An Investigation into Peer-Assisted Learning in an Online Lab Environment

Rui Li[1], John Morelock[2], and Dominik May[3*]

[1]**Tandon School of Engineering, New York University, Brooklyn, United States**
[2]**Engineering Education Transformations Institute, University of Georgia, Athens, Georgia, United States**
[3]**School of Mechanical Engineering and Safety Engineering University of Wuppertal, Wuppertal, Germany**

ORIGINAL

Abstract

Peer learning is one method to encourage meaningful learning in electrical engineering courses. It involves the sharing of ideas, knowledge, and experiences and emphasizes interpersonal learning. However, there are different viewpoints in relation to the best way to implement and assess peer learning in a lab environment, and contemporary literature on online laboratories (OL) rarely explores peer learning opportunities. In this paper, we aim to investigate the benefits of students' peer learning activity in an online electronics lab course. The key challenge was whether the OL could ensure smooth communication and collaboration between the students. In our case, we applied Zoom online conferencing software as a communication tool and LabsLand as an interactive OL tool. Specifically, we used a remote lab application for electrical circuit building, which makes physically existing lab infrastructure remotely usable through an online user interface. Methods we used to assess our learning outcomes included online surveys, online lab usage, and lab report scores. The survey results showed there are positive opinions about component skill development from group lab activities. In an online lab, the tasks were divided based on team members' strengths. In terms of peer learning, some students felt there was an improvement in partners' skills in terms of the circuit assembly. The OL usage showed a high level of engagement in group activity. Students willingly spent more time on lab experiments beyond regular lab hours. The scores of lab reports showed this new way of peer learning could achieve learning outcomes comparable to conventional, physical labs using peer learning. Accordingly, we concluded that the OL was an alternative and effective way to encourage peer learning.

Keywords: Electronics, LabsLand, Learning Analytics, Online Laboratory, Peer Learning

1 Introduction

Peer learning is a type of collaborative learning that involves students working in small groups to discuss concepts or find solutions to problems (Innovation CfT, 2020). Peer learning has been demonstrated to be a promising method to improve students' academic performance in STEM courses (Topping, 2005). For example, Beer and Jones (2008) and Pålsson et al. (2017) found that peer learning improves nursing students' self-efficacy to a greater degree compared to conventional supervised learning. More generally, Beer and Jones (2008) list major benefits of being part of an effective peer learning network such as additional assistance with challenges, especially from peers; more perspectives on solving problems; better access to expertise; more meaningful participation in the group work; and feeling a stronger sense of identity within the study discipline and overall university life. While most of the peer learning activities have been conducted in the face-to-face format, a major shift to distance learning has been happening during the COVID-19 pandemic.

However, even without considering COVID-19, recent technological advancement has dramatically changed the landscape of higher education, particularly with respect to online learning. An increasing number of universities offer online courses, enrollments in online courses are steadily on the rise, and 2012 was regarded as the "Year of the MOOC" (massive open online course) (Pappano, 2012). As a result, the rapid development of online teaching formats has raised many research interests in the area of digital instructional design (Hone and El Said, 2016; Guo et al., 2014; Breslow et al., 2013; Christensen et al., 2013). One challenge of online learning is helping the online student to establish a social presence (Madhavan and Lindsay, 2014). Alkhaldi et al. (2016) pointed out that research was lacking regarding how to effectively incorporate meaningful collaboration between students in online environments, which was one way to improve social presence. Alkhaldi et al. (2016) suggested educators should take advantage of technological advances to implement innovative online labs, and student collaboration in online labs was deemed to be one of the areas that is interesting to investigate further.

2 Literature Review

Researchers have pointed out that online learning in technology-enhanced environments could effectively support STEM learning.Arguedas-Matarrita et al. (2017) evaluated the potential use of the online lab tool in a training workshop for schoolteachers in Costa Rica. The schoolteachers' feedbacks were positive, and they would like to use this tool in future teaching activities. Grodotzki et al. (2018) designed a remotely-operated testing cell. In general, the participants showed good interest in this online format. Faulconer et al. (2018) ran a comparison study between online and in-person chemistry labs for a sample size of 823. The study showed students, who took in-person chemistry lab, tended to get fewer "A"s and more "D"s than their online counterparts. Tejado et al. (2019) presented a VL (Virtual Laboratory) as an interactive tool to support learning in systems theory-related courses at the University of Extremadura from 2015 to 2016. The use of VL was helpful for students to understand the basic concepts of modeling linear dynamical systems. Diaz et al. (2013) presented the design and development of the MOOC for learning industrial electronic circuits. The pilot course had 2000 enrollments.

Generally speaking, online labs provide a platform for students to learn synchronously and asynchronously with either remotely accessible or fully virtual lab equipment, independently from typical constraints that can be found with classical, in-person lab courses, such as time, space, and resource constraints. Online labs could, hence, help the students learn independently outside scheduled lab times. Over the last decade, more literature review papers summarized the current state-of-the-art in terms of online lab instruction in engineering and science education(Potkonjak et al., 2016; Brinson, 2015; Hernández-de Menéndez et al., 2019; Nikolic et al., 2021). Almost all studies comment on the highly diverse research results that stem from diverse lab technologies, the variety of lab application strategies in the curricula, and, nonetheless, different instructional goals connected to each lab. Another important observation shared by the studies was the common lack of peer-to-peer social interaction in many online lab applications. Studies showed peer learning could help to establish a social presence (Aragon, 2003; Lowenthal and Dunlap, 2020). However, as the lower social presence is a challenge for online learning (Bali and Liu, 2018; Kaufmann and Vallade, 2020) in general, this is also true for online lab activities. So far, only a few studies investigated the benefits of integrating peer learning in an online lab environment and compared the learning outcomes with those of physical environments.

This study hopes to fill these gaps in the literature by using mixed methods to study a novel implementation of peer learning in the online electronic circuit lab. In assessing our lab implementation, we sought to answer the following research questions about students' peer learning experiences in online labs as compared to their peer learning experiences in the initial physical labs:

1. How did peer learning in an online lab affect students' perception of both their and their partner's circuits-related skill development?

2. How did peer learning in an online lab affect how students distributed lab tasks?

3. How did having access to an always-available online lab affect students' engagement outside class time?

This study allowed us to understand how physical learning environments can be transformed into online peer-learning environments. This paper focuses on the quantitative analysis of the online lab study; a separate publication was on preliminary insights to meet the tight deadline of an early COVID-19 special issue, and this paper builds upon that work by answering new research questions. (Li et al., 2020).

3 Methods and Context

3.1 Class Setup

The lab instruction of a class of 38 engineering students in Spring 2020 was initially conducted in the physical circuit lab. The course topic was fundamental circuit assembly and analysis. When the pandemic began, the labs were switched to an online format. Zoom Meetings software was used as an interactive communication platform. In particular, breakout rooms were used to allow students to work in small teams of 2-3 students on lab activities after a brief introduction (Figure 1a). The lab activities were divided into four different tasks: circuit measurement, circuit calculation, circuit simulation, and circuit assembly. The students were encouraged to select a team leader to distribute the tasks to individuals.

Circuit assembly was conducted via the Virtual Instrument Systems in Reality (VISIR) module in an online lab platform called LabsLand® . The VISIR module enabled students to assemble and measure a circuit using a realistic circuit board interface (Figure 1b). The circuit created by students was then automatically tested in a dedicated laboratory at the University of Deusto in Spain, and the outcome was communicated back to the students. Students had access to the online lab around the clock, though they were only expected to collaborate during the synchronous lab periods over Zoom. Combining Zoom and VISIR had many benefits in encouraging students' peer learning. For example, VISIR offered a top-down view of the circuit board. All the group members could have a clear picture of the progress of the circuit assembly via the "screen sharing" feature over Zoom. One student could connect or disconnect the electronic components while others offered real-time advice, and the course instructor could conveniently assess a circuit visually by visiting students' breakout rooms. Meanwhile, the LabsLand® platform offered unlimited access to the module and circuit boards, which could not be achieved by the physical labs the course originally used. During COVID-19, VISIR offered a safe and convenient way to perform electronic labs.
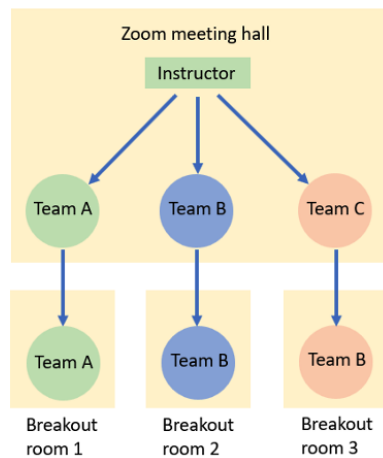
(a) Lab workflow
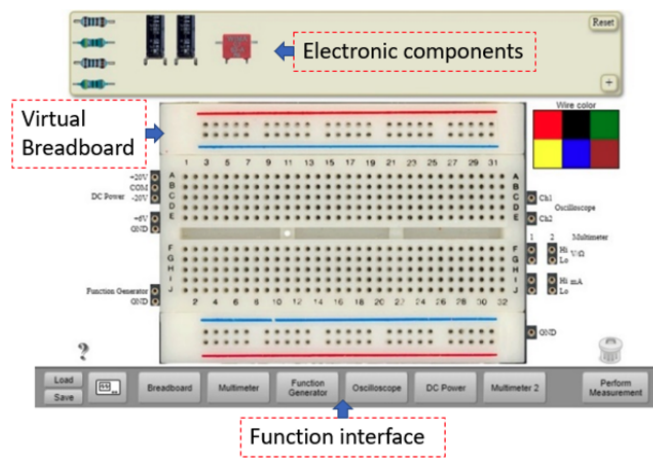
(b) Online lab interface

Figure 1. Shows (a) the online lab workflow and (b) the online lab interface.

3.2 Assessment and Research

Three types of data were collected: online surveys, lab report scores, and online lab usage data. These three assessment methods are summarized in Figure 2 The physical lab survey was administered before the online lab.
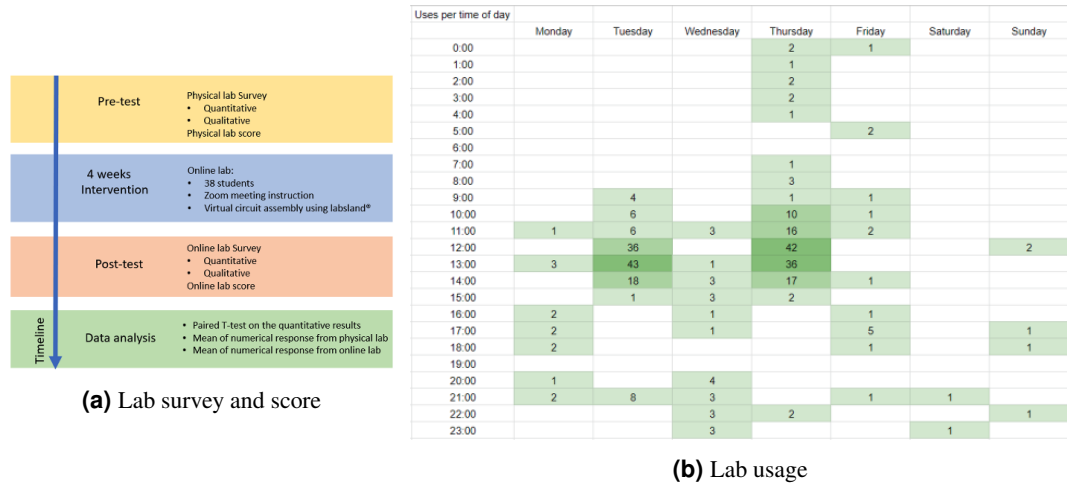

(a) Lab survey and score

Uses per time of day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0:00				2	1		
1:00				1			
2:00				2			
3:00				2			
4:00				1			
5:00					2		
6:00							
7:00				1			
8:00				3			
9:00		4		1	1		
10:00		6		10	1		
11:00	1	6	3	16	2		
12:00		36		42			2
13:00	3	43	1	36			
14:00		18	3	17	1		
15:00		1	3	2			
16:00	2		1		1		
17:00	2		1		5		1
18:00	2				1		1
19:00							
20:00	1		4				
21:00	2	8	3		1	1	
22:00			3	2			1
23:00			3			1	

(b) Lab usage

Figure 2. Shows three assessment methods, (a) is the procedure for collecting lab surveys and scores, and (b) is the lab usage example.

3.2.1 Lab Surveys

To assess student perceptions of skill development and task distribution among team members, we collected student survey data in two phases (Fig. 2a). The survey had quantitative and qualitative parts. Analysis of quantitative survey results included graphing the data, as well as paired descriptive and inferential statistics (e.g., paired t-test) to compare student responses between the two surveys. Qualitative survey results were analyzed using an open coding method. Table 1 exhibits the quantitative survey questions relevant to the research questions of this study. First, we collected online survey data from students regarding their experience in the physical lab. Second, we collected online survey data from students using the same instruments at the end of the semester in the online lab.

Table 1. Survey questions relevant to the research questions of this study

Question	Scale	Items
How knowledgeable would you consider yourself now regarding the following [physical/online] lab skills?	1 (Novice) – 10 (Expert)	Circuit Assembly Circuit Measurement Circuit Calculation Circuit Simulation
How knowledgeable would you consider your lab partner(s) now regarding the following [physical/online] lab skills?	1 (Novice) – 10 (Expert)	Circuit Assembly Circuit Measurement Circuit Calculation Circuit Simulation
How does your level of knowledge regarding lab skills affect how you and your partner divide labor during labs?	Open answer (qualitative)	

3.3 Lab score

To supplement student perceptions of skill development, we also compared student lab report scores in a lab that was structured similarly in both the physical and online labs. The lab instructions, as shown in Table 2, were given to the students, and the student lab reports were

compared. The similarity between the physical and online labs was the objectives are related to the Wheatstone bridge. The differences between those two labs are the lab objectives: the physical lab aims to measure the unknown resistance using an assembled Wheatstone bridge, while the online lab aims to design and build a Wheatstone bridge from scratch.

Table 2. Lab instructions for physical and online labs.

	Physical Lab	Online Lab
Prompt	Your task in this project is to measure the unknown resistor of a Wheatstone bridge.	Your task in this project is to design and build a balanced Wheatstone bridge using four resistors.
Steps	- Construct a sample circuit using a Multisim® circuit simulator - Measure the unknown resistor in the electronics laboratory - Submit a structured technical report after the lab	- Verify your design using a Multisim® circuit simulator - Construct and test your designed circuit in LabsLand® - Submit a structured technical report after the lab

3.4 Lab usage

The online lab presented students with a learning curve, especially on the user interface. Also, only one student from each lab group could access the interface during lab hours. We posited that students' ability to revisit the software outside of designated class time would be helpful for some students. Accordingly, we analyzed the usage data for those who logged into the class online lab during each hour of the week. Figure 2b shows an example of the lab usage data, which is presented in terms of the number of students using LabsLand® in the hourly slots.

4 Results

4.1 Survey Results

Table 3 summarizes the students' responses to the skill development questions. The number range for the answer is 1 (novice) to 10 (expert). There were some significant differences in specific lab skills—particularly, some students felt less competent in circuit measurement and circuit calculation when working in the online lab environment. However, they felt their partners' skills in circuit assembly increased in the meantime. However, in those cases, the differences between the means of numerical responses were small. Our sample size (n=31) was small as seven students chose not to participate in the survey. We opted for a relatively large, exploratory level of significance of less than 0.15. The P-value was calculated using paired sample T-test.

Table 3. Summary of the skill development responses (n=31)

	Component skills	P-value	Mean physical lab	Mean online lab	Significant difference?
Personal skill development	Circuit measurement	0.04	7.50	6.73	**Yes**
	Circuit calculation	0.07	7.62	7.00	**Yes**
	Circuit assembly	0.38	6.15	6.54	No
	Circuit simulation	0.71	7.23	7.35	No
Partner's skill development	Circuit measurement	1	7.35	7.35	No
	Circuit calculation	0.65	7.23	7.42	No
	Circuit assembly	0.11	7.65	8.35	**Yes**
	Circuit simulation	0.31	7.85	7.50	No

Our online lab structure was designed for a group of students who have complementary lab skills, so they can efficiently distribute the tasks according to their strengths, as shown in 52% of the students' responses in Figure 3. We believed that the affordances of the online environment encouraged students to adopt more well-defined roles and choose tasks based on their strengths; particularly, only one person was able to work with the software at a time.
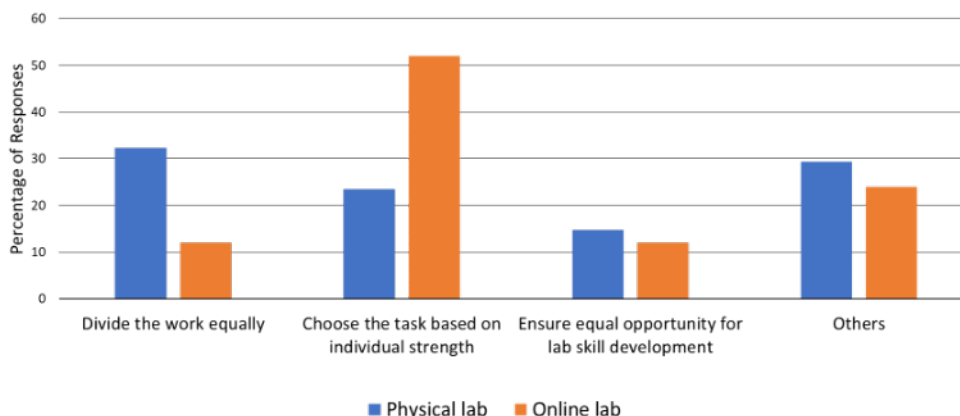

Figure 3. How students reported dividing work among their teams in physical vs. online lab environments.

4.2 Lab scores

Despite the small differences in students' perceptions of their lab skills, there was no significant difference between student lab scores in the online lab and physical lab (Table 4). The mean score for the physical lab was 96.1, while the mean score for the online lab was 97.8. This result potentially suggested that students could achieve comparable outcomes via peer learning in an online lab environment to a physical learning environment. As mentioned before, the lab exercise was divided into four components to assess the students' learning: measurement, calculation, simulation, and assembly. The online lab structure, as well as the grading rubric, are attached in Appendix A. The exception is that they are allowed to make up the labs due to internet disruption.

Table 4. Lab score comparison between the physical and online labs (n=38)

Physical lab score		Online lab score	
Mean	96.1	Mean	97.8
Standard deviation (±)	7.8	Standard deviation	5.3

4.3 Lab usage

In this study, the regular lab hours are 12:30 pm to 2:00 pm every Tuesday and Thursday. Table 5 shows the usage of LabsLand® is still quite high outside the normal lab hours. During lab hours, only one student could operate the LabsLand® while others were instructing. Like other always-access systems, Labsland® offers an opportunity for a substantial subset of students who could practice lab skills or revisit lab activities outside lab hours.

Table 5. Frequency of student logins outside lab hours (Tuesday and Thursday)

Day of the week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Usage	1	6	10	19	5	0	2

5 Discussion

The result showed that the synchronous online lab setup was successful in supporting student learning nearly as well as a physical lab environment while providing the benefit of always-accessible lab activities that many students used. (Figure 3). Our study provides some insights into the potential benefits of peer learning in an online environment. Based on what we found in this study, we confirm that the students tend to divide their labor based on their own skill sets in the online lab environment. Compared with the physical lab, more students were willing to divide the tasks based on individual strengths, as the proportion increased from 24 % to 52 % (Figure 3). Based on that, the student could only partially acquire some lab skill sets. Table 3 showed students perceived that both the skills of circuit measurement and calculation had decreased noticeably for one of the group members. Those results suggest that online lab activities may hamper the development of some necessary lab skills in favor of those on which each student chose to focus.

On the other hand, having an always-available online lab could mitigate the negative impact on individual skill development and allow the students to have more independent learning experiences. The online environment provides the out-of-school learning opportunity as a complementary and reinforcement agent, which broadens the learning environment for the student and provides novelty in education Kaya and Dönmez (2009); May et al. (2020); Loro et al. (2018). Marques et al. (2014) stated that the VISIR lab gives extra accessibility and flexibility to the students. In our study, according to the lab usage data, the students took advantage of the always-accessible lab outside the classroom (Table 5). However, there is no solid evidence to prove they could potentially fill the skill gaps by doing so. Accordingly, more structured out-of-class activities may be necessary to engender the outcome of all students achieving an acceptable level of proficiency in all essential lab skills.

6 Conclusion

This study demonstrated that online labs have numerous benefits for the pandemic and post-pandemic classroom learning. On the learners' side, Labsland® was a cost-effective tool that allowed the students to sharpen their lab skills or enhance their learning of engineering principles by revisiting the lab content in their own time. The online lab structure was designed to solve engineering problems collaboratively while improving individual skill sets. Through peer learning, some students saw improvement in their peers in terms of the circuit assembly.

Online collaboration encouraged more role-playing and task-specific teamwork, which has been shown as a hallmark of successful workplace teams. In the existing lab setting, one student worked on circuit assembly while others provided real-time feedback over Zoom. Therefore, to optimize the team efficiency, the team leader would assign one member with more experience in circuit assembly to work on Task 3 (Appendix A). That could also potentially place more burdens on the team leader. A possible improvement is to facilitate team formation on the instructor's side before task assignment. The instructor could pick the students with complementary skillsets for the teams and potentially improve their personal skill development (Table 3). On the other hand, Labsland offered an immersive experience that gave students a feeling of being present in a hands-on physical lab. The instructors could design an online lab using Labsland with learning objectives from the physical labs.

The assessment data, including survey, lab usage, and lab score, were used to evaluate the peer-learning in the online environment. In a nutshell, this study indicated that combining the online learning tools of Zoom meetings and VISIR lab software is an effective way to support student learning in online environments. Individual lab skills could be further improved by more structured out-of-class self-learning activities.

Acknowledgment

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A Appendix

ENGR 2170: Circuits
Online Laboratory: AC and Wheatstone Bridge

Objective

This lab will use the knowledge of circuit laws. Before the lab, please do the following pre-planning activity:

1. Ask your lab partner about their pre-knowledge of Thevenin's theorem.

2. Vote to have a team leader.

3. The team leader distributes Task 1-3 inside the group.

4. Report the progress with each other every 15 minutes.
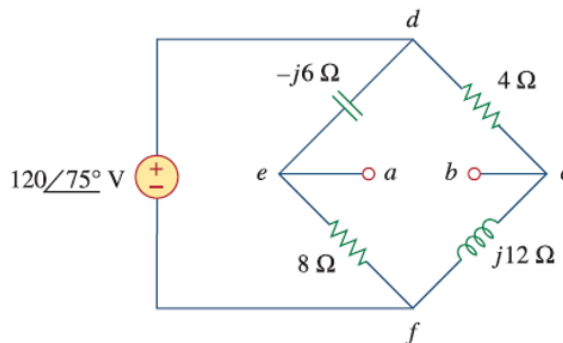
Task 1: Calculation

See below for the circuit given in Figure A1.

Figure A1. circuit diagram for calculation task

1. Calculate the Thevenin equivalent circuit of the circuit above

2. What is the voltage across Terminal a-b?

3. What is the value of gain K in this case?

Task 2: Multisim® simulation

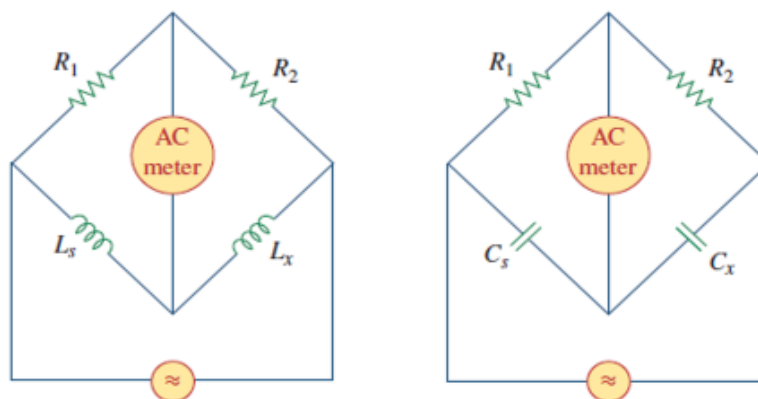An AC bridge is used in measuring the inductance L of any inductor or capacitance C of a capacitor.

Figure A2. AC bridges used to measure unknown capacitors and inductors

The following elements in Table A1 are provided.

Table A1. Elements provided for circuit construction.

Element	Value
Resistors	1-5kΩ
Capacitors	1-5F
Inductors	1-5H
DC Source	any
AC Source	any

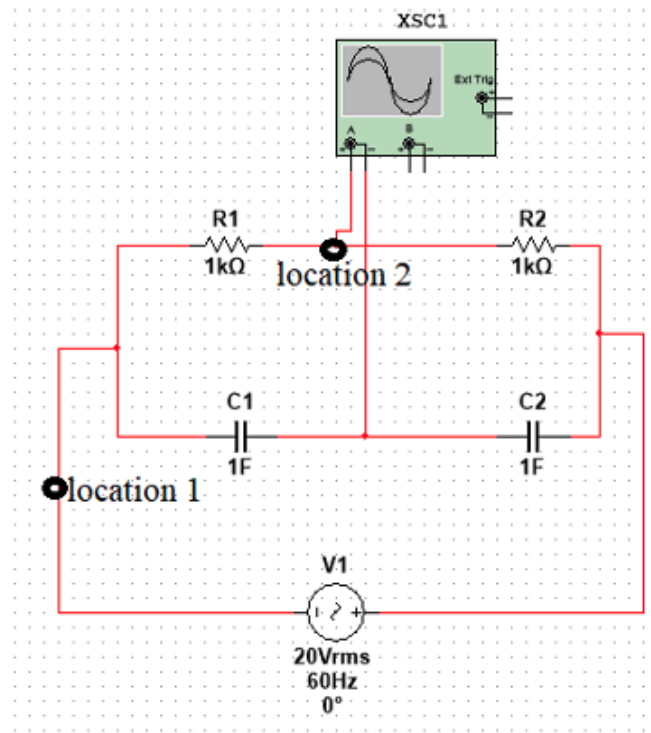Construct an AC bridge so that the voltage reading of the AC meter is zero at location 2.

Figure A3. A sample Multisim® circuit diagram

4. What resistors, capacitors, or inductors did you choose to build the circuit?

5. Take a picture of your measured outcome at location 1 and location 2.

6. If you change the AC source to a DC source of the same voltage, what is the voltage reading between terminal a-b?

Task 3: Labsland® assembly

Now, use the component in Labsland® to build a Wheatstone bridge using a function generator, and four resistors of your own choice. Set the function generator to be a sine wave.
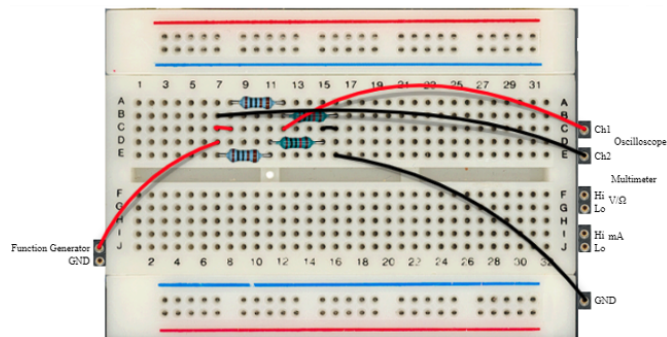

Figure A4. One example of the Labsland® circuit

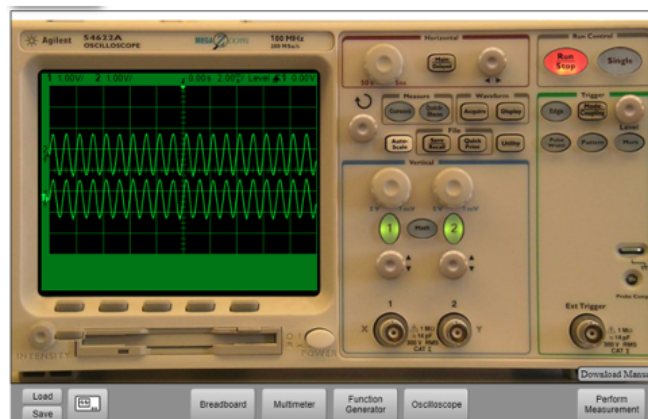7. what did you observe on channel 1 of the O-scope?

Figure A5. One of the expected results

8. what did you observe on channel 2 of the O-scope?

9. What is the gain between the input signal obtained from channel 1 and the output signal from channel 2?

Grading criteria for a lab report:
- 10% of the mark given to effective communication, i.e., good writing
- 30% of the mark given to completion of task 1
- 30% of the mark given to completion of task 2
- 30% of the mark given to completion of task 3