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A Comparative Study of An Online Lab Using Labsland and Zoom during COVID-19

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ABSTRACT

COVID-19 made a sudden transition from physical labs to online labs and changed the landscape of lab learning. In this work, we used the VISIR circuits module of remote laboratory platform LabsLand®, together with the video conferencing platform Zoom, to simulate the real electrical circuits lab environment for a class of 38 students in the 2020 spring semester. In this paper, we studied the students' perception and academic performance in the online lab settings in comparison with previous physical labs.

Key words: Remote Laboratory, Synchronous Team-Based Learning, COVID-19

INTRODUCTION

COVID-19 was an unprecedented event to trigger rapid implementations of online learning. This shift made inevitable the sudden transition from physical labs to online labs, which posed challenges for both instructors and students. Several studies have explored the feasibility, benefits, and challenges of online labs (Ma and Nickerson 2006; Brinson 2015). For example, a review of empirical research showed that student skill and content knowledge development could be equal or even higher in online labs in comparison to hands-on labs (Brinson 2015). Another study showed the importance of effective student guidance measures in the context of computer-supported inquiry learning with online labs, based on the inquiry phases orientation, conceptualization, investigation, conclusion, and discussion (Zacharia and Constantinou 2008). Additional studies on online lab usage in engineering courses show promising results (e.g., Curry, Craig, and Zhu 2016; Dixit et al. 2017; Santiago Jr et al. 2017).

In this work, we used the VISIR circuits module (Hernández and Zubía 2017) of remote laboratory platform LabsLand® (LabsLand 2020), in conjunction with the video conferencing platform Zoom, to simulate a real electrical circuits lab environment for the 2020 spring semester. We investigated how students, who have experience using the real lab equipment, perceived the online lab in comparison with the physical counterparts.

METHODS

Implementation

The overall implementation is shown in Figure 1. The instruction of a class of 38 students was initially carried out in the actual physical lab. Following the announcement of the COVID-19 transition to online learning, a pre-test survey was used to capture student perceptions of the physical lab that was given to students. The online lab using Zoom and VISIR was treated as an intervention. At the end of the intervention, a post-test survey about the online lab experience was given to the students. After all the data were collected, data analysis was carried out to determine how students perceived the online lab vs. the physical lab. The Appendix exhibits the questions in each survey. This paper focuses on selected findings that have salient implications for engineering education practice.

Physical Lab

When the semester began, students voluntarily formed lab groups of two or three members. Each week, groups completed lab activities, including calculation, simulation, and circuit assembly. Circuit assembly was conducted in an instructional lab equipped with breadboards, electronic components, and measurement tools (multimeters, oscilloscopes).

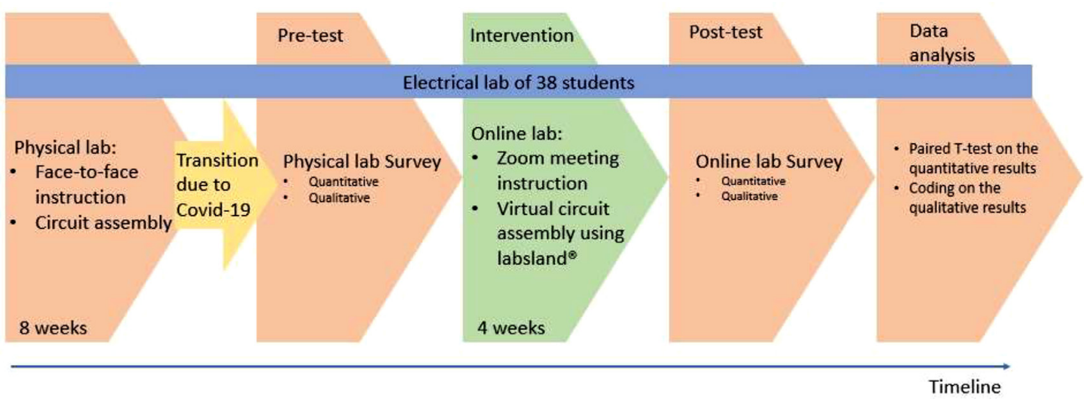


Figure 1. Flow of implementation and research methods.

(a) Systematic setup of the Zoom meeting **(b) VISIR interface**

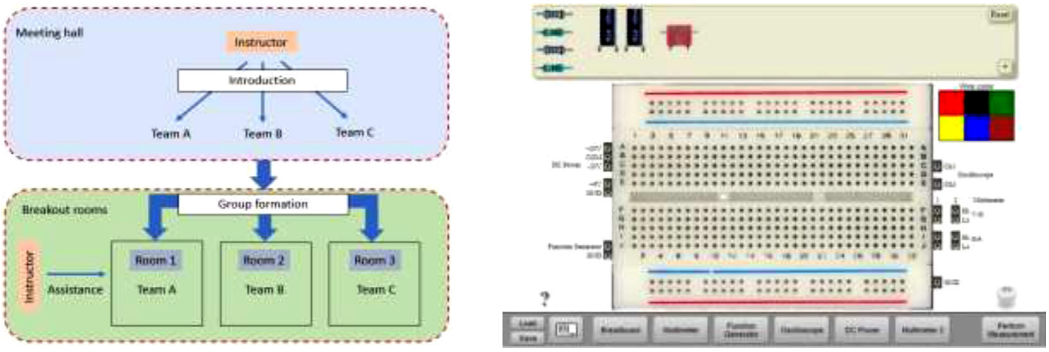


Figure 2 .(a) Shows how the Zoom meeting was set up to run the collaborative task, (b) shows the VISIR interface, which simulates and connects to real electronic lab equipment.

Online Lab

In order to allow lab teams to collaborate from a distance, a Zoom meeting was used as an interactive and communication platform (Figure 2(a)). Each week, a brief introduction to the lab was given to the students. Then, student teams were each assigned to their own breakout rooms where they could complete lab activities together and request help from the instructor as needed.

Lab activities were divided into three tasks: calculation, simulation, and virtual circuit assembly. Virtual circuit assembly was conducted via the VISIR module in Labsland (Figure 2(b)). VISIR provided an online interface to allow students to build circuits that were automatically assembled and could be measured in a remote laboratory located at the University of Deusto in Spain.

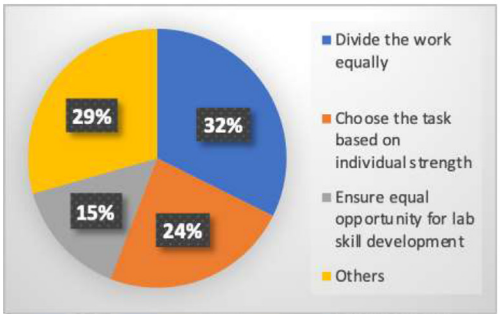
PRELIMINARY RESULTS

Overall, the online lab provided a safe and time-efficient environment for students to work together under the supervision of the instructor. However, students noted key differences between the physical and online labs that can inform instructional practice.

Qualitative Results

One difference between the physical and online labs was how students reported collaborating. As Figure 3 shows, students in the physical lab most often divided lab work evenly, while students in the online lab overwhelmingly divided labor based on teammates' strengths in each

(a) The results of the physical lab



(b) The results of the online lab

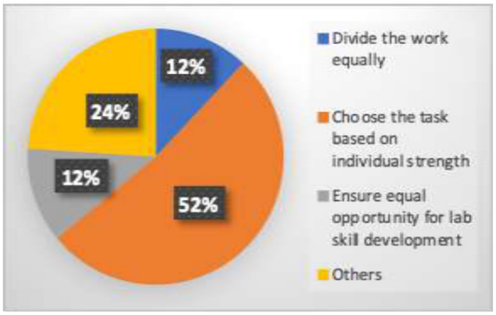


Figure 3. Student responses to the question, "how does your level of knowledge regarding lab skills affect how you and your partner divide labor during labs?"

Table 1. Top five benefits and challenges of the online labs.

Benefits	Challenges
High accessibility, multiple access	The online lab is less intuitive than the physical lab
Can work on the labs at a personal pace in an own remote environment.	The software could be more user-friendly/high learning curve.
No lab cleaning issues	More difficult to ask for help
Easier to run the simulation	More difficult to diagnose and resolve errors in the circuit
Encourage self-learning	Communication with lab partner is less smooth

lab task. Results suggest that collaborating online encouraged more intentional, role-oriented teamwork approaches, which has been shown to be a hallmark of successful workplace teams (Belbin 1981).

Students were also asked about the benefits and challenges of online labs. Table 1 shows the top five responses of each. The data suggest that online labs were beneficial in terms of the ability to access the lab, ease of execution, and pacing. However, students also emphasized that, compared to physical labs, the software was not as intuitive, had a high learning curve, and that communication with partners and the instructor was less smooth.

Quantitative Results

A paired T-test was used to compare the numerical responses from both surveys**.** Table 2 summarizes the results. All items used a Likert scale from 1 (strongly disagree) to 5 (strongly agree). On average, students rated both labs positively on all items, but most students found the physical labs preferable in terms of accessibility, practical experience, and ability to iterate. Importantly, students

Table 2. Comparison of responses from physical and online lab surveys using paired t-tests. The level of significance is 0.1 to accommodate the relatively small sample size.

Survey item	P-Value	Mean of the numerical response of the physical lab (1–5)	Mean of the numerical response of the online lab (1–5)	The number of paired responses (sample size)
Significant difference ($p < 0.1$)				
• Accessibility of team activities	0.06	4.58	4.12	26
• Lab accessibility	0.08	4.50	4.04	27
• Practical experience	0.08	4.35	3.85	27
• Quick solution iteration	0.004	4.00	3.54	27
Insignificant difference ($p > 0.1$)				
• Availability of the instructor	0.75	4.47	4.54	26
• Safety	1	4.58	4.58	27
• Complete labs efficiently	0.17	4.38	4.04	27
• Ability to work together	0.18	4.46	4.08	27

reported the online lab was comparable with the physical lab in terms of instructor availability and student collaboration, both of which are crucial to the teaching and learning process.

Lab Score Results

In addition to the student surveys, the lab scores were recorded, and the comparison was made between physical lab and online lab groups. For example, there is no significant difference between the scores of one specific lab topic—Wheatstone bridges at the significant level of 0.05. This finding was generally true for other topics covered during the online labs.

CONCLUSIONS AND NEXT STEPS

The results suggest online labs successfully cultivated teaching and learning conditions reminiscent of a physical lab environment in an online setting. To address the challenges of online labs, several measures could be taken:

1. Even realistic online lab interfaces may be unintuitive for students. Learn the interface's quirks and be prepared to spend a significant amount of time helping students overcome learning curves.
2. Online labs require more formal, intentional means of student collaboration than physical labs. Consider prefacing labs with a discussion of what effective real-world teamwork looks like, and how role-taking can help students build teamwork skills (Belbin 1981).

3. As in physical labs, students need access to the instructional team for questions about the lab activities and interface. Structure labs to maximize students' ability to receive help from the instructor or assistant(s).

Following these guidelines with appropriate online lab software can provide an environment for collaborative engineering lab work that students can experience regardless of their physical location or access to lab hardware.

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APPENDIX: DATA COLLECTION SURVEYS

Online lab survey

Quantitative questions

Q1

With regard to the **online** labs, what extent would you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
1. I found lab activities to be accessible.					
2. Lab activities helped me gain practical experience.					
3. The instructor was accessible during labs.					
4. I was able to quickly iterate on problem solutions.					
5. I was able to fail safely without damaging lab equipment or myself.					
6. My partner and I were able to effectively work through problems as a team.					
7. I was able to complete lab tasks in a timely manner.					
8. Accessibility of the lab space was sufficient for me to complete lab tasks.					
9. The virtual lab software was user-friendly.					

Q2

On a scale of 1 (Novice) to 10 (Expert), how knowledgeable would you consider **yourself now** regarding the following online lab skills?

	1 (Novice)	2	3	4	5	6	7	8	9	10 (Expert)
1. Circuit assembly (e.g., using the virtual breadboard in Labsland)										
2. Circuit measurement (e.g., using a virtual multimeter in Labsland)										
3. Circuit calculation (e.g., voltage or current)										
4. Circuit simulation (i.e., using Multisim)										

Q3

On a scale of 1 (Novice) to 10 (Expert), how knowledgeable would you consider **your lab partner now** regarding the following online lab skills?

	1 (Novice)	2	3	4	5	6	7	8	9	10 (Expert)
1. Circuit assembly (e.g., using the virtual breadboard in Labsland)										
2. Circuit measurement (e.g., using a virtual multimeter in Labsland)										
3. Circuit calculation (e.g., voltage or current)										
4. Circuit simulation (i.e., using Multisim)										

Q4

What amount of effort do you believe you contributed to the online lab activities (e.g., designing and measuring circuits, performing calculations, soldering, writing lab reports, etc.) compared to your partner? For example, 100 indicates you do all the work, 50 indicates an even division of labor, and 0 indicates that your partner does all the work.

	0	10	20	30	40	50	60	70	80	90	100
My contribution											

Qualitative questions

Q5: How does your level of knowledge regarding lab skills affect how you and your partner divide labor during online labs?

Q6: If you or your lab partner contributed a higher percentage to online lab activities than the other person, why do you think that is?

Q7: What do you see as the main benefits of working as part of a pair during online labs?

Q8: What do you see as the main challenges of working as part of a pair during online labs?

Q9: What do you see as the main benefits of online labs (as opposed to in-person labs)?

Q10: What do you see as the main challenges of online labs (as opposed to in-person labs)?

Physical lab survey

Quantitative questions

Q1

With regard to the **Physical** labs, what extent would you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
1. I found lab activities to be accessible.					
2. Lab activities helped me gain practical experience.					
3. The instructor was accessible during labs.					
4. I was able to quickly iterate on problem solutions.					
5. I was able to fail safely without damaging lab equipment or myself.					
6. My partner and I were able to effectively work through problems as a team.					
7. I was able to complete lab tasks in a timely manner.					
8. Accessibility of the lab space was sufficient for me to complete lab tasks.					

Q2

On a scale of 1 (Novice) to 10 (Expert), how knowledgeable would you consider **yourself now** regarding the following lab skills?

	1 (Novice)	2	3	4	5	6	7	8	9	10 (Expert)
1. Circuit assembly (e.g., using the breadboard, soldering, interpreting circuit diagrams)										
2. Circuit measurement (e.g., using a multimeter)										
3. Circuit calculation (e.g., voltage or current)										
4. Circuit simulation (i.e., using Multisim)										

Q3

On a scale of 1 (Novice) to 10 (Expert), how knowledgeable would you consider **your lab partner now** regarding the following lab skills?

	1 (Novice)	2	3	4	5	6	7	8	9	10 (Expert)
1. Circuit assembly (e.g., using the breadboard, soldering, interpreting circuit diagrams)	○	○	○	○	○	○	○	○	○	○
2. Circuit measurement (e.g., using a multimeter)	○	○	○	○	○	○	○	○	○	○
3. Circuit calculation (e.g., voltage or current)	○	○	○	○	○	○	○	○	○	○
4. Circuit simulation (i.e., using Multisim)	○	○	○	○	○	○	○	○	○	○

Q4

What amount of effort do you believe you contributed to the lab activities (e.g., designing and measuring circuits, performing calculations, soldering, writing lab reports, etc.) compared to your partner? For example, 100 indicates you do all the work, 50 indicates an even division of labor, and 0 indicates that your partner does all the work.

	0	10	20	30	40	50	60	70	80	90	100
My contribution											

Qualitative questions

Q5: Reflecting on your responses to the questions above, how does your level of knowledge regarding lab skills affect how you and your partner divide labor during labs?

Q6: If you or your lab partner contributed a higher percentage to lab activities than the other person, why do you think that is?

Q7: What do you see as the main benefits of working as part of a pair during labs?

Q8: What do you see as the main challenges of working as part of a pair during labs?