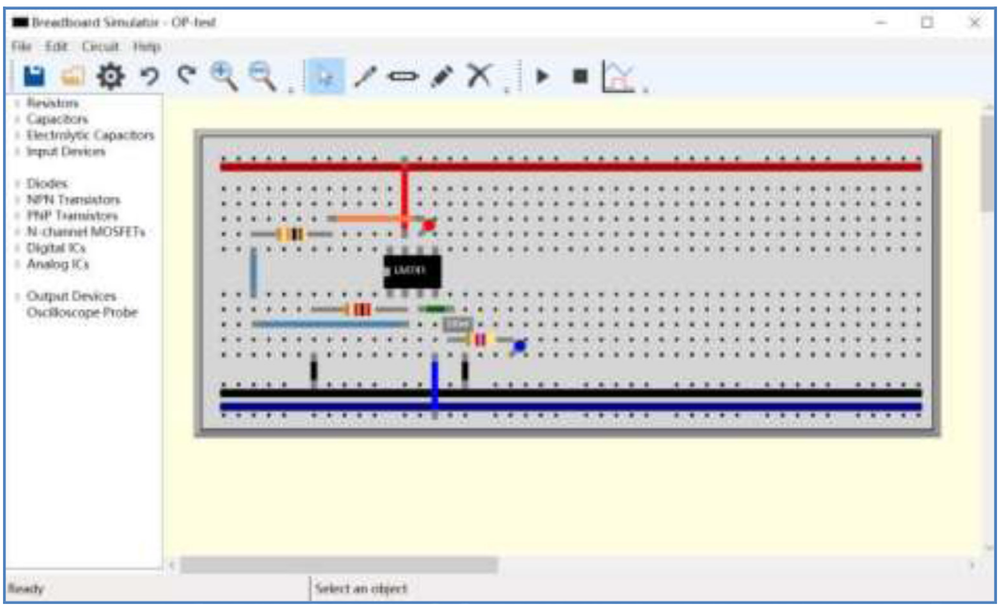

Figure 4. Active filter circuit on Breadboard_Sim.

	Lab 3	Lab 4	Lab 5
Equipment shipped to students	Electronic balance	Electronic balance	
	Thermocouple	Beam (Aluminum)	Beam (Aluminum)
	Wires	Wires	Wires
	Portable multimeter	Portable multimeter	MPU6050
		Strain gage	USB-TTL module
		Masses (500g)	
		Battery box	
		Clamp	Clamp
Equipment from students' homes	Induction cooker	9V battery	Poly-Doh
	Cup		Foam
	Alarm clock		
(shaded)	Shared in different lab projects		

Figure 5. Equipment used in pocket labs.

pocket labs at home. The equipment list is shown in Figure 5. To facilitate collaboration and teamwork, students in the same group were also required to conduct experiments during the same time period.

The goal of "Lab 3: Temperature Sensors and Statistical Analysis of Data" is to determine the operating characteristics of thermocouples and estimate the power required to boil water. In the original project, a thermocouple must be connected to a dedicated thermometer to measure temperature data. Based on the working principle of thermocouple, the teaching team proposed connecting a portable multimeter to the thermocouple. Meanwhile, students could make use of heating devices such as induction cookers and gas stoves to boil water at home.

The goal of "Lab 4: Determine the Strain in Cantilever Beams" is to measure the mechanical strain using a full strain bridge. In the original project, a strain indicator is needed to measure strain. In order to change it into a pocket lab, the teaching team decided to use a portable multimeter to connect with the full strain bridge. This way the strain value can be derived based on the relationship between the strain, ε, and the output voltage, ΔU.

$$\Delta U = GF * \varepsilon * U \tag{1}$$

For "Lab 5: Use of Accelerometers in the Measurement of Dynamic Mechanical Systems" a specific accelerometer, a data acquisition unit and an amplifier were essential to measure vibration signals in the original project. Fortunately, the teaching team found an inexpensive and easy-to-use MPU6050 accelerometer to replace the above devices so that students could conduct this experiment at home. Figure 6 displays the experimental setup in the original project and pocket lab, respectively.

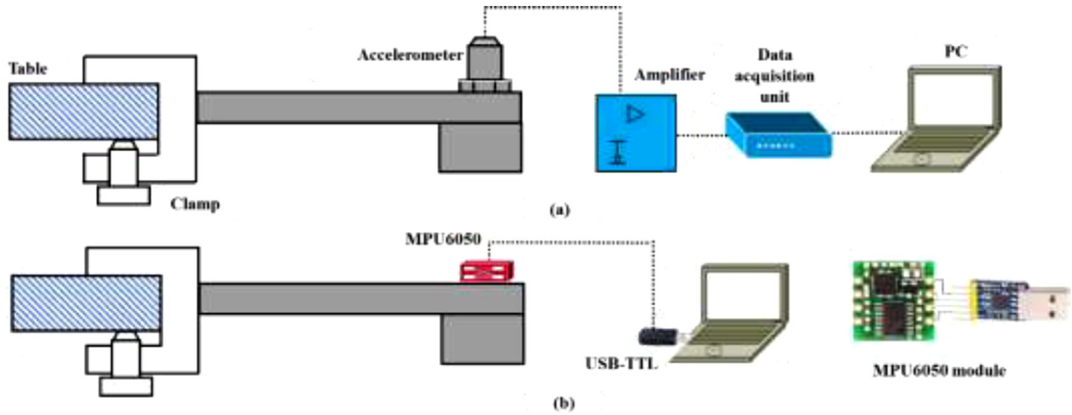

Figure 6. (a) Original experimental setup (b) Experimental setup of pocket lab.

To ensure each experiment's feasibility, the teaching team first tested each project. Meanwhile, video demos, real-time online guidance and feedback surveys were provided to continuously meet student needs and gauge their satisfaction with these remote learning methods. Figure 7 displays the tutorial video of Lab 3 and the videos for all lab sessions can be downloaded via https://drive.scupi.cn/s/mkxiG9LaMHxTXX8.

Figure 7. Lab demo video.

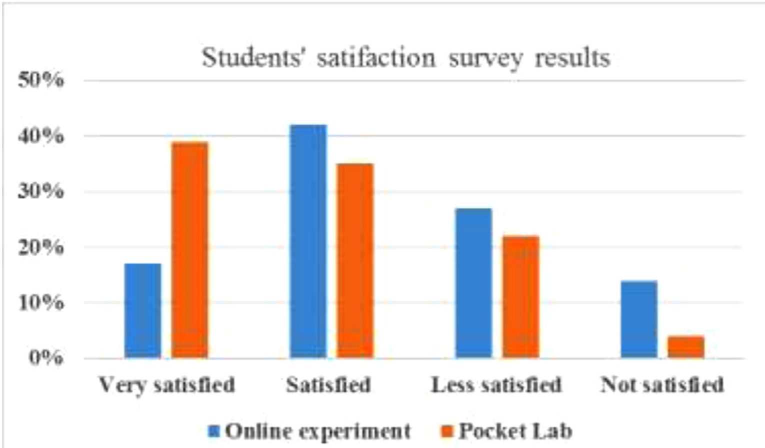

Figure 8. Students' satisfaction on lab sessions.

PRELIMINARY RESULTS

Figure 8 shows the students' satisfaction on the online experiment and pocket lab. It can be seen that most students are satisfied with our new teaching methods. However, compared with online experiments, students are more satisfied with pocket labs. This is because students have to attend the online experiments at set times and operate the equipment remotely while pocket labs are asynchronous and students can operate the equipment in person.

Figure 9 shows the students' performance on the lab sessions. The averages for all Lab sessions are above 80. Most of the students participated the lab sessions with good attitudes and were able to write detailed lab reports.

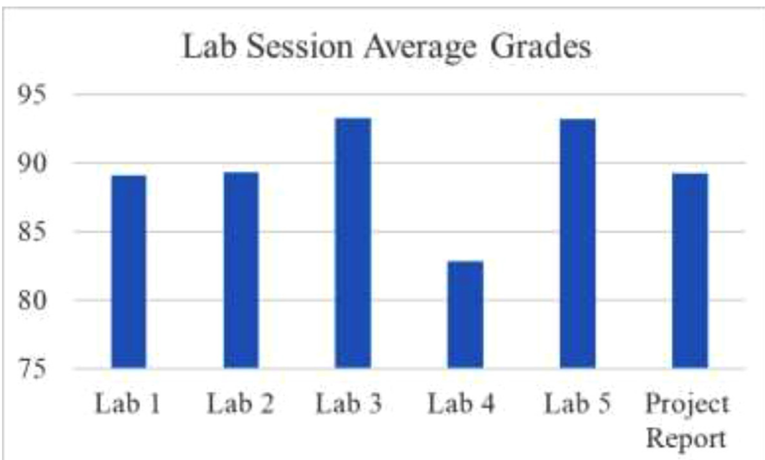

Figure 9. Students' performance in lab sessions.

NEXT STEPS

We had some success in letting students gain hands-on experience despite tough conditions. As the preparation schedule for the teaching team at the beginning of the term was relatively tight, we found that there were parts of our teaching plan that could have been improved. For example, when conducting online experiments, we learned that we should leave as much time as possible for students, since they may encounter some unexpected situations. Besides, teamwork and effective communication between team members are essential for a good user experience, which means in the future, the teaching team needs to work more closely in coordinating its tasks with students. In the future, there should be a community or a forum for the students to share their experiences to allow for instant and honest feedback.

ACKNOWLEDGEMENT

The authors would like to acknowledge the great support from the Yixingbiao [易星标] Company and the constructive suggestions and comments from the SCUPI Writing Center and the reviewers.

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