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Work in Progress: Adapting to the changes in the teaching pedagogy post-pandemic in Electrical and Computer Engineering courses

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Abstract

This Work in Progress Paper presents adaption techniques for teaching second-year Electrical and Computer Engineering courses post-pandemic. Challenges faced by students and faculty will also be presented in this paper along with some guidance and best practices. COVID-19 began impacting education in early 2020 and many land-grant universities were not fully equipped with the tools to offer the best learning experience to students due to lock-down and inability to access the laboratories and teaching equipment. This global pandemic had caused the universities to change their operations and impelled instructors to quickly adapt to online instruction. Many universities began to invest their resources to explore teaching pedagogies that best fit the needs of their students. University's learning management systems facilitated the delivery of the course content remotely with some minor enhancements. Although engineering courses could easily be revamped to distance learning platforms, there were still some challenges due to the nature of the coursework and assessment of outcomes. The availability of vaccination and university mandates had made it possible to return to the in-person teaching and learning modality. The purpose of this paper is to: a) present some of the challenges faced by the second-year engineering students during the transition to and from the distance learning approach, b) share some of the results from the assessment of student attitudes during this transition, and c) share some of the best practices adopted by the instructors during these uncertain times.

The curriculum for the two electrical and computer engineering (ECE) courses taught at the large research institution covers the fundamental concepts of electrical analog and digital circuits and provides an opportunity for students to explore the applications of circuits in the real world. In a normal learning environment, ECE courses tend to be difficult due to higher expectations for problem-solving, math, and scientific concepts, and adding external factors such as the pandemic adds more complications. The focus of this research work is to study the second-year engineering course and present the challenges associated with the delivery of the course content, teaching engineering concepts and applications in either online or hybrid settings and communication between instructors and students in the post-pandemic period. This paper also presents an assessment of student attitudes to switching teaching modalities (in-person to online and vice versa) and their performance. With the learning assessment comes the lessons learned and evaluation of teaching strategies that have been investigated by the instructors to facilitate learning during these difficult times.

Challenges associated with the course offerings and assessments were observed in the two courses offered at a regional campus of a large research institution. The courses are three-credit-hour and introduce problem-solving, circuit analysis techniques, testing, troubleshooting techniques, and teamwork. Teaching strategies during the post-pandemic setting will include identification and evaluation of several online platforms to support teaching in a hybrid model, restructuring the content, and utilizing alternative methods to assess course goals will be

discussed in this paper. This paper provides an opportunity to learn from the unique experience, develop skills to address the continuously changing teaching and learning environment that has evolved as a result of the pandemic, and support students and faculty with a variety of academic needs.

Introduction

Electrical and Computer Engineering is a practical discipline and laboratories have always been an integral part of its curriculum. Undergraduate introductory courses cover a wide variety of fundamental topics that allow students to explore the discipline such as fundamentals of electrical circuits, digital logic, signals, systems, etc. Technological advancement has also impacted the curriculum of this discipline. Engineering students take physics, chemistry, and calculus-based mathematics courses along with some general education courses in the first year. In addition, they take electrical and computer engineering core courses in their second year to complete the requirements for admission into the major. It is well known that students face social and psychological challenges and academic anxiety as they begin their journey at college [1-4]. Even students with strong academic records face challenges due to several factors related to the transition from high school to college. Differences in the learning environment and teaching methods, course responsibility, higher academic expectations, complicated admissions, university policies, and time management cause anxiety among engineering freshmen and even sophomores. In addition to these d causes of anxiety among students, if there are teaching or learning disruptions, students tend to get more anxious and stressed [5], resulting in a lack of concentration and feelings of withdrawal.

A COVID-19 pandemic began in early 2020 and disrupted nearly all types of activities and social interactions worldwide including teaching and learning. Educators worldwide were impelled to devise strategies and innovative ways to minimize the impact of the pandemic on student learning [6]. The most popular approach was to deliver the courses remotely to students to avoid community spread. A plethora of teaching pedagogies have been investigated by researchers in the past, especially in science, technology, engineering, and mathematics areas such as active learning, flipped classroom, online discussion groups, and peer mentoring [7-12]. Students were also forced to adapt to the continuously changing teaching methodologies as there were strict regulations on in-person interactions. Online instruction has been proven to be effective for teaching theoretical knowledge [13]. However, courses involving laboratories required hands-on experiments which were difficult to execute in a remote setting. Educators adopted several simulation tools to replace the hands-on experiments to a certain extent. Many of the project-based laboratory courses suffered due to a lack of research capabilities. In addition, projects demand social interaction as students work in groups, brainstorm ideas, utilize laboratory equipment, and closely interact with the instructors.

This paper presents some of the challenges faced by the instructors and students in Electrical and Computer Engineering courses offered at one of the regional campuses of The Ohio State University. Even though some researchers have conducted studies in 2020 to investigate the effect of the pandemic on teaching and learning [7-9], there remains more work to be done to study how instructors and students cope with the continuously changing global conditions,

especially at regional campuses with small classes sizes. The paper also assesses the student's behavior and attitudes as they navigated their courses during this transition. In-class participation, attendance, and active Q&A with the instructor during the online lecture sessions are used as pointers to assess the motivation of students in class. Faculty interactions with the students while they are in the class describe a certain level of motivation. Timely completion of the assignments, punctual attendance during office hours, and request for feedback on assessments are also some pointers to determine the motivation of students. Prior research on disasters shows us that events like COVID-19 can reveal a culture's core beliefs and values and reveal some of the underlying challenges and attitudes that are otherwise not evident [13-15]. This pandemic has allowed us to investigate engineering culture during a crisis, which may provide future direction for cultural change. Since the end of the pandemic seems to be near, more research is needed to provide some guidance on the future course of action in case of a similar global turmoil. The author hopes to guide an attempt to fill this gap with this paper. The paper is divided into the following sections: Course Overview, Challenges due to COVID-19, Methodology for analyzing student performance and attitudes in pre-pandemic, during, and post-pandemic course sections, Results and Discussion, Best Practices, and Future Work.

Course Overview

A short overview of the curriculum will be presented in this section. The two ECE courses are titled Introduction to Electrical Circuits and Systems and Introduction to Digital Logic. Both are hands-on laboratory courses where students learn to build, test, and troubleshoot. These courses are 3 credit hours each and are offered at the regional campus only during the Spring semester. The class enrollments are very small since the majority of the students prefer to transfer to the main campus after the first year. These two courses are required for Computer Science and Electrical and Computer Engineering disciplines.

Introduction to Electrical Circuits and Systems

Curriculum: This course (also referred to as the Analog Circuits course) introduces students to basic electrical laws and circuit analysis techniques. The first half of the course covers DC circuits, and the remaining half covers AC circuits. Students learn about passive and active circuit elements and their behavior along with the analysis of time- and phasor- domains. Students become competent in analyzing, designing, and implementing first-order and second-order circuits and simple active filters. One of the course goals is to utilize modern computer tools for analog simulation and learn critical troubleshooting skills. Simulation tools such as PSpice, LTSpice, and TinkerCad were used to elaborate on the circuit design principles and measurement techniques.

Laboratories: The laboratory component of the course involves the demonstration of the physical principles, and the use of electrical instruments such as oscilloscopes, function generators, and digital multimeters. Students had a total of 7 labs to complete during the semester. Laboratory instructions, manuals, and video presentations have been made available to the students. Teams are formed with three students per team and each team is provided a lab kit, safety glasses, a breadboard, and a toolbox including all the probes.

Assessments: Since the circuit's courses are based on analysis and mathematical calculations, the homework assignments include circuits with unknown parameters to be calculated. There are two midterms and a comprehensive final exam. Since there isn't a lot of technical writing involved in this course, students are not required to deliver the lab reports instead lab worksheets are completed for each lab exercise. The worksheet serves as an assessment of students' analytical and troubleshooting skills. Participation grades are given to encourage attendance and interaction with instructors and peers.

Introduction to Digital Logic

Curriculum: This course (also referred to as the Digital Logic course) introduces students to the different number representations used in today's digital systems and their arithmetic properties and conversion techniques. Students can analyze and synthesize networks of digital logic gates using Boolean Algebra. The content is divided into combinatorial and clocked sequential circuits. The topics include logic gates, gate timing, delays, Karnaugh maps, registers, and counters, and designing sequential circuits based on state graphs and state tables. The course involves the implementation of design schematics into hardware using modern FPGA boards and a development environment based on Intel processors. Students work in groups to build not only critical thinking skills but also team working skills which will be helpful in future courses, especially with the Capstone Design. Students become competent in analyzing, designing, and implementing sequential circuits. One of the course goals is to utilize modern computer tools for digital design simulation and learn critical troubleshooting skills.

Laboratories: The laboratory component of the course involves designing a Simon Says Game using Altera DE2 115 FPGA board. Quartus Prime tools such as ModelSim, Signal Tap II, and Memory Editor allow students to simulate digital circuitry, and visualize the signals by writing values to the registers within ROM and RAM without the need to connect the hardware. Students begin the laboratory exercises with the simple execution of logic operations (EX-OR, NAND, NOR operations). Once they acquire basic knowledge of ModelSim and VHDL programming, they are introduced to encoders, registers, and counters. The laboratory exercises currently require students to follow the design provided to them in the manual to develop a Simon Says Game. Therefore, there isn't any brainstorming or critical thinking required. However, students learn to run an audio synthesizer and design the sequential circuit for the Simon Says game machine. Students had a total of 7 labs to complete during the semester. Students executed their game to demonstrate their programming skills in the final lab. Laboratory instructions, manuals, and video presentations have been made available to the students. Teams are formed depending on the size of the classroom and each team is provided a lab kit including DE2 115 FPGA board and a toolbox with all the required probes. Each week, students review "ReadMe" files and watch pre-recorded videos to prepare for the lab exercise.

Assessments: To assess student learning and attainment of the outcomes, homework assignments, and midterm exams are given during the semester. Questions based on concepts, number conversions, logic circuit design, analysis, and synthesis are asked in the homework. Practical application of sequential circuits is presented in the exams and students are required to analyze the system requirements to design digital circuits. The laboratory work is

comparable to a project since the labs build upon each other, therefore, there is some amount of technical writing involved in this course. Since these courses serve as introductory ECE courses, students are provided with templates for the lab reports. In other words, students are spoon-fed to build technical writing skills. Participation is highly encouraged in these courses and attendance is important to be successful.

Challenges due to COVID-19

For several centuries, land grant institutions have had teaching models that predominantly relied on in-person, face-to-face, and direct delivery of the content. The dynamics of evolving social, economic, and academic relations demanded the use of effective tools, machines, processes, and systems hence paving the path for online applications and cloud-based environments for data management. Education was quickly impacted by these changes which led to the introduction of techniques that took teaching and learning outside the classrooms. Several strategies have been introduced in higher education to promote growth, enrollment, and retention. Technological advancements have facilitated instructors to introduce tools and applications in the classroom not only to assist students with learning disabilities but also to enhance technical literacy among all students. Students' literacy in computer systems and online applications has been a cornerstone in improving the efficacy of active learning, flipped classrooms, project-based learning, and other strategies. However, there are several challenges that instructors face in implementing these strategies into their classes, especially with the outbreak of a pandemic.

1. *Anxiety among faculty*: Switching the delivery mode during a semester is challenging. Due to the sudden onset of the pandemic in 2020, instructors were impelled to switch from in-person classes to online or hybrid classes. This uncertainty caused anxiety among faculty since there was no preparation for this change. Several institutions were equipped with learning management systems that facilitated the synchronous or asynchronous delivery in Spring 2020. The faculty was under stress about the attainment of the course goals and student evaluation of the teaching. Instructors teaching Electrical and Computer Engineering courses were at a disadvantage since most of the courses require laboratory work. Due to the lack of availability of tools or applications to deliver the labs remotely, there were some drastic measures taken.
2. *Role of Administration:* Due to the CDC guidelines that universities had to follow; administrative personnel served a critical role during the pandemic. With the flexibility in applying policies for students, faculty, and staff, it became less stressful, especially for the untenured faculty. Some institutions chose to skip 2020 from the faculty evaluation for teaching and research while others chose to relax the rules. With the end of Spring 2020, the teaching and learning departments/institutes across the globe began researching best practices to train their faculty. The community of scholars, researchers, and faculty began collaborating to overcome these challenges.
3. *Anxiety among Students:* As much as it was difficult for faculty to switch to online delivery during the semester, it was difficult for students as well. During a regular semester, students learn and adapt to the teaching method of an instructor which helps them build a bond with the instructor. Situations like the pandemic break that bond and

cause confusion and lack of focus among students. The disruption in learning and lack of concentration in remote settings urge students to explore alternatives such as online videos or tutorials or even online tutors whose teaching methodology is different from that of an instructor. Convoluted information instills a feeling of stress and withdrawal which will be detrimental to their career.

4. *Dependency on Learning Management Systems:* Availability of a learning management system (LMS) facilitated the delivery of course content during the pandemic. Many institutions especially online universities implemented these systems several years ago. At this institution, Canvas LMS is used for content delivery for online classes, however, some features were incompatible in these systems such as synchronous teaching sessions. Zoom filled in the gap and fulfilled the requirement of synchronous meetings. It was a learning curve for many instructors to upload their content to the LMS systems and set up Zoom meetings. However, with time and help from LMS and Zoom technical support, online teaching was made possible. Although Analog Circuits and Digital Logic courses were taught using LMS, there were some challenges with the grading technical problems. Active learning, flipped classroom, online discussion groups, and other teaching strategies were effectively implemented in these courses with the help of the LMS. There are options for concept-based questions in LMS such as quizzes which could be auto-graded. However, the instructors had to review the questions requiring problem-solving since the analysis techniques or steps/approaches are critical for a grade in such courses.
5. *Assessment of Student Learning Outcomes or Program Objectives:* With the disruption in teaching comes the inconsistency in grading and assessments. There is always variability in grading from instructor to instructor, and if the teaching methods also vary, it complicates the process of assessment. Student learning outcomes are assessed each year at the department level and due to the pandemic, data was not gathered during Spring 2020. Although regional campus enrollments are very low, the department includes the assessment of student learning outcomes and program objectives. Therefore, there is a need to include verbiage in the Self-Study and ABET reports about the changes in the program due to the pandemic and the challenges with the assessment of student learning outcomes. Some of the new programs submitting readiness reviews for ABET accreditation are required to disclose the teaching modes for each semester [16]. ABET (Accreditation Board for Engineering and Technology Inc.) requires the institutional administrative officer to notify them of changes that potentially impact the extent to which an accredited program satisfies ABET accreditation criteria or policies. There has been some guidance already published from ABET [17] and the institutions have to review these guidelines before submitting the Self-Study for future reviews.

Methodology for analyzing student performance and attitudes

The two ECE courses (Analog Circuits and Digital Logic) studied in this paper are offered at the regional campus. The course content and laboratory work are consistent with the central campus offering and therefore these courses are highly regulated by the Department of Electrical and Computer Engineering.

To assess the student performance pre-, during and post-pandemic, student grades in those sections were compared using the Chi-Square Statistical test. The Chi-square ($\chi 2$) statistic is used to compare two or more independent groups [18]-[23].

The Chi-square statistic is used to determine if the sample data matches the observed population which is called the "Goodness of Fit Test". The Chi-Square test is also useful in comparison of two variables which is called the "Test for Independence".

In this study, the Chi-square test is used to statistically compare the pre-, during, and post-pandemic (Spring 2019, 2020+2021, and 2022) sections and student grades (which correlates to the student performance) in the two ECE courses. Since this is the work in progress paper, the author expects to get a more comprehensive analysis and results from the 2022 grades. If the resulting p-value of comparison is greater than 0.05, that means the grades are not different for the three sections. The grades with low expected frequencies among the three sections will be grouped.

Results and Discussion

The two ECE courses (Introduction to Analog Circuits and Systems and Introduction to Digital Logic) were taught by the author at the regional campus.

For the Analog Circuits course, students completed a total of 7 labs throughout the semester. Students performed laboratory experiments in groups of two. 100% of the lecture and lab components were taught in person in Spring 2019. In Spring 2020, 60% of the lectures and labs were taught in person and 40% were taught online using Zoom and PSpice, and TinkerCad software platforms. In Spring 2021, 100% of the lectures were taught online and 100% of the labs were taught in person.

For the Digital Logic course, students completed a total of 6 labs throughout the semester. Students performed laboratory experiments in groups of three. 100% of the lecture and lab components were taught in person in Spring 2019. In Spring 2020, 60% of the lectures and labs were taught in person and 40% were taught online using Zoom and Quartus Prime software platforms. In Spring 2021 100% of the lectures were taught online and 100% of the labs were taught in person.

The grade distribution for these two courses is shown in Table 1 below.

Courses	Grade Distribution				
	Homework	Laboratory	Midterm 1	Midterm 2	Final Exam
Analog Circuits	20%	20%	15%	20%	25%
Digital Logic	20%	20%	15%	20%	25%

Table 1. Grade Distribution for two ECE courses (Introduction to Analog Circuits and Systems and Introduction to Digital Logic)

For the Analog Circuits course, laboratory, and overall student grades in Spring 2019, 2020, and 2021 are compared in the table below (Table. 2). If the resulting p-value of the Chi-Square comparison is greater than 0.05, that means the grades are not statistically different for the three terms.

Term	Laboratory Grades				
	90- 100%	80-90%	70-80%	< 70%	Total
Spring 2019	4	0	0	0	4
Spring 2020	4	1	1	1	7
Spring 2021	4	1	1	2	8
P-value = 0.77, ***the results are not statistically different***					

Term	Overall Grades				
	A	B	C	D, E, F, W	Total
Spring 2019	4	0	0	0	4
Spring 2020	3	3	1	0	7
Spring 2021	2	3	2	1	8
P-value = 0.29, ***the results are not statistically different***					

Table 2. Chi-Square Comparison Test of Laboratory Grades and Overall (final) grades in Introduction to Analog Circuits and Systems for 2019, 2020 and 2021 courses

For the Digital Logic course, laboratory, and overall student grades in Spring 2019, 2020, and 2021 are compared in the table below (Table. 3). If the resulting p-value of the Chi-Square comparison is greater than 0.05, that means the grades are not different for the three terms.

Term	Laboratory Grades				
	90- 100%	80-90%	70-80%	< 70%	Total
Spring 2019	9	0	0	0	9
Spring 2020	7	1	0	0	8
Spring 2021	11	1	0	0	12
P-value = 0.58, ***the results are not statistically different***					

Term	Overall Grades				
	A	B	C	D, E, F, W	Total
Spring 2019	5	3	1	0	9
Spring 2020	3	5	0	0	8
Spring 2021	7	3	1	1	12
value = 0.61, ***the results are not statistically different***					

Table 3. Chi-Square Comparison Test of Laboratory Grades and Overall (final) grades in Introduction to Digital Logic for 2019, 2020 and 2021 courses

The method used for assessing the student attitudes was to analyze attendance and class participation. Based on the observations in the classroom and online via the Zoom participant roster, the instructor observed that there were no significant differences in attendance in the 2019, 2020, and 2021 courses. However, the instructor has identified minor differences in student participation in the online classes. Since the online classes are conducted via Zoom, there were no requirements for a camera or microphone since the majority of the students come from rural backgrounds, and the university chose not to mandate the high-speed requirement for online classes. The instructor has observed that the learning motivation dropped by 50% in an online setting compared to the in-person class. As mentioned earlier in this paper, some of the pointers that led to this observation are attendance, student interactions with peers and instructors, leading the group discussions, and overall performance in a remote setting. Learning interest or motivation was gauged using the instructor's observation of the student in the class. As mentioned earlier, this study was conducted in a small-sized class, so there is a higher possibility of instructors knowing individual students very well. Therefore, the instructor can observe each student at least weekly if not every class session. Also, the in-person labs assisted in the measurement of motivation since the students' ability to apply the skills were demonstrated during the laboratory exercises. Although students were able to build analog circuits on the breadboard, they seemed to have forgotten the techniques to analyze data and needed a review in order to solve for the unknown quantities. Therefore, this warrants more studies to be conducted to investigate the student attitudes and behavior in an online learning environment. Although there were significant differences in motivation, students made all efforts to be respectful of each other's ideas and prompt during the sessions.

The data from the two ECE courses taught during Spring 2019, 2020, and 2021 by the same instructor shows no significant difference in student performance. Several points could be noted from this study: a) During a pandemic, the instructor was able to successfully adapt to the rapidly changing teaching modes and conducted the majority of the laboratory exercises excluding those that required hardware, b) Alternative solutions were devised to ensure course goals are achieved even though the approach was shifted to online simulation platforms, and finally, the comparison of laboratory and overall (final) grades for both ECE courses that are taught pre-, during and post-pandemic also indicates that the student performance for these courses has not been affected. The important aspect of assessing the course goals is to ensure that cheating and plagiarism are minimized in a course. These issues are observed in all teaching modalities (in-person, online, and hybrid), however, it is known that online or hybrid instruction improves the chances of cheating and/or plagiarism since the students are not physically present in class while taking the test or assessment. But the majority of the institutions have implemented learning management systems that are equipped with software that handles plagiarism such as Copyleaks for Canvas, SafeAssign for Blackboard, and Turnitin for D2L. Therefore, the concerns of cheating and plagiarism are not escalated due to remote instruction. On the contrary, remote instruction requires consistent implementation of these tools to ensure all students are assessed using similar grading and evaluation schemes. Other significant factors impacting the results could be the class size, variety of teaching methods, and instructors' teaching styles. More data need to be collected in the future to provide statistically significant results over a broad group of student populations.

Best Practices

The author believes that this study could provide some guidance to the instructors teaching ECE courses about the analysis of different teaching modes and warrants the need to study larger class sizes to see the impact of online teaching and learning versus in-person. Some of the best practices are discussed below:

- *Preparation*: Preparation is a key to being successful in any task. Therefore, preparing faculty and students for the future by presenting several case studies and scenarios such as the pandemic will be beneficial. University administration should invest in designing training workshops for new faculty and students for the unpredictable situation.
- *Health and Wellness Teams*: Due to elevated stress levels, people tend to become overwhelmed by small changes in the routine. In earlier studies, yoga and meditation were used to address the feelings of hopelessness and being depressed [19]. This is when the health and wellness coaches can come in to provide some relaxation techniques and workshops to maintain a balance in the work, study, and personal lives. The observations from the health coaching were found to align with prior research showing such techniques can support many aspects of mental health. It is a general notion that the health and wellness coaches are available as part of student services and must be responsible to address such needs of the students. The team must be trained in the institutional data policy, FERPA, and other policies to preserve the privacy of students. Students will feel comfortable reaching out to the school officials to be able to share their experiences and get help. Hence, institutions should invest in establishing these types of service centers to assist students with stress, anxiety, mental health, and other health-related issues.
- *Administrative Support*: Faculty and teaching staff have been the focus during this pandemic to ensure that students are cared for and supported throughout the pandemic. Therefore, administrative personnel may choose to offer some course releases or flexibility in the research expectations, especially during challenging times. In addition, there could be bonuses offered to faculty and staff who opted to teach more courses than usual.
- *Academic Adviser:* Academic advisors also play a critical role in helping ease some of the stress students have. This is because the advisors are a gateway into the courses and hence, they can provide some guidance to students as to which course is more demanding in terms of time and effort. This will allow students to plan their coursework especially if there are other underlying issues that they are experiencing.

Future Work

More work across a wider sample is needed to understand the degree to which the teaching modalities affect student performance. Similar studies will help in proposing strategies to address anxiety and stress among students and faculty due to global pandemics or similar situations. Because this study was conducted at a small regional campus of a large research institution, the class size is small which allows for one-on-one interaction with instructors. Also, all the resources available to the students for their health and wellness, career advising, diversity, and

social clubs allow for extracurricular activities on campus. These activities help support feelings of belongingness and well-being, especially for freshmen. Future work will analyze two more semesters' worth of data. Results from Spring 2022 data will be published in 2023 which will provide a holistic approach for closing the loop and offering guidance for continuous improvement post-pandemic. In addition, the author is proposing a student survey or interview as part of a comparative case study and will build on the framework established in this paper. The discursive response and comments from students will provide some insight into the post-pandemic teaching and learning approaches. There have been several studies investigating the capability of connecting hardware to a cloud environment to offer an alternative for universities requiring remote access to the hardware. The author hopes to study those platforms to provide additional support to offer remote laboratories.

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