Challenging the Impact of Pandemic on Engineering Laboratory Courses - Solution, Evaluation, and Lesson

Ruiyun Fu, Ph.D.
Electrical and Computer Engineering, Mercer University, Macon, GA, 31207

Abstract

The COVID-19 pandemic has caused tremendous impacts on K-12 and higher education generally in the past year. And the situation is more severe in the laboratory courses of undergraduate engineering majors. The engineering lab courses have high requirements on students' hands-on experience and collaboration, as well as the communication with instructors to solve their problems on experiment setups. In this paper, the changes to the lab sessions of the "Electronics" course are introduced and applied to accommodate the COVID-19 protocol on campus, while alleviating the pandemic impact on students' learning quality and performance. The student's outcomes are analyzed and compared before and after the pandemic occurrence. From the analysis and evaluation, it is found that an on-campus learning environment is inevitable to ensure the knowledge-gain quality and learning experience of students for many engineering laboratory courses. In addition, proper modifications can be made to engineering lab courses to accommodate the new teaching environment during the pandemic, while ensuring the safety of students and the quality of ABET-required laboratory performance.

Keywords

COVID-19, engineering, evaluation, laboratory course, solution.

1. Introduction

Since the March of 2020, the outbreak of the COVID-19 pandemic has significantly impacted the normal progress of K-12 and higher education across the United States, and its influence still goes on... For engineering lab courses in higher education, the situation is much more severe due to the nature of hands-on experience and collaboration in these courses. Some engineering experiments rely on expensive equipment and devices in the labs on campus. And some laboratory experiments require frequent communication with instructors and teammates to solve their problems on experiment setups. Therefore, the instructors should challenge back the pandemic impact on engineering laboratory courses by redesigning the contents and schedules of these courses coordinately.

Previously, the effect of the COVID-19 pandemic was discussed in engineering higher education [1]. The paper concludes that it is essential to understand and have the preparation mechanism in place for future pandemics. The work in [2] gains an understanding of how first-year engineering students are feeling and getting acclimated in response to their education, personal matters, and the response of their university due to the pandemic. And the students' expectations of instruction in engineering laboratory courses during the pandemic were discussed in [3]. This study helps in planning the course better for future offerings, by using the best features from each mode. The work in [4] investigated if the sudden change of instruction mode due to the COVID-19 pandemic has any effect on the course outcomes. This study compared the situations of two courses' outcomes such as student grades, numbers of students dropping the course, available resources, grading criteria, etc. before and during the pandemic. The compared two courses are from two separate departments where one course is Engineering Economics and another course is DC Circuits and Design. In addition, seven faculty members from a regional public university explained the adjustments they made to their laboratory courses in order to minimize the impact of the pandemic on students learning related to Electrical and Computer Engineering Technology [5].

In this paper, the changes to the lab sessions of the "Electronics" course are introduced and applied to accommodate the COVID-19 protocol on campus, while alleviating the pandemic impact on students' learning quality and performance. The "Electronics" is a key fundamental, ABET-required course for the undergraduate students in Electrical Engineer major. This paper presents how the solutions used by the instructor to challenge the impact of the pandemic on the "Electronics Laboratory" course. The student's outcomes are analyzed and compared before and after applying those changes and solutions. The effectiveness of the proposed changes and solutions is analyzed based on the feedback and evaluations from students and the instructor. The solutions and lessons from this study can be used as references by peers for their engineering lab-course teaching for the post-COVID new normal.

Following this introductory section, the paper is organized as follows: Section II introduces the syllabus and schedules of the "Electronics" lab course and the proposed changes and solutions of alleviating the impact of the pandemic; after that, in Section III the student's outcomes are analyzed and compared among three semesters: the spring semester of 2019 (as "Not Impacted"), the spring semesters of 2020 (as "Partially Impacted") and the spring semesters of 2021 (as "Fully Impacted"); finally, Sections IV summarizes the evaluations from students and inductor and draws a conclusion of this study.

2. Changes to "Electronics Laboratory" Course during Pandemic

For engineering lab courses in higher-education institutes, the impact of the pandemic is much severe due to the requirement of hands-on experience in engineering experiments. For this study, the course information of "Electronics Laboratory" is introduced briefly. In response to the COVID-19 protocol on campus, the changes and solutions to the course are proposed accordingly and presented here in detail.

2.1. Introduction of "Electronics Laboratory" Course

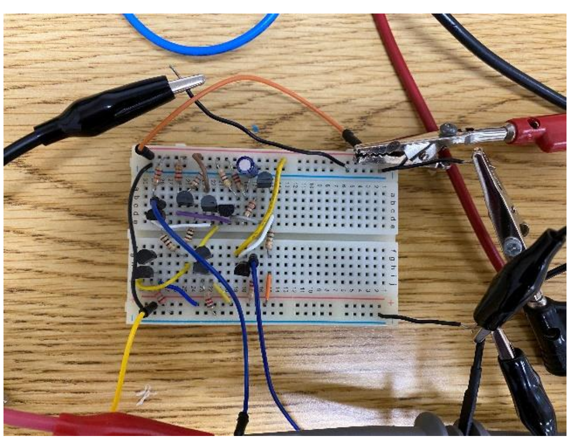
The "Electronics Laboratory" course is an ABET-required laboratory course in electrical engineering in 4-year higher-education institutes. This course is a key fundamental course for junior students and is co-requisite with the course – "Electronics II". According to the syllabus developed by the author, this course focuses on "*Hand-on laboratory experiences with a focus on the circuit design process*" and the catalog objective is "*At the conclusion of this course you will* *be able to design single and multistage amplifier. You will be able to verify the designs using LT-Spice. You will be able to verify your designs in the lab. You will gain experience in circuit fabrication using soldering and wire-wrapping techniques. You will gain an appreciation for the power consumption in circuits.*"

There are 11 (eleven) experiments of electronics circuit design and testing scheduled in this course. Students are required to spend one 3-hours meeting per week in the lab and be evaluated based on their performance on lab and formal reports. The lab performance consists of a) prelab work, and b) lab skills and demonstration. These requirements in the syllabus are listed below. Normally, students are assigned in 2-person groups to perform the experiments.

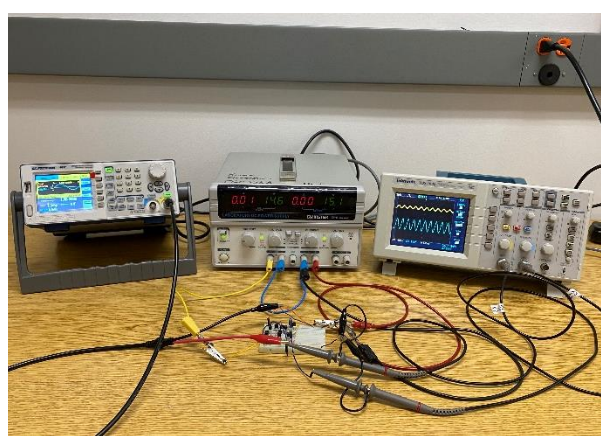
- **Prelab:** These are to be written documents indicating how a particular laboratory's objectives are to be accomplished. Circuits must be designed, by hand, and shown. Where possible (and it almost always is) LT-Spice simulation must be done prior to the lab to verify each design objective. All instruments and equipment needed should be indicated. The connection of the instruments to the circuit must be shown. Data that is to be recorded or collected must be indicated.

- **Demos:** At the end of each lab period you must demonstrate that the laboratory objectives have been met. A final schematic diagram of your circuit must be submitted. Figure 1 presents an example of electric circuits designed by students and its lab setup. This example is medium-level in difficulty among the eleven (11) experiments.

- **Formal Write-up:** These reports must be typed. The report should include a cover page, a quantitative abstract, brief instruction, a methods section, results, and a conclusion and discussion section. Graphs must be neat, they must be captioned and have labels. Experimental points on the graph must be indicated with circles, squares, etc. At least sample calculations should be shown in the body of the document. Raw data must be shown either in the body of the report or in an Appendix. Circuit diagrams must contain the actual measured values use in the laboratory. The idea of the report is to communicate that you have successfully achieved the objectives of the laboratory. Therefore, waveforms at key points in the circuit must be sketched, photographed, or downloaded from oscilloscope traces.



(a) electronics circuit design



(a) laboratory setup for testing

Figure 1. An example of students' electronics circuit design.

2.2. Changes to "Electronics Laboratory" Course

In this study, there are three scenarios analyzed and compared, as described in Table I.

Table I. Three teaching scenarios before and after the pandemic occurrence

Semesters	**Pandemic Situation**	**Teaching Scenario**
Spring 2019	No pandemic	Traditional progress, all on campus
Spring 2020	Pandemic occurs in the middle of the semester	First-half on campus in traditional progress "+" Second-half online, with changed requirement
Spring 2021	Pandemic throughout the whole semester	Changed progress, all on campus; online option available

In spring 2020, since the pandemic hit in early March – the right middle of the semester, all courses were moved online per the COVID-19 protocol from the university. At that moment, students had finished 6 out of 11 experiments in the lab. To overcome the sudden hit, the author had to change the lab instruction and requirements to accommodate the online teaching environment. The left 5 experiments were modified into simulation-based practice and more requirements were added on the printed circuit board (PCB) design of electronic circuits and relevant Q&A. In addition, the student's practice and reports were changed from teamwork to individual work. In this way, the personal interaction was minimized on campus, while the FDA, CDC, and university administration dealing with the solutions to the pandemic in a big picture. The online teaching at the beginning of the pandemic did alleviate the panic and stress of students, instructors, and parents.

In spring 2021, per the COVID-19 protocol from the university, all course teachings were required to be back on campus, although online learning was still optional to students. With the preparation in fall 2020, the author had the following major changes to the "Electronics Laboratory" course to fit in with the new normal:

a) The change of student number in each team. Before the pandemic, the students are required to work in a 2-person group. In case the student number is odd, there is one and only one 3-person group. The purpose is to ensure each student's participation in experiments and train their teamwork capability. During the pandemic, the author changed the rule, and permit one-person groups. In spring 2021, there are 3 out of 20 students chose one-person groups.

b) The change of experiment instructions and schedule. Due to their relatively-independent topics, the number of 11 electronics experiments remains unaltered. It ensures the integrity of this laboratory course and the quality of students' hands-on training. Before the pandemic, the students are required to complete each experiment within a certain period step by step. During the pandemic, the author changed the rule of lab attendance:

most experiments cover more than one meeting. So, if the student team can complete that experiment earlier and pass the instructor's checking on their demo, they don't have to show up at the rest meeting time. Once the students complete all experiments and pass the instructor's checking, they don't have to show up for the rest meeting time. In this way, the personal meeting times in the lab can be reduced as possible;

c) The new requirements of prelab-simulation tasks, individual prelab-reports, and final reports. Before the pandemic, only one prelab report and one final report are required from each student group. During the pandemic, the author added additional questions and simulation tasks in the prelab instruction. Also, the author required individual prelab-report and individual final reports from each student (no matter they work in two-person groups or alone). From this change, it is noticed that the students become more familiar with the technical information and experiment procedure before they come to the lab. In this way, the personal interaction time can be reduced in the lab and the efficiency of students' experiments is increased.

d) The option of online learning is still available to the students who prefer to perform in-home labs. In this study, all students chose to perform on-campus experiments in the lab. The electronics lab provides the oscilloscopes, power supplies, digital multimeters, sensors, and other equipment and devices, which cost thousands of US dollars per testbed and are not affordable to most students by themselves.

In addition, required by the university's administration the following statement was added into syllabus: "*Because of the COVID-19 virus, in compliance with the XXX University Face Covering Policy, a mask or appropriate face covering, which covers the wearer's nose and mouth, is required in the classroom.*"

3. Evaluation and Comparison of Student's Outcomes

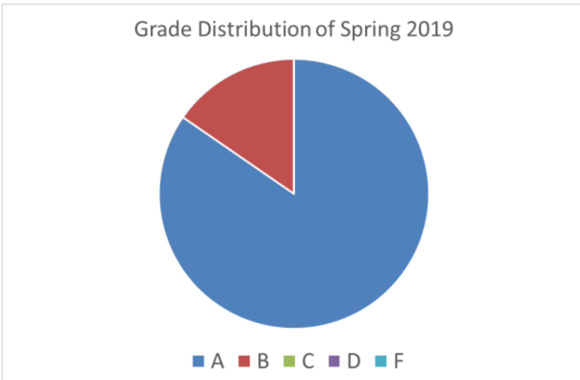
The student's outcomes are analyzed and compared among the three semesters/scenarios: the spring semester of 2019 (as "Not Impacted"), the spring semesters of 2020 (as "Partially Impacted"), and the spring semesters of 2021 (as "Fully Impacted"). In this section, the student's outcomes are evaluated in the aspects of the student grade distribution and the "Engineering Course Evaluation" reports from students.

Figure 2 shows the student distribution in the three semesters. The grading scheme is listed in Table II. Due to the different student headcounts, the student distributions are presented in pie charts for easy comparison. The average headcount of these three semesters is 19.

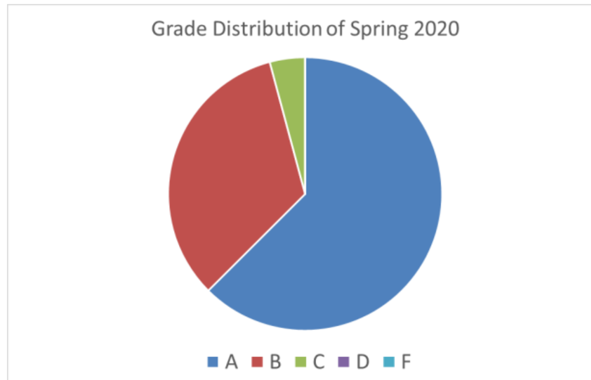
Table II. Grading scheme of "Electronics Laboratory" course

1. Individual lab practice exam	100 points
2. Labs (Prelab 50 points, lab skills 10 points, demos 40 points)	100 points each
3. Formal Reports	100 points each

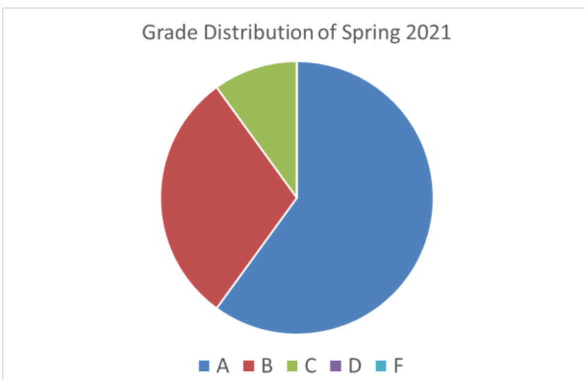
(There will be three or four formal reports during the term)	
Final grades will be based on: A – 90-100%; B – 80-89%; C – 70-79%; D – 60-69%; F - <60%.	



(a) under "Not Impacted" scenario



(b) under "Partially Impacted" scenario



(c) under "Fully Impacted" scenario

Figure 2. Student grade distributions in three semesters:
a) Spring 2019, and not impacted by the pandemic;
b) Spring 2020, and partially impacted by the pandemic; and
c) Spring 2021, and fully impacted by the pandemic.

From Figure 2, it is noticed that the ratio of "A" grade decreases, and some "C" grade increases a little bit. It means the pandemic indeed impacted the student's performance at some level. But it is also noticed that the ratio of the "A/B" grade is still in the normal range, even under the "Fully Impacted" scenario. By analyzing and comparing the student's performance in detail, here are some findings to explain the data in Figure 2:

1) The "C" grades in 2020 and 2021 were caused by the missing lab demo and final reports from students. According to the university's COVID-19 protocol, the students who demonstrate symptoms are subject to COVID tests. During the testing period, the students have to be in quarantine and not allowed in the lab. It caused students' delay in lab work in this course, as well as the accumulation of work in other courses. For those students, the author permitted late lab performance and report submission without penalty. Unfortunately, some students still failed to complete all their lab mission and reports by the end of the semester;

2) Some students in part-time jobs faced financial difficulties during the pandemic. Also, the "limbo" condition causes panic to some students and distracts their attention and focuses on academic work.

Overall, the ABET requirements and the purpose of hand-on training can be maintained well by applying the changes and solutions proposed in Section II. Some impact from the pandemic is inevitable but still controllable.

Table III presents statistical measurements of students' responses to the lab courses during the three semesters. It is noticed that there was no extraordinary change in the distribution of students' responses. In addition, Table IV lists the samples of students' comments on the lab course teaching during the three semesters. It is also noticed that most students liked their working in the lab over online learning, especially in a lab course.

Table III. Summary of student's responses to the "Electronics Laboratory" courses ([1] strongly disagree; [2] disagree; [3] Neutral; [4] agree; [5] strongly agree)

MUSE questions	**Spring 2019**	**Spring 2020**		**Spring 2021**	
		Section1	Section2	Section1	Section2
The course stimulated my interest in the subject.	4.5	4.5	4.3	4.2	5.0
Overall experience: the course as a whole was a worthwhile experience	4.5	4.5	5.0	4.6	5.0
The prerequisite courses prepared me well for this course.	4.3	4.5	4.7	4.2	4.5
The instructor was well prepared for class.	4.8	5.0	4.7	4.6	4.5
The instructor was interested in teaching.	5.0	4.5	4.7	4.6	5.0
The instructor was available outside of class.	4.5	5.0	4.7	4.8	4.5
Overall experience: Instructor was an effective teacher	4.8	4.5	4.7	4.4	4.5
Overall mean	**4.4**	**4.5**	**4.7**	**4.3**	**4.8**
Survey response percentage	30.77%	11.1%	50%	35.71%	33.33%

Table IV. Samples of student's comments to the "Electronics Laboratory" courses

Spring semester of 2019:

- "*I liked that we were building circuits we had learned about in class. Any troubleshooting we had to do to meet specifications for the circuit required us to truly understand the circuit. The prelabs were very difficult but helped me understand analysis for various types of amplifiers, which overall helped me do better in the ECE XXX classroom section because I understood more from repeated analysis.*"
- "*The PCB lab was very fun and rewarding.*"

Spring semester of 2020:

- "*I would have liked to continue working in a team for the whole of the semester. **I know the circumstances were different**, but I think we could have still managed to work as teams online throughout the remainder of the semester.*"
- "*The labs were a bit challenging so find a good lab partner and be prepared to spend a lot of out of class time working on the labs.*"
- "*Some of the labs were really interesting, it was nice seeing really complicated amps being built on our own.*"
- "*I would have liked more time in the lab.*"

Spring semester of 2021:

- "*I enjoyed the opportunity to work in the labs*."
- "*I liked how well tied in the material was with that of the main electronics II class. I also felt that the lab reports solidified my knowledge on the labs.*"
- "*This lab was time consuming but was very helpful to my understanding of the course.*"
- "*I liked how we got to design our own circuits in the lab. I liked that the instructions were very open ended and then we got to decide how to approach the problem best. For example, for the multistage amp, we got to decide what type of amp to use for each stage.*"

4. Conclusion

Based on the student performance evaluation from the activities of course content and schedule changes, it has been found that: a) most students prefer on-campus lab sessions over at-home or online ones; b) due to the social-distancing rule and COVID protocol applied on campus, sometimes delay occurs in some student groups but is controllable with instructor's extra guidance after class; c) compared to peer's online lab teaching experience in other universities, the on-campus lab practice can do much better work in time management, hardware checking and code debugging in a "mask-to-mask" environment in the lab. Therefore, an on-campus learning environment is inevitable to ensure the knowledge-gain quality and learning experience of students for many engineering laboratory courses. Proper modifications can be made to engineering lab courses to accommodate the new teaching environment during the pandemic, while ensuring the safety of students and the quality of ABET-required laboratory performance.

References

1 Mehrabian, A., & Buchanan, W. W., & Rahrooh, A. (2021, March), *THE EFFECT OF COVID-19 PANDEMIC IN ENGINEERING HIGHER EDUCATION* Paper presented at ASEE 2021 Gulf-Southwest Annual Conference, Waco, Texas. https://peer.asee.org/36410.

2 Setien, M. B., & Walton, T. N., & McCullough, M. B. A., & Knisley, S. B. (2021, July), *WIP: Impact of COVID-19 Pandemic on a First-Year Engineering Cohort Ranging From Learning Methods, Personal Decisions and University Experience* Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://strategy.asee.org/38088.

3 Alkhoury, K., & Edrees, A. Z., & Sodhi, J., & Borgaonkar, A. D., & Shekhar, P. (2021, July), *Investigating Students' Expectations of Instruction in Engineering Laboratory Courses During the COVID-19 Pandemic* Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://strategy.asee.org/37400.

4 Ferdous, S. F., & Badar, M. A., & Javaid, M. (2021, July), Impact of COVID-19 on Engineering and Technology Course Outcomes Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://peer.asee.org/37277.

5 Javaid, M., & Wittenmyer, E. L., & Henriquez, O., & Pritchett, L. D. (2021, July), Undergraduate Engineering Laboratories During COVID-19 Pandemic Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. https://peer.asee.org/37948.

Biographical Information of the paper's Author

Ruiyun Fu received the B.S. and M.S. degrees from the Huazhong University of Science and Technology, Wuhan, China, in 2004 and 2007, respectively, and the Ph.D. degree from the University of South Carolina, Columbia, SC, USA, in 2013, all in electrical engineering. She is currently an Assistant Professor with the Department of Electrical and Computer Engineering, the School of Engineering, Mercer University, Macon, GA, USA. Her research interests include power electronics and power systems, dc/dc converters and dc/ac inverters, renewable energy conversion system design, modeling and simulation of power semiconductor devices for switching converter applications, and modeling and simulation of wide bandgap semiconductor devices (SiC, GaN, etc.). She is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE).