Work in Progress: Online Electrical Engineering Laboratories Sessions: Analysis, Challenges, and Border Environment

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Abstract

The global COVID-19 crisis has accelerated the adoption of online delivery methods supported by accessible technologies, applications, and academic learning platforms. There is a larger demand for remote courses by companies, universities, and grade schools. Distance education has become one of the learning options most used by universities, where interactive learning is available. Students can also review the content of the courses on a Learning Management System (LMS) and study in their own time, supplemented with face-to-face or remote tutoring sessions in case of specific doubts. Online education is focused on learning content more than the communication between students and tutors. At the University of Texas at El Paso, Texas, Department of Electrical and Computer Engineering, we have additional challenges due to the USA and Mexico border's geographic location because some of our students are living in Mexico, and we are supporting them virtually. The delivery of online laboratories was implemented using remote access to the equipment in the university's physical laboratories; moreover, students acquired portable equipment designed to work at home, creating an environment similar to a real laboratory but with some limitations. Students opted for one method or another depending on vendor availability or their resources.

This paper explores the differences, as well as the limitations, between the tools used for distance learning in the circuit's laboratories. As a case of study, there is a comparison between face-to-face and remote laboratory sessions and personal laboratory at home scenarios. Also, the paper describes the students' benefits and challenges and the response of students due to geographic limitations.

Keywords: Online Education, Digital platforms, laboratory online.

Introduction

Since World Health Organization declared the pandemic for COVID-19, educational institutions were forced to shut down all across the world. Traditional education, focused on face-to-face lectures in the classroom or laboratories, was changed to online education using digital platforms, virtual tutoring, video-conference tools, learning software, and student resources for the courses [1],[2],[3].

Several advantages are related to virtual education, such as accessibility and flexibility, student attendance, affordability, and various learning styles. Accessibility and flexibility are associated with the student's opportunity to attend the classes from anywhere, anytime. Also, each course session can be recorded for later reference allowing access to students at convenient times. Given that online courses can be taken from any location, students avoid missing classes; thus, attendance is improved [4]. The increased affordability is related to reducing students' external financial costs such as transportation, food, rent, apartment, and printed materials during these restricted times. A variety of learning styles is correlated to the type of learning process for each student. Some students are audio learners, while others are visual learners or need the instructor or peer interaction to understand the concepts. Online education allows several options personalizing the learning process for each student. Fig.1 shows the advantages of online education [5],[6]. The most common disadvantages of the online learning system are technical issues, such as internet connectivity, computer or peripheral component failures, and the difficulty of getting the components or specific devices for the courses or laboratories.

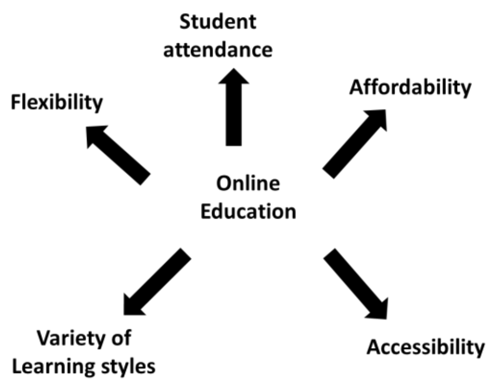


Figure 1. Virtual Education Advantages

Based on these circumstances, the University of Texas at El Paso, Texas, in the USA border with México, decided to migrate the large majority of courses to online mode, including the laboratory sessions and suspended on-site attendance due to government restrictions since the beginning of the crisis. The Department of Electrical and Computer Engineering faced additional hurdles because most laboratories require specialized instruments to provide electrical signals and take the measurements. This paper is focused on the analysis of the circuit's lab in an online environment.

Case of study: Circuits laboratories for the Department of Electrical and Computer Engineering

The unexpected outbreak of Covid forced the University of Texas at El Paso to migrate all its courses in an online format, using synchronous (live online) and asynchronous modes. The model used for the circuit's laboratory (from the Department of Electrical and Computer Engineering) is live online.

The Circuits Lab learning outcomes are described below.

1- Learn how to use the oscilloscope, function generator, power supply, and multimeter.
2- Improve the technical writing and computer-aided circuit analysis and design.
3- Study electrical networks such as pure resistive networks, RC (resistor and capacitor combination), RL (resistor and inductor combination), RLC (Resistor, inductor, and capacitor combination), Operational amplifier networks and their behavior.
4- Create a troubleshooting procedure to improve the circuit implementation time.

One of the most critical challenges in this laboratory is getting the specialized portable instruments as they are needed to take measurements from the projects and provide electrical signals to the circuits. Students had to purchase or borrow a personal instrument for use at home, some had acquired it for a previous introductory course, but others had to obtain it during the first weeks. Some available devices used for Circuits Lab were Analog Discovery from Digilent or ADALM2000/1000 from Analog Devices. These devices include an oscilloscope, variable power supply, multimeter, and function generator for lab execution.

Table 1. Portable Equipment required for Circuits Lab - Options

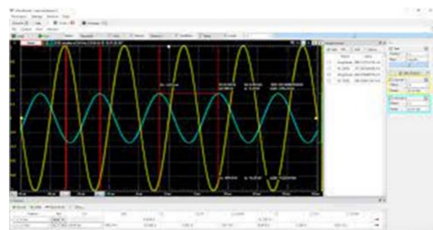
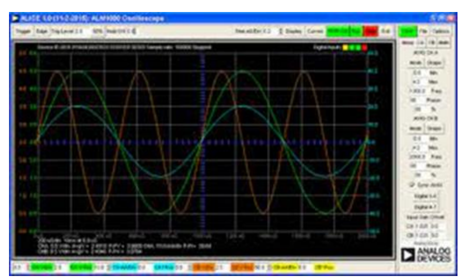
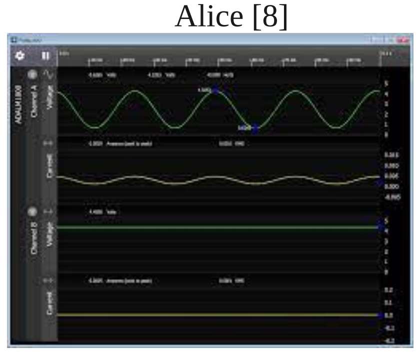
Equipment	Software	Manufacturer
 Analog Discovery [7]	 Waveforms [7]	Digilent
 Adalm2000 [8]	 Scopy [8]	Analog Devices
 Adalm1000 [8]	 Alice [8]  Pixelpulse [8]	

Table 1 shows the portable equipment options for Circuit's Lab. Notice that for labs 1 and 2 a standalone multimeter was used by some students, while the portable device arrived at their home. Sometimes students did not get the equipment on time because it was out of stock, long lead time, or insufficient resources to buy it, generating stress and some decided to drop from the course.

The Circuits Laboratory course was delivered on the Blackboard Ultra platform® to provide the content of the course and grades on time; students could also attend the live laboratory session and schedule office hours in case of doubts. Students worked individually from home.

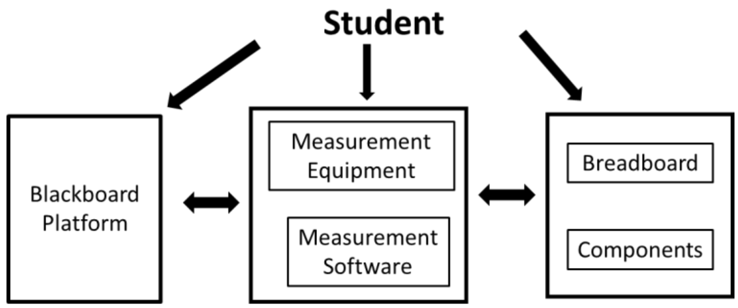
Two methods were implemented to conduct the laboratory course to avoid students falling behind or missing sessions in the Circuits Laboratory. The first option consisted of the students who acquired the portable measurement instrument; they had to build the circuit on the breadboard, following the assigned handout, take the measurements and compare the results with the calculations and simulation created on Multisim. The second option targeted the students who cannot get the measurement equipment and/or components on time. For them, NI ELVIS II+ equipment is used to build the circuits indicated in the instructions. Fig. 2 shows the NI ELVIS II+. The instructor assembles the circuits on the NI ELVIS II+ breadboard and students can access one of the NI ELVIS II+ stations (located in the Physical Laboratory at the University of Texas at El Paso) through the Virtual Private Network (VPN) provided by the University, and take the measurements required via NI ELVIS II+ virtual instruments. Then, the students can compare the calculations, simulation values, and measures to complete the laboratory practice. Fig. 3 illustrates these methods. Although the two methods proposed to help the students to complete the course requirements are working, there are some differences in the learning level.

Virtual Instruments (Labview ®) NI ELVIS II+

Figure 2. NI ELVIS II+ Equipment and Launch Software [9]

In Summer 2020, twenty-four (24) students were enrolled in the Circuits lab; two of them could not get the equipment on time (Leadtime 8 weeks) and used the NI ELVIS II+ option for all the laboratory practices. Two more students got multimeters for labs 1 and 2 and bought or borrowed the measurement equipment for the rest of the course.

In Fall 2020, Forty-nine (49) students were registered, five students used the NI ELVIS II+ option, and six used multimeters for lab 1 and 2. For laboratory practices, 3 to 10, ten students got the personal instrumentation or measurement equipment, and one student could not get the equipment or the components, then the student dropped the course. Table 2 shows the Circuits Lab enrollment statistics for Summer and Fall 2020.



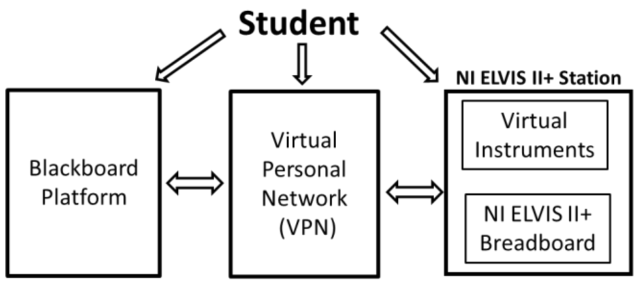


Figure 3. Methods used in Circuits Laboratory at the University of Texas at El Paso.

Some of the observations made according to the method used by the students are described below.

Table 2. Summarize of students working on laboratory methods

Term	Students enrolled at the beginning of the semester	Students did not acquire the measurement Equipment	Students using ELVIS option for the entire course	Students using ELVIS Option for Labs 1 and 2 only	Students using Multimeter for Labs 1 and 2	Total students using portable or remote Measurement Equipment option
Summer 2020	24	2	2	-	2	22
Fall 2020	49	1	-	5	6	48

Method 1: Students used the personal Measurement equipment option from the beginning of the semester

Students learned how to use electronic components (resistors, inductors, capacitors) and devices such as power supplies, breadboard, and waveform generators. Consequently, students developed the wiring ability, making their lab work easier and more efficient, and the demonstration part took a maximum of two hours.

Most of the difficulties experienced for laboratories 1, 2, and 3 were observed in circuit connections on the breadboard. As a result, a troubleshooting skill was developed by each student, decreasing the implementation time by 30% (average) and solving the problems without the instructor interaction, improving the self-learning.

The group was divided into small groups generating collaborative learning, discussing the laboratory experience, and sharing their troubleshooting methods, increasing their knowledge in circuit topics, and improving the quality of the questions for the instructor [10].

Notice that the students who used the multimeter for practices 1 and 2 instead of Analog Discovery or Adalm2000 or Adalm1000 had a similar learning experience.

Method 2: ELVIS equipment for remote access

The students learned how to use the university's VPN system to access the laboratories and NI ELVIS II+ equipment and gain experience on the virtual instruments. However, they experienced many difficulties constructing the circuits for the demonstration tasks and wiring the acquisition measurement equipment. The cause of these problems is that students did not understand how the breadboard worked, and wired the components and measurement equipment according to the handouts, consuming the entire lab session time building one circuit. Fig. 4 shows the comparison between average time per session, average time used for students working on method 2 and the maximum time used per session for method 2.

Another observation was the students' questions asked to the instructor were limited to fundamental questions about how to wire the circuits or how to use the measuring equipment, but there were no questions about the topic discussed in the lab.

Observations made due to home location in Mexico, instead of the University of Texas at El Paso, Texas):

The electronic components were easily obtained by the students in the local electrical stores; however, the measurement equipment was difficult to buy (for some students) because the lead time was longer than in the USA and paid extra cost for shipping to México. Then, these students were supported via NI ELVIS II+ stations; while they got the measurement device (borrowed or bought in the USA).

Before the pandemic outbreak, students worked at the lab for three (3) hours to complete the handouts. Some of them required extra help to finalize the lab works, while others finished before the lab session end and worked on the lab report. Statistics are not available for classroom-based sessions.

Discussion

Due to the pandemic's problem worldwide, schools and universities had to change the teaching mode to fully online abruptly. The University of Texas at El Paso implemented all its theoretical courses and laboratories in this mode.

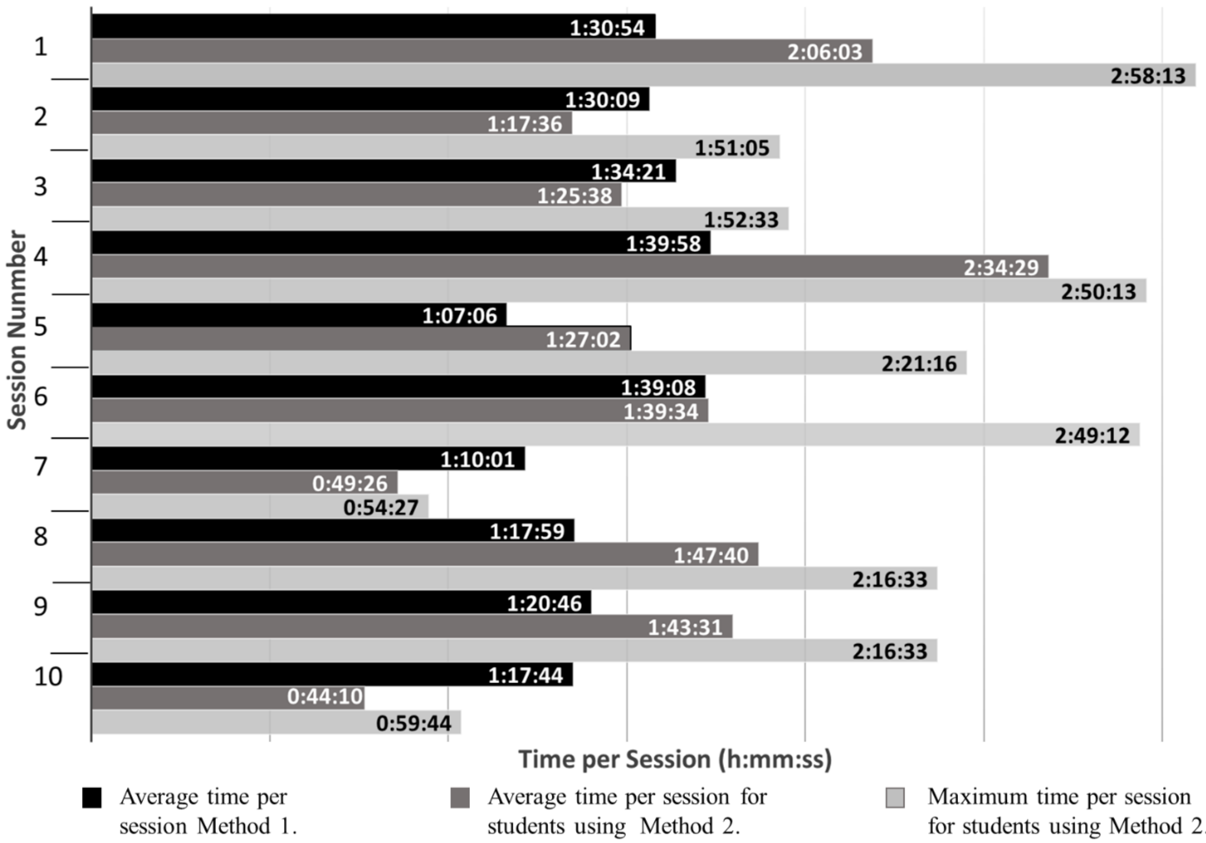


Figure 4. Comparison between Method 1 and 2. Average time per session for Methods 1 and 2 and maximum time for Method 2.

In the Department of Electrical and Computer Engineering at University of Texas at El Paso, all theoretical courses and laboratories changed to a virtual method. For the Circuits laboratory, the teaching team created two teaching methods: Method 1-Using measurement equipment (Analog Discovery or ADALM2000) and Method 2 – Using the NI ELVIS II+ provided by the University of Texas at El Paso.

Although the two teaching methods worked to accomplish the course requirements, different learning levels were observed. The students who used the measurement equipment at home, quickly learned to connect the circuits proposed in each practice's handout, solved the problems that arose due to the equipment or components' bad connections, and autonomously completed the lab exercises.

Using the NI ELVIS II+ equipment method, the students developed autonomy when performing the labs; however, the learning level was not as high as method 1. The knowledge of the wiring circuits, equipment, and troubleshooting process was missed. Consequently, students became stressed, spent more time completing the lab practices, and always required the instructor's help.

According to Table 2, the total number of students enrolled in the Circuits Lab was 72 at the end of Summer 2020 and Fall 2020. Then, 88.8% of them approved the course accomplished the learning objectives, and 11.18% failed the course. Table 3 shows the final grades distribution for both methods. Notice that any of the students who worked with method 2 failed the course. For comparison the statistics of face-to-face sessions between Fall 2017 to Fall 2019 reported a 91% passing rate.

Table 3. Distribution of final grades

Final grade	Percentage of students according to the final grade. (Total students enrolled = 72)	Percentage of students according to the final grade for Method 1. (Total students = 65)	Percentage of students according to the final grade for Method 2 (Total students = 7)
A	56.9%	52.77%	4.16%
B	22.2%	19.44%	2.77%
C	9.72%	8.33%	1.38%
F	11.18%	9.8%	1.38%

Comparing the methods created for virtual sessions to face-to-face sessions held at the university´s laboratories before the pandemic where the group was divided into small working groups to generate collaborative learning, just one or two students per group participated actively in the lab exercise implementation. This generated a non-homogeneous learning level; in other words, some students learned everything about the troubleshooting process, wiring components, and so on [11]. The others waited for the final practice result and collected the data for the lab report. In this session method, the instructor interaction was required all the time to solve the circuit problems.

Conclusions

To summarize, the individual work implemented during the pandemic stage helped increase the level of self-learning, in a homogenous way, by most students and encouraged the department to conduct more research on different teaching methods. The students also benefited from more structured collaborative and participatory work, with the instructor becoming a moderator.

According to the online session experience, some suggestions can be implemented later in the face-to-face sessions.

1. Allow collaborative work between students, encouraging individual work in each laboratory practice, both in implementing and preparing reports, simulation and mathematical calculations.

2. Alternate tasks and handling of laboratory equipment between students using physical (Oscilloscope, Multimeter, Function Generator) and virtual measurement equipment (e.g., NI ELVIS). Ensuring everyone works with the systems, specially wiring the components. A better option is that each student wires their own circuit and just share the instruments.

3. Include educational platforms (Blackboard, Moodle) as an essential part of the course to provide all the tools, content, and grades to deliver the course support. This provides a consistent structured set of materials and instructions. An additional benefit is that students that might not get enough experience during the regular lab session, will have access to asynchronous online materials.

4. Ensure that the University is able to provide assistance to students to acquire the instrumentation and reduce logistic problems with components.

References

[1] S. Dhawan, "Online Learning: A Panacea in the Time of COVID-19 Crisis," *Journal of Educational Technology Systems*, vol. 49, no. 1, pp. 5-22, June 2020.

[2] L. Mishra, T. Gupta, and A. Shree, "Online teaching-learning in higher education during lockdown period of COVID-19 pandemic," *International Journal of Educational Research Open*, vol 1, 2020. [Online]. Available: Science Direct, https://www.sciencedirect.com/science/article/pii/S2666374020300121. [Accessed February 24, 2021].

[3] V. Singh and A. Thurman, "How many ways can we define online learning? A systematic literature review of definitions of online learning (1988-2018),". *American Journal of Distance Education*, vol. 33, no. 4, pp. 289–306, October 2019.

[4] M. Kebritchi, A. Lipschuetz, and L. Santiague "Issues and challenges for teaching successful online courses in higher education," *Journal of Educational Technology Systems*, vol. 46, no.1, pp. 4–29, 2017.

[5] M. Castro and G. Tumibay, "A literature review: efficacy of online learning courses for higher education institution using meta-analysis," *Education Information Technology*, pp. 1-19, November 2019.

[6] P. Alves, L. Miranda, and C. Morais, "The Influence of Virtual Learning Environments in Students' Performance," *Universal Journal of Educational Research*, vol. 5, no. 3, pp. 517-527, March 2017.

[7] Digilent, 2021. [Online]. Available: https://store.digilentinc.com [Accessed: April 9, 2021].

[8] Analog Devices, 2021. [Online]. Available: https://www.analog.com [Accessed: April 9, 2021].

[9] National Instruments, 2021. [Online]. Available: https://www.ni.com [Accessed: April 9, 2021].

[10] C. Williams and S. Eberechukwu, "Collaborative Learning in a Virtual Classroom: Its Status in the Current Digital Era," *European Journal of Research and Reflection in Educational Sciences*, vol. 3, no. 5, pp. 45-51, 2015.

[11] R. Chandra, "Collaborative Learning for Educational Achievement. International Journal of Research & Method in Education," *IOSR Journal of Research & Method in Education (IOSR- JRME)*, vol 5, no. 2, pp. 4-7, March 2015.