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Undergraduate Engineering Laboratories During COVID-19 Pandemic

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Abstract

Laboratories have always been considered an integral part of undergraduate engineering education.

The recent COVID-19 pandemic has globally affected higher education and educators are devising innovative ways to minimize the impact of the pandemic on student learning. The most popular approach of converting instruction to online is applicable for teaching theoretical knowledge. However, laboratory experiments require hands-on activities. Simulations can replace the hands-on experiments to a limited extend. Moreover, laboratory sessions involve social interaction as students work in groups, share laboratory equipment, and interact one-to-one with laboratory instructor.

This paper explores the impact of COVID-19 on laboratory courses in Electronics and Computer Engineering Technology (ECET) department of Indiana State University (ISU) through statistical analysis of grade distribution of students and number of experiments covered. The authors present the comparison of Fall 2019 laboratory course when the challenges of pandemic did not exist with the Fall 2020 laboratory course when the precautions for COVID-19 pandemic were observed. The comparison is done for laboratory courses taught by the same instructor in Fall 2019 and Fall 2020. Faculty members from ECET department explain the adjustments they have made to their laboratory courses to minimize the impact of the pandemic on students learning.

Overall, the authors managed to cover almost all the experiments in Fall 2020 as they used to cover in Fall 2019. The statistical comparison of final grade distribution also indicates no difference between these two semesters which were conducted under quite different circumstances. The null hypothesis is that there exists no difference between the course final grades for pre-pandemic (Fall 2019) and post-pandemic (Fall 2020) semesters. The hypothesis has been tested using Chi-square goodness of fit test at $p=0.05$.

Keywords

Laboratory, pandemic, pedagogical adaptation.

Introduction

Engineering is a practical discipline. Therefore, laboratories have always been considered an integral part of engineering education, particularly undergraduate engineering education. Laboratory experiments not only help students to understand theoretical concepts, they also serve the purpose of teaching the required engineering hands-on skills. Laboratory experiments almost always involve groups of students working together under supervision of lab instructor. Thus, students also learn teamwork through laboratory sessions [1]-[3].

A pandemic is defined as an epidemic of infectious disease that has spread across many countries. COVID-19 was declared by World Health Organization (WHO) as a pandemic on March 11th. 2020 [4]. The recent COVID-19 pandemic has globally affected all activities which require social interaction. University experience is one of these affected areas and educators world-wide are devising innovative ways to minimize the impact of the pandemic on student learning [5]. The most popular approach is to move instruction online. Online instruction is good for teaching theoretical knowledge [6]. However, laboratories require hands-on execution of experiments. Simulations can replace the hands-on experiments to a limited extend. Moreover, laboratory sessions involve social interaction as students work in groups, work on the shared laboratory equipment, and interact one-to-one with lab instructor.

In this paper seven faculty members from Electronics and Computer Engineering Technology (ECET) department of Indiana State University explain about the adjustments they have made in their laboratory courses to minimize the impact of the pandemic on students' learning. Since the COVID-19 pandemic started in March 2020, there are not enough studies to investigate its effects on student learning particularly for engineering laboratory courses. This paper is an attempt to fill this gap.

The paper describes the method of statistically analyzing pre-pandemic (Fall 2019) and post pandemic (Fall 2020) laboratory courses in the Method section. This section also explains the COVID-19 regulations adopted by Indiana State University. These regulations are applicable to all laboratory courses. Explanation for each laboratory course and statistical analysis of grade distribution is presented in Results section. Finally, the paper summarizes the information from various laboratory courses taught during pandemic by various instructors in Conclusions and Discussions section.

Method

Comparison Using Chi-Square

The Chi-square ($\chi 2$) statistic is used to compare two or more independent groups [7]-[10]. Observed and expected frequencies have to be obtained. The Chi-square statistic is $\chi^2 = \sum_{i=1}^{i=3} \frac{(O_i - E_i)^2}{E_i}$ and critical value is p=0.05. Pearson published a paper on the χ^2 test in 1900, investigating a test of goodness of fit [11].

The Chi-square test is used to determine if pre-pandemic (Fall 2019) laboratory course grades are statistically different than post-pandemic (Fall 2020) course grades when both courses are taught

by the same instructor. If the resulting p-value of comparison is greater than 0.05, that means the grades are not different for two courses. The grades with low expected frequencies are grouped together. Lowest expected frequency is a debatable issue among the researchers [7].

COVID-19 Regulations at Indiana State University (ISU)

ISU made it mandatory for every individual in university buildings to wear face masks. So, all students and instructors wear masks all the time during laboratory sessions.

Instructors were provided with disinfectant wipes and hand sanitizers. Every laboratory room is also provided with hand sanitizer. Students can wipe laboratory equipment with disinfectant wipe before and after the experiment.

Students and instructors fill an online COVID-19 symptoms assessment survey very day before entering university buildings and only come to university campus if they are clear of symptoms. In case a student needs to isolate or quarantine, he or she needs to inform Student Affairs. Student Affairs then informs the associated instructors to make adjustments for that student. Since laboratory sessions were conducting following precautions, infections of any student with COVID-19 did not infected the whole class or required the whole class to quarantine.

Results

The explanation of each laboratory course pre-pandemic (Fall 2019) and post pandemic (Fall 2020) is provided in this section.

DC Circuits and Design:

Two sections of this course were taught by Prof. Javaid during Fall 2020.

The Section-1 had about half of the class total capacity. So, both theory and lab. classes were conducted in person. Pre pandemic students used to perform laboratory experiments in groups of two. However, during pandemic students performed experiments individually. The class performed all the experiments as the pre-pandemic class. The grade distribution for this section as compare to the Fall 2019 is given in Table 1.

Table 1: DC Circuits and Design Course Fall 2020 Section-1 and Fall 2019 Grades

	A	B	C, D, F, W	Total
Fall 2020-Section 1	8	2	3	13
Fall 2019	10	7	6	23
*p-value = 0.51, the results are **not** statistically different*				

Section-2 had more than half of class total capacity. So, this section was taught in a hybrid mode with theory lectures taught as synchronous online sessions and lab classes were conducted in-person with half the class present at a time. Online lectures were conducted on Zoom platform. Pre-pandemic students used to perform laboratory experiments in groups of two. However,

during pandemic students performed experiments individually. The class performed all the experiments as in-person experiments except the last experiment which was converted to an online simulation demonstration. It was due to classes converted to online mode in the last two weeks of fall semester. The grade distribution for this section as compare to the Fall 2019 is given in Table 2.

Table 2: DC Circuits and Design Course Fall 2020 Section-2 and Fall 2019 Grades

	A	B	C, D, F, W	Total
Fall 2020-Section 2	8	4	7	19
Fall 2019	10	7	6	23
*p-value = 0.6, the results are **not** statistically different*				

Introduction to Robotics and Automation:

This course was taught by Prof. Javaid and Prof. Clyburn during Fall 2019 and Fall 2020 to different sessions. Comparison of sections taught by each instructor is presented separately and shown in Table 3 and Table 4.

Since the course sections had more than half of class total capacity, they were taught in a hybrid mode with theory lectures taught as synchronous online sessions and lab classes conducted in-person with half the class present at a time. Online lectures were conducted on Zoom platform. Pre pandemic students used to perform laboratory experiments in groups of two. However, during pandemic students could either perform experiments individually or in a group of two depending upon their comfort level. Majority of students chose to work in group of two. Students were also allowed to seek help from fellow students in performing lab experiment as per their comfort level. The class performed all the experiments as in-person experiments. The grade distribution for Prof. Javaid is shown in Table 3, and for Prof. Clyburn is shown in Table 4.

Table 3: Introduction to Robotics and Automation Course Fall 2020 and Fall 2019 Grades - Taught by Prof. Javaid

	A	B	C	D, F, W	Total
Fall 2020	13	2	2	6	23
Fall 2019	11	4	7	6	28
*p-value = 0.37, the results are **not** statistically different*					

Table 4: Introduction to Robotics and Automation Course Fall 2020 and Fall 2019 Grades - Taught by Prof. Clyburn

	A	B	C	D, F, W	Total
Fall 2019	2	4	4	8	18
Fall 2020	5	5	6	4	20
*p-value = 0.39, the results are **not** statistically different*					

Programmable Logic Controllers and Control Systems

Prof. Malooley taught this course. It had less than half of the class total capacity during Fall 2020. So, both theory and lab classes were conducted in person. The class performed all the experiments as the pre-pandemic class. The grade distribution for this course as compare to the Fall 2019 is given in Table 5.

Table 5: Programmable Logic Controllers and Control Systems Course Fall 2020 and Fall 2019 Grades

	A, B	C, D, F, W	Total
Fall 2019	17	3	20
Fall 2020	9	1	10
*p-value = 0.7, the results are **not** statistically different*			

Industrial Electronic Current Control System

This course had less than half of the class total capacity during Fall 2020. So, both theory and lab. classes were conducted in person. The class performed all the experiments as the pre-pandemic class. Since, the total number of students for both Fall 2019 and Fall 2020 classes were less than 10 for this course, statistical comparison of grades cannot be performed.

This course was taught by Prof. Malooley.

Electronic Fundamentals

Ms. Wittenmyer taught the laboratory course of Electronic Fundamentals pre-pandemic (Fall 2019) and post pandemic (Fall 2020). The theory and lab classes were conducted in-person during Fall 2020. Pre-pandemic (Fall 2019) students performed laboratory experiments in groups of two. However, during pandemic (Fall 2020) students performed laboratory experiments either individually or in groups of two (depending on student choice) utilizing CDC recommended social distancing. The post-pandemic class performed all the experiments as the pre-pandemic class. The grade distribution for this course is given in Table 6.

Table 6: Electronic Fundamentals Course Fall 2020 and Fall 2019 Grades

	A, B	C, D, F, W	Total
Fall 2019	17	6	23
Fall 2020	18	5	23
*p-value = 0.73, the results are **not** statistically different*			

Applications of Robotic and Automation Systems

Prof. Clyburn taught this course. It had less than half of the class total capacity during Fall 2020. So, both theory and lab classes were conducted in person. The class performed all the experiments as the pre-pandemic class. Since the total number of students for both Fall 2019 and Fall 2020 classes were very low for this course, statistical comparison of grades cannot be performed.

Digital Computer Circuits

Mr. Henriquez taught the laboratory course of Digital Computer Circuits pre-pandemic (Fall 2019) and post pandemic (Fall 2020).

During Fall 2019, students were partnered up to share the equipment. Students had a total of 18 labs to complete. Some students relied on their partners for the labs. This was visible in the practical exam. During Fall 2020, students were not allowed to be in groups. Class size was smaller, and each student was able to work on their own labs. This allowed students to work on the labs individually but still be able to consult their classmates. 20 labs were conducted during this time as students were much quicker to finish their labs.

The grade distribution for this course as compare to the Fall 2019 is given in Table 7.

Table 4: Digital Computer Circuits Course Fall 2020 and Fall 2019 Grades

	A	B, C	D, F, W	Total
Fall 2019	5	5	3	13
Fall 2020	6	7	8	21
*p-value = 0.65, the results are **not** statistically different*				

Practical Digital Logic Design

Mr. Pritchett taught the laboratory course of Practical Digital Logic Design pre-pandemic (Fall 2019) and post pandemic (Fall 2020). This is an FPGA Programming class, in which laboratory projects range from introduction to Vivado, which takes the average student less than two hours, to multiple-input multiple-output circuits that may involve six hours or more of programming preceded by as many hours of design. We schedule six contact hours per week for this three credit class. In 2019, that time was used roughly one third didactic lecture and two thirds lab.

In Fall 2020, to maintain social distancing rules, Mr. Pritchett split the class into A/B halves, so the total scheduled contact time for each student was reduced to 3 hours per week. Mr. Pritchett also tried to split the class time closer to half delivering lecture and half lab. Vivado software is publicly available, so student programming time is not strictly limited to class time. Mr. Pritchett did not, however, ask the student to buy the FPGA boards on which their projects are demonstrated, so troubleshooting and demonstration was limited to class time.

In Fall 2020, the class accomplished five of the FPGA development projects. In Fall 2019, the class accomplished six projects. The grade distribution for this section as compare to the Fall 2019 is given in Table 7.

Table 5:Practical Digital Logic Design Course Fall 2020 and Fall 2019 Grades

	A	B	C, D, F, W	Total
Fall 2019	7	5	10	22
Fall 2020	5	9	5	19
*p-value = 0.23, the results are **not** statistically different*				

AC Circuits and Design

Prof. English taught the laboratory course of AC Circuits and Design pre-pandemic (Fall 2019) and post pandemic (Fall 2020).

In Fall 2019, the total number of officially enrolled students for this course was 10. Two students withdrew from the course. Pre-pandemic students performed laboratory experiments in groups of two. The laboratory experiments utilized actual laboratory experiment during the first portion of the course while the students utilized simulated equipment (Multisim) during the second portion.

In Fall 2020, the total number of officially enrolled students for this course was 14. Two students withdrew from the course. Both theory and laboratory classes were conducted in a face-to-face manner. Post-pandemic students performed experiments individually during both portions of the class. The classes performed all of the experiments. The laboratory experiments utilized actual laboratory experiments during the first portion of the course while the students utilized simulated equipment (Multisim) during the second portion. Instructor and student both worked to wipe down equipment and assure as much COVID-19 protection as possible.

Due to small number of data (n), statistical comparison of this course cannot be performed between Fall 2020 and Fall 2019 class.

Conclusions and Discussions

The data from laboratory courses taught during Fall 2020 by various instructors of Indiana State University indicate two main points.

1. During pandemic (Fall 2020), instructors have successfully adapted the laboratory courses to conduct almost all the laboratory experiments as conducted pre-pandemic.

2. The comparison of grades for laboratory course taught pre-pandemic (Fall 2019) and post-pandemic (Fall 2020) also indicates that the student performance for these courses has not been affect during a planned semester while observing the precautions for pandemic.

Other observations of this data are:

- Indiana State University has small class sizes which allowed for practicing social distancing in laboratory sessions. Particularly, a reasonable number of courses have less than half of class capacity.

- Some courses could not cover a small number portion of laboratory experiments which were conducted pre-pandemic. It was due to the reduced contact time with students which was caused by dividing the class in two halves to practice the social distancing requirement. Another reason was the university instructions moving online during the last two weeks of semester.

- One course even indicated increase in the number of laboratory experiments performed due to the improvement in student performance. Students worked on laboratory experiments individually during pandemic, instructor suggests that working independently has improved student performance.

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