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Teaching and Learning during COVID: Lessons Learned and Future Impacts

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Teaching and Learning During COVID: Lessons Learned and Future Impacts

Abstract

The COVID-19 pandemic has forced educational institutions and many industries to move to an online communication model. Educators and students across the world, for the most part, have been working to accommodate socially distanced and virtual schools while addressing the associated fears and concerns. For educational institutions, online synchronous meetings using Zoom or similar software platforms have replaced face-to-face teachings. The approach to handle the teaching disruptions caused by the pandemic is somewhat similar among educational institutions. The disturbance seems to be more manageable for the lecture-based courses than the laboratory classes. This paper is based on our experience in teaching electrical engineering courses. We observed several sudden changes that we contributed to this disturbance, among them a drop in student satisfaction and learning achievements. Since the only difference between the pre-pandemic and pandemic period was the delivery methodology, to better understand the root of the problem, we constructed four research questions and applied the available data for student learning outcomes for three different electrical engineering courses with different delivery mechanisms. The data indicate that interventions that will make the courses more interactive will have the highest impact. The paper concludes with an observation regarding the enrollment numbers during the pandemic and discusses some possible scenarios.

Introduction

The COVID-19 pandemic has impacted most aspects of our day-to-day activities, including education. During the first year and half of the pandemic educational institutions and many industries decided to move to an online communication model. We call this period the "online-COVID." Beginning fall 2021 semester, we witnessed that many institutions started offering a mix of face-to-face and online course offerings. We will call this period the "hybrid-COVID." This work will focus on online-COVID, which we identify as the period between March 2020 and June 2021, where almost all educational deliveries happened online. Educators and students across the world, for the most part, have been working to accommodate socially distanced and virtual schools while addressing the associated fears and concerns. Online synchronous meetings using Zoom [19] or similar software packages for educational institutions have replaced most face-to-face teachings.

The approach to handle the teaching disruptions caused by the pandemic is mostly similar among educational institutions worldwide. References [1-4] present a small work sample in this area. In [1], the authors presented the implementation of distance education in Electrical engineering courses during the summer semester of 2020 for two Bulgarian universities. Their approach included needs analysis, aimed at identifying the key requirements of the education; learning material development; selection of teaching methods; increasing competencies; assessing students, and assessing the education methodology. Next, the required virtual labs were selected and implemented. In [2], the authors focused on the legal challenges of distance learning, creating remote workplaces for both students and university lecturers. In [3], the authors investigated face-to-face, and online education's perceived effectiveness based on a student survey at the end of the 2020 summer session at their university. They concluded that the students had adopted online education pretty quickly, but there still might be several issues that need to be addressed. In [4], the authors explore the potential of microlearning within design education. Microlearning offers learning opportunities through small bursts of training materials that learners can comprehend in a short time, according to their preferred schedule and location.

In the United States, higher educational institutions moved to online delivery in March 2020. With the exception of the online delivery institutions, the academic community, including instructors, students, and staff, were forced to quickly adapt to a completely online teaching and learning environment to which they were not accustomed. In [5], the authors presented some techniques and strategies employed to overcome the difficulties of remote learning, such as the challenges of engaging learners with limited or inconsistent internet access, the strategy and decisions in using synchronous versus asynchronous delivery, and techniques to conduct experiments remotely. [6] introduces some practices of transferring the in-person activities to an online format, including lecturing, in-lab work, office hours, exams, and project activities. In [7], faculty members from a regional public university explain the adjustments they made to their laboratory courses to minimize the pandemic's impact on students learning. [8] presents advantages and disadvantages of virtual teaching versus in-person teaching of the same course. Student feedback via survey is supplied, providing statistical data. The survey and grades/course evaluations show that the shift to pure online teaching was successful. In [9], the author describes a set of software simulation exercises that were developed to complement the limited hands-on opportunities in Fall 2020 due to the COVID-19 pandemic for an electric circuits course. [10] presented the experience for a school with little or no experience teaching online or at a distance and covered some of the resources they used to overcome those shortcomings. It also pointed to the lack of discipline that many students had with the online delivery. In [11], the authors studied student experience based upon the delivery model provided by the instructor. The authors concluded that students preferred synchronous interactions with instructors. Instructions that were asynchronous or non-interactive reduced student engagement. In [12], the authors present several easy-to-adopt tools such as MS teams [18] to boost the learner-learner interaction in virtual meetings.

As expected, there were many challenges that educators and learners needed to handle. For instructors who were not familiar with using synchronous delivery tools, using the technology and using it effectively, converting their lectures to accessible files, making sure that there is effective learning process is taking place based on the delivery, making sure that the integrity of exams is observed, have been some of the ongoing challenges. For students, adapting to the new delivery system that pushes more learning responsibilities to them than before, which also requires more discipline, has been among the top challenges. Besides these, technical issues such as network issues have also played a role. In general, the sudden move to online delivery as the only available choice has caused stressful situations for instructors and students.

In this paper, using student outcome assessment surveys, we will reject or confirm the following four research inquiries. We use the word "confirming" since we are evaluating the data and not conducting a statistical analysis.

Research Inquiry #1: Institutions/Departments with strong online/distance programs/infrastructure will receive a higher student satisfaction during COVID delivery.
Research Inquiry #2: Students with a significant online educational experience will benefit more during the COVID online delivery and obtain intended educational goals.
Research Inquiry #3: Student dissatisfaction with COVID online delivery is closely associated with their accustomed delivery methodology.
Research Inquiry #4: Student satisfaction and learning achievements will increase by adding more interactive activities to the online delivery.

We will first briefly go over the typical challenges as they provide a pathway for future improvements and then present our teaching approach for electrical engineering courses with and without lab components. We will then compare students' teaching evaluations and comments over this period with the prior two years for several of our electrical engineering courses. Since we also collect student learning outcomes surveys, we will present the comparative results for the past two years. The data provide a better sense of students' achievements and how COVID-19 has affected learning. We also briefly discuss the mental health impact on students and instructors. Finally, we present our plan for future course delivery based on the lessons learned during COVID.

COVID-19 Common Challenges

Although the challenges that higher institutions worldwide faced were similar, their impacts were not the same and depended on the available resources experienced in online (synchronous) delivery, planning, and execution. The following table lists some of these challenges and their impact.

Table 1. Common Teaching-Learning Challenges related to COVID-19

Challenge	Teaching Impact	Learning Impact	Overall cost to improve
Online delivery infrastructure	High	High	High
Faculty expertise in online delivery	Avg-High	Low-Avg	Low
Hardware infrastructure (institution)	Avg-High	Avg-High	High
Hardware infrastructure (students)	Avg-High	High	Avg-High
Student knowledge on how to learn in an online environment	Avg	High	Low-Avg
Evaluation method (exams)	Avg-High	Avg-High	Avg
Laboratory	High	High	High

The major teaching challenge has been the transition of teaching material from a face-to-face format to an effective online learning format. After that we can name the instructors' knowledge and training on how to deliver a synchronous online course. From the learning point of view, although today's students are familiar with online learning, but until recently, not counting those who have decided to pursue an online degree, they were not forced to take everything online. This has caused a lack of preparation to adjust to the online learning environment and along with the lack of effective online teaching format has caused major impact during the last couple of years. We believe, this was the major factor behind enrollment declines during the online-COVID phase in universities. It is worth mentioning that moving to a face-to-face model after this period did not have the excepted rate of return of students to universities.

We now focus our attention to the work that we have done in the department of electrical and computer engineering at University of Wisconsin-Platteville (UW-Platt). First, we will describe our experience in distance delivery and then we will discuss on the online delivery during COVID. The department has been long engaged in distance delivery to the students across the state through "Collaborative Engineering program," which a short description follows.

At the request of local industry, UW-Platt started remote electrical engineering collaborative programs in 2006 at two locations in the state that had a strong manufacturing presence (Fox Valley and Rock County) by placing a single UW-Platt faculty member at each site [13]. These programs were specifically developed to allow place-bound nontraditional students, who work during the day, to obtain their entire under-graduate electrical engineering degree on a part-time basis without relocating and without having to travel to the main campus. As part of the collaborative agreement, prerequisite courses (math, science, English, humanities, etc.) were offered by the local two-year University of Wisconsin System (UW-System) Schools, while all courses within the engineering major were offered by faculty from UW-Platt, under their ABET accreditation. At these two sites, the local faculty member taught the engineering core classes, while the technical elective courses were offered remotely from main campus.

Starting in 2008, the UW-Platt extended the undergraduate collaborative engineering program to remote students throughout the state at their nearest two-year UW-System School (state-wide program). These remote students were added to the roster of one of the local sections of the class, with a streaming video (SV) designation. Lectures offered in-person to the local students (either main campus, Fox Valley, or Rock County) were recorded and posted in a timely manner to the class webpage for streaming video (SV) access by remote students at their convenience. All other course content (syllabus, reading assignments, homework, homework solutions, laboratory projects, examples, web-based resources, etc.) is also posted on the course webpage. All assignments and laboratory reports, for both local and distance students taking the course, are submitted and returned via an electronic dropbox. Grades are uploaded to the course webpage so that students can track their progress. Separate office hours, usually in the evening, are set up using web-conferencing software to accommodate the needs of the place-bound students in the class. Exam proctors were also arranged at the nearest two-year UW-System School. This methodology worked quite well to accommodate the different schedules of students within the program [14].

When the state-wide program first began, distance labs were facilitated by traveling lab managers. The lab managers would reserve rooms at the two-year campuses for lab usage on a biweekly schedule. They would transport and set-up equipment needed for a particular lab and verify operation prior to the arrival of the students [15-16] For entry-level courses, the lab manager was trained to assess proper usage of lab equipment and to evaluate the construction and performance of simple circuits. For mid- to upper-level coursework, the student and faculty member met online to complete their lab check-off. Cameras, speakers, and microphones became the eyes, the voices, and the ears of the faculty member while he/she checked specification compliance3. If the student was having trouble with his/her lab, that student was encouraged to setup an office-hour meeting with the faculty member where this same technology was used to assess the situation and to help troubleshoot the problem.

As technology improved, we incorporated those improvements into the distance program. One such improvement, the Analog Discovery [21] portable analog circuit design kit, allowed students to have a virtual set of lab equipment at home and eliminating the need to travel to their regional two-year system school for basic labs. Due to budget restrictions and the growth of the collaborative engineering program [9], in 2016, we began to require that all EE students in the collaborative program purchase an Analog Discovery design kit, thus greatly reducing the travel expenses of program lab managers. By 2018, all laboratory projects in the first two circuits courses and the analog electronics course were written so that they could be performed on an Analog Discovery whether the students had access to regular laboratory equipment or not.

Since we had many years of experience with distance education before the pandemic, it did not hit our program as hard as many others. We already had a structure in place to offer content online, provide remote office hours, and provide lab content remotely. Our two biggest problems were scaling our procedures from having roughly 10-15% of our students remote to 100% remote, obtaining the required resources, and figuring out a way to assess our students remotely without using in-person proctors.

Next, we will look at several courses with different structures and requirements and compare student evaluation data for the time before COVID and during the online-COVID and assess our research questions. The first course is representative of courses that we offer in a traditional face-to-face format with a distance delivery option for students enrolled in the program.

Digital Logic Spring 2020 (EE 3770)

Logic and Digital Design is the first digital electronics course in the curriculum. It covers Boolean algebra, logic gate, some MSI components, and a brief introduction to VHDL. In addition to the theoretical coverage, there are five individual design projects resulting in breadboarded logic circuits and a group final design project implemented using an Altera Cyclone board. At the beginning of the semester, students acquire a parts kit containing all the components necessary for the five design projects.

Usually, toward the last three weeks of the course, each final project group will check out an Altera Cyclone board to implement and demonstrate their final project to the class.

Logic and Digital Design was, of course, among the courses being taught when COVID caused a mid-semester shutdown in the spring of 2020. The interruption to the design projects was minimal, as students already had the components necessary to complete the projects. Circuit outputs for the student designs in this class are generally demonstrated using LEDs or 7-segment displays, which were easily done via webcam. The biggest challenge was helping students create 5 V supplies with what they had at home.

The most common solution was to use an obsolete USB charging cable, cut the mini-USB connector off, and connect the conductors to the posts of a breadboard. With this minor adjustment, the projects were completed as usual for the remainder of the course over Zoom. The group final design projects did not go as well.

Project groups were formed in Canvas [20], which provided a group workspace, discussion board, and conferencing area. Without exception, the student groups chose to set up a group in Discord and do their work there. Designs were completed using Altera Quartus II, and simulations were used to demonstrate the functionality of the projects. While this effectively demonstrated the success of the groups' projects, the presentations were dry and harder to follow. Digital timing diagrams are no substitute for blinking LEDs, 7-segment displays, and buzzers. Peer evaluations of the final project presentations shown in Table 2 show a significant drop in student perceptions of the presentations.

Table 2. Peer evaluations of final project presentation in Logic and Digital Design. Evaluation criteria listed are: OR=Organization, SK=Subject Knowledge, CL=Clarity, VA=Use of Visual Aids, SP=Speaking, PA=Professional Appearance

Offering	Enrolled Students	Project Groups		OR (1-4)	SK (1-4)	CL (1-4)	VA (1-4)	SP (1-4)	PA (1-4)	Total (6-24)
Fall 2018	68	15		3.76	3.82	3.63	3.69	3.43	3.54	21.88
Fall 2019	29	9		3.88	3.88	3.75	3.89	3.71	3.79	22.91
Spring 2020	53	12		3.38	3.58	3.21	3.25	3.18	3.19	19.79

In all the offerings, the presentation groups contained a mixture of local and distance students, so portions of each of the presentations were given using video conferencing or similar tools in each of the classes.

Verbal feedback from students confirmed that the presentations from the spring of 2020 were harder to follow, and students were not convinced other group's projects worked by the presented material.

As was pointed out, the department has been engaged with distance delivery for almost ten years. All of our electrical engineering courses have a distance delivery section, and all of our faculty have been engaged in the delivery process. This meant that we had a minimum problem switching to online delivery. On the other hand, most of our students, like other institutions, had very limited experience taking online courses. As the data in Table 3 indicates, there was a drop in student evaluations for this course for the traditional face-to-face students. Table 4 shows the same assessments for distance students, and we do not see the same results. We should point out that students enrolled in our distance program are mature adults working full-time and have a good understanding of the requirements and the learners' expectations that come with the program. The requirement of having more discipline, which is part of online learning and was mentioned before, is also indirectly confirmed as another important factor. Results for distance education show an improvement in students' learning outcomes. We contribute this to the extra efforts that faculty did during the online-COVID by changing the mode of delivery from face-to-face to synchronous online. The previous offering for distance delivery included recorded lectures, online meetings, and hybrid (a combination of simulation and hands-on) labs. The recorded lectures were designed for in-class delivery mode. The recorded lectures for online-COVID were designed for online synchronous delivery.

Table 3. Learning Outcome Results for Logic and Digital Design Course - Face-To-Face Offerings

Learning Outcome Question	**Traditional students-rating before COVID (scale 1-5)**	**Traditional students-rating during online-COVID (scale 1-5)**	**%Change For traditional students**
Understanding of binary and hexadecimal number systems and two's complement arithmetic.	5	4.72	-5.5%
Understanding of Boolean Algebra and proficiency in the use of theorems and laws to manipulate Boolean expressions.	4.87	4.20	-13.8%
Understanding of digital systems, logic gates, truth tables, and combinational circuit design.	4.87	4.76	-2.4%
Ability to design, simplify, build, and test combinational circuits.	4.87	4.59	-5.8%
Ability to design and build circuits using medium-scale integration components such as Multiplexer, Decoder, and Adder.	4.87	4.40	-9.8%

Understanding of flip-flops. Ability to derive state table and state diagram.	4.6	4.05	-12.1%
Ability to implement a state machine using CAD tools for schematic capture and simulation.	4.53	3.91	-13.7%
Ability to design a simple state machine.	5	4.02	-9.0%
Average	4.83	4.33	-9.0%

Table 4. Learning Outcome Results for Logic and Digital Design Course - Distance Offerings

Learning Outcome Question	**Distance students-rating before COVID (scale 1-5)**	**Distance students-rating during online-COVID (scale 1-5)**	**%Change For distance students**
Understanding of binary and hexadecimal number systems and two's complement arithmetic.	4.83	4.5	-6.8%
Understanding of Boolean Algebra and proficiency in the use of theorems and laws to manipulate Boolean expressions.	4	5	25%
Understanding of digital systems, logic gates, truth tables, and combinational circuit design.	5	4.5	-%10
Ability to design, simplify, build, and test combinational circuits.	4.83	4.5	-4.9%
Ability to design and build circuits using medium-scale integration components such as Multiplexer, Decoder, and Adder.	4.67	5	-6.8%
Understanding of flip-flops. Ability to derive state table and state diagram.	4.5	5	11%
Ability to implement a state machine using CAD tools for	4.83	5	3.5%

schematic capture and simulation.			
Ability to design a simple state machine.	4.33	5	15.5%
Average	4.62	4.81	4.1%

We now examine the four research questions for this course.

Research Inquiry #1: Institutions/Departments with strong online/distance programs/infrastructure will receive a higher student satisfaction during COVID delivery. Although we do not have direct data to confirm or reject this inquiry, the indirect data that shows the difference between our traditional and distance deliveries indirectly confirms this claim.

Research Inquiry #2: Students with a significant online educational experience will benefit more during the COVID online delivery and obtain intended educational goals.

Based on the presented data, research inquiry #2 is "confirmed."

Research Inquiry #3: Student dissatisfaction with COVID online delivery is closely associated with their accustomed delivery methodology.

Based on the presented data, research inquiry #3 is "confirmed."

Research Inquiry #4: Student satisfaction and learning achievements will increase by adding more interactive activities to the online delivery.

Based on the presented data, research inquiry #4 is "confirmed." The online-COVID lectures included more interactive activities than the lectures, and data in Table 4 shows an increase in students' satisfaction with the learning achievements for distance students.

Next, we will look at the data for a course with a hybrid structure. The lecture part has been delivered synchronously online for all participants before and after the pandemic. The lab was face-to-face before the pandemic and online during the online-COVID period.

Introduction to Electric Machines and Power Systems (EE 3410)

Introduction to Electric Machines and Power Systems is a junior-level course that introduces the basics of the single-phase/three-phase power system and the operation principles of major power system devices such as the transformer, induction motor, and synchronous generator. Besides the theoretical content discussed in the lectures, this course also includes multiple lab projects on these topics to gain plenty of hands-on experience. The class changes during online-COVID are described below.

Lectures

Since this has been a streaming course before COVID, the lecture format was kept the same during the online-COVID. That is, the combined synchronous and asynchronous instruction handles the lecture. All students are required to attend synchronous live lectures. Meanwhile, all live lectures are recorded for students who have to miss the live lecture or who want to review afterward.

During the online-COVID period, the adoption of Zoom in the live lecture delivery offered more opportunities to engage students in the live lectures better. One example is to have short (3-5 minutes) in-class quizzes for students to finish during lecture time. The quiz scores are counted as either part of HW grade or class attendance grade. Students requiring accommodation for the time-based assignment are allowed to have more time to finish the quiz after the class. Other examples are polling, breakout rooms, and annotate tools to enable students to discuss in small groups and even directly write down their solution procedure on the lecture slide. All these methods effectively attract students' attention during lecture time.

Labs

Before the COVID, the course had all labs conducted face-to-face using LabVolt hardware and LVEMS software. In the face-to-face labs, 3-4 students form one lab group, 1-2 students work on wiring hardware modules in the Labvolt cabinet, and other students work on LVEMS software tools to take measurements such as meter readings oscilloscope waveforms, and phasor diagrams. Students can shift roles in the middle of labs.

During the COVID, Microsoft Teams is selected as the platform for students to work in groups online. The web application LVSIM is adopted to conduct all labs in simulation mode. LVSIM mimics both the LabVolt hardware modules/cabinet and the LVEMS software tools, which offers students similar hands-on lab practice as they would have in the face-to-face labs in the following aspects:

- Students get to operate the simulated LabVolt hardware and LVEMS software, such as choosing and placing modules into the cabinet, the wiring on the modules, turning around knobs to change voltage output, switching in/out the load, and using the same software tools to take measurements.
- Students encounter similar discrepancies in the simulated lab equipment, such as the fixed voltage source outputs a higher voltage value than the rated 120V for a single phase. The inductive load has inherent resistance influences the voltage-current relationship and presents nonzero real power consumption.
- The simulated hardware wiring can be saved as a lab project file and shared with other students in the Microsoft Teams. This makes it easy for students in the same group to switch roles, even they may be physically located in different places.
- The following figure shows a screenshot of the LVSIM user interface with hardware modules in a cabinet and different software tools.

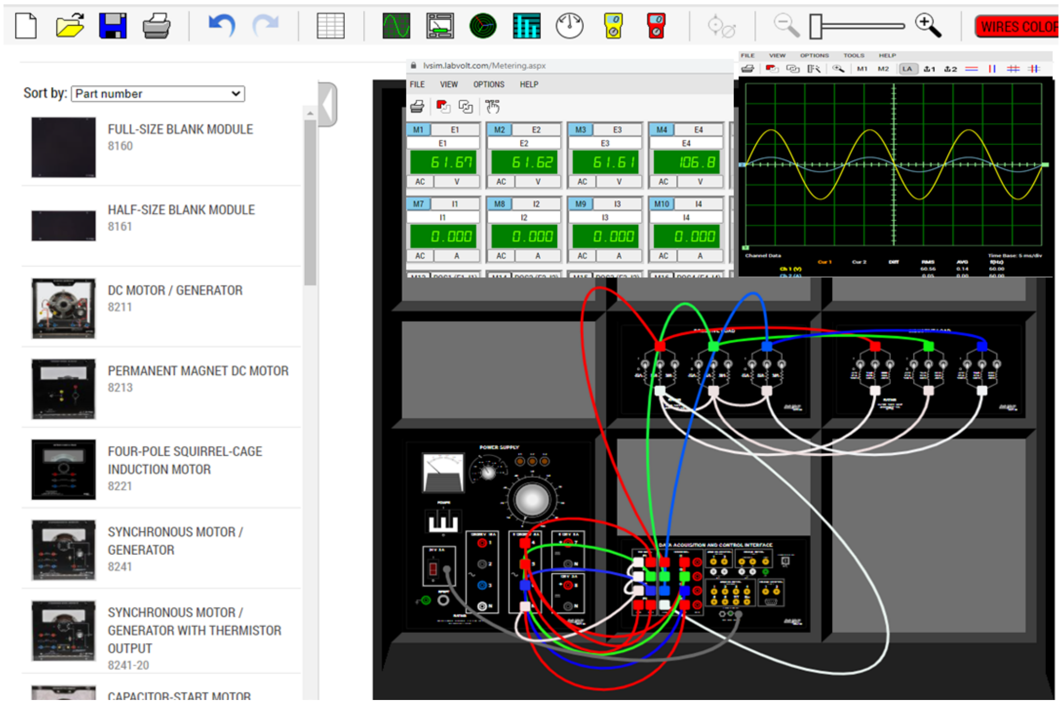

Figure 1 Web Application LVSIM User Interface

In addition, the web application LVSIM allows students to work on the lab outside the specified lab time, without requiring the instructor's presence, as would be required for a face-to-face lab due to the safety concern of the high voltage operation.

Although LVSIM provides students with similar lab exercises and additional convenience during the COVID, students working on this simulation platform inevitably miss some real-world experience that they would obtain when they physically work in front of the actual high voltage lab equipment. For example, students do not smell burning if they have a current value exceeding the equipment rating; they do not get nervous and excited by actually standing next to the induction motor and hearing its high-speed spinning sound. Moreover, as there is no real danger in an online lab, students tend not to take precautions to turn off the power first before they begin to change wiring, although LVSIM will pop up a warning message each time. This is a dangerous habit if students physically work on high voltage equipment. Since all students who take this course are junior-level students, they will stay in school for at least another year, it's planned to bring students back to the power lab when the COVID restriction is lifted, so they have a chance to work on the actual lab equipment under real-world high voltage environment.

Exams

All the class exams are changed from face-to-face exams with proctors to online exams during the COVID. Multiple online proctoring tools are available to protect the exam integrity, such as Examity, ProctorU, and Respondus. Since the UW-Platt purchased the Respondus Lockdown

Browser with Webcam, this tool is adopted for the class online exams. Resondus startup sequence includes:

- The webcam check.
- Students' photo ID.
- Environment check.
- Facial detection check that students need to complete before starting the exam.

The Lockdown Browser prevents students from visiting URLs to search for information during the exam. The exam videos for each student are available after the exam for the instructor to review regarding any incident flags.

The Respondus exam requirement is added to the class syllabus to ensure all students know what they need to prepare for the online exam at the beginning of the semester. A survey is done in the first week of the semester to see if all students have the required equipment for the exam. It turns out, on average, two or three students in a class with about 35 students may not have a webcam or stable internet access or just prefer to have the exam with an actual proctor. These students are directed to take exams with the UW-Platt testing center instead. A practice exam is also set up to allow students to practice on the Respondus before each exam.

To further ensure the integrity of the exams, multiple exam question banks for true/false statements, multiple choices/answers, essays, small and large numerical problems are built up. All midterm and final exam questions are randomly selected from these question banks. Students will get different true/false statements, multiple-choice/answers questions, and essay questions. Random values are generated for the same problem regarding the numerical questions, so students will get different numbers to work on. For the numerical problem that is difficult for students to enter solution procedure into the online exam page, students are asked to show their handwritten work in front of the webcam before they submit the online exam and then scan their work to submit to Dropbox within a specific time after the exam is done.

This course is an example of an online lecture and lab. The description, as mentioned above, explained a limited intervention. We now present the rating for the expected learning outcomes for this before and during the online-COVID.

Table 5, much like Table 3, shows a decline in ratings during the online-COVID, but the average rate is smaller. We contribute the smaller drop to the interventions as compared to EE 3770. This confirms our research inquiry #2. Table 6 shows the same ratings for the distance students, indicating positive changes between before- and online-COVID. This is again similar to what we observed for the EE 3770 course that confirms the added interventions to the lecture delivery produced positive results and confirms our research delivery questions that student satisfaction and learning achievements will increase by adding more interactive activities to the online delivery.

Table 5. Learning Outcome Results for Logic and Digital Design Course - Face-To-Face Offerings

Learning Outcome Question	**Traditional students-rating before COVID (scale 1-5)**	**Traditional students-rating during COVID (scale 1-5)**	**%Change**
Knowledge of voltage, current, complex power, and impedance relationships in single phase systems.	4.6	4.8	5.3%
Knowledge of voltage, current, complex power, and impedance relationships in three phase systems.	4.4	4.1	-6.4%
Familiarity with the theory, design, construction, application, and operation of certain major classes of AC power equipment including synchronous machines, transformers, induction motors, inductors and capacitors, transmission lines and interconnected power networks.	3.8	3.9	2.1%
Improved design and problem-solving skills through labs and projects involving electromagnetic devices.	3.4	3	-12.4%
Ability to operate and make measurements on high-voltage and high-current systems safely.	4.2	3.2	-24.1%
Ability to process laboratory data with software tools and write effective technical reports.	4.2	3.7	-11.9%
Average	4.1	3.8	-7.7%

Table 6. Learning Outcome Results for Logic and Digital Design Course - Distance Offerings

Learning Outcome Question	**Traditional students-rating before COVID (scale 1-5)**	**Traditional students-rating during COVID (scale 1-5)**	**% change**
Knowledge of voltage, current, complex power, and impedance relationships in single phase systems.	4	4	0%
Knowledge of voltage, current, complex power, and impedance relationships in three phase systems.	4	5	25%

Familiarity with the theory, design, construction, application, and operation of certain major classes of AC power equipment including synchronous machines, transformers, induction motors, inductors and capacitors, transmission lines and interconnected power networks.	3	4	33.3%
Improved design and problem-solving skills through labs and projects involving electromagnetic devices.	4	4	0%
Ability to operate and make measurements on high-voltage and high-current systems safely.	4	4	0%
Ability to process laboratory data with software tools and write effective technical reports.	4	4	0%
Average	3.8	4.2	8.7%

We now examine the four research questions for this course.

Research Inquiry #1: Institutions/Departments with strong online/distance programs/infrastructure will receive a higher student satisfaction during COVID delivery. As with the previous course, although we do not have direct data to confirm or reject this inquiry, the indirect data that shows the difference between our traditional and distance deliveries indirectly confirms this claim.

Research Inquiry #2: Students with a significant online educational experience will benefit more during the COVID online delivery and obtain intended educational goals.

Based on the presented data, research inquiry #2 is “confirmed.”

Research Inquiry #3: Student dissatisfaction with COVID online delivery is closely associated with their accustomed delivery methodology.

Based on the presented data, research inquiry #3 is “confirmed.”

Research Inquiry #4: Student satisfaction and learning achievements will increase by adding more interactive activities to the online delivery.

Based on the presented data, research inquiry #4 is “confirmed.”

Next, we will look at another course similar to EE 3770 but with significant interventions during the online-COVID. This course did not have any distance students enrolled during the online-COVID; therefore, that data portion is not included.

Introduction to Microprocessors (EE 3780)

This is a four-credit course that includes a laboratory component. During the online-COVID, the instructor for this course incorporated the idea of the virtual classroom by using a combination of Microsoft Teams and Zoom. Microsoft Teams was introduced as a virtual study room with many virtual tables (channels), where each table (channel) served as an integrated platform for group meetings. By integrating MS Teams with Zoom meetings, he offered a zero blackout, fully interactive learning environment. Clearly, this example illustrates an attempt to introduce active learning. The lab assignments, like other courses, were handled through simulations. Table 7 shows student learning outcomes before- and during online-COVID. As the data shows, the intervention has positively changed student learning outcome assessment. The results clearly show the interventions' positive effect and suggest that research inquiry #4 has a high impact than research inquiry #3 and suggests a pathway for a better student learning experience that would not require previous exposure to online learning. We believe this is a significant point that needs to be further studied.

Table 7. Learning Outcome Results for Logic and Digital Design Course - Face-To-Face Offerings

Learning Outcome Question	Traditional students-rating before COVID (scale 1-5)	Traditional students-rating during COVID (scale 1-5)	%Change
Understanding of binary and hexadecimal number systems and two's complement arithmetic.	4.58	4.81	4.8%
Understanding of Boolean Algebra and proficiency in the use of theorems and laws to manipulate Boolean expressions.	4.38	4.69	6.6%
Understanding of digital systems, logic gates, truth tables, and combinational circuit design.	4.54	4.88	7.0%
Ability to design, simplify, build, and test combinational circuits.	4.46	4.57	2.4%
Ability to design and build circuits using medium-scale integration components such as Multiplexer, Decoder, and Adder.	4.29	4.69	8.5%
Understanding of flip-flops. Ability to derive state table and state diagram.	3.92	4	2.0%
Ability to implement a state machine using CAD tools for schematic capture and simulation.	3.83	4.06	5.7%
Ability to design a simple state machine.	3.71	4.19	11.5%
Ability to write proposals, progress reports, and test reports.	3.83	4.33	11.5%
Average	4.17	4.47	6.7%

We now examine the four research questions for this course.

Research Inquiry #1: Institutions/Departments with strong online/distance programs/infrastructure will receive a higher student satisfaction during COVID delivery. As with the previous course, although we do not have direct data to confirm or reject this inquiry, the indirect data shows that the course intervention can have the same positive effect as prior experience.

Research Inquiry #2: Students with a significant online educational experience will benefit more during the COVID online delivery and obtain intended educational goals.

We did not have related data to make a judgment for this inquiry.

Research Inquiry #3: Student dissatisfaction with COVID online delivery is closely associated with their accustomed delivery methodology.

We did not have related data to make a judgment for this inquiry.

Research Inquiry #4: Student satisfaction and learning achievements will increase by adding more interactive activities to the online delivery.

Based on the presented data, research inquiry #4 is "confirmed."

Remarks and Conclusion

In this paper, we presented our teaching approach for electrical engineering courses with and without lab components during the COVID time that all course deliveries were made through online methods. We stated four research inquiries and used the expected learning outcomes surveys to either accept or reject them. The data indirectly confirmed the importance of online delivery structure for institutions/departments and directly confirmed the importance of prior experience with online courses for students as a factor that will influence their learning ability. The data also confirmed that student satisfaction is influenced by the delivery methodology they are accustomed to and introducing interventions that can make the delivery more interactive can overcome the negativity they may have toward online learning.

Based on the data, we will introduce appropriate technologies in our online courses to make them more interactive and follow an active learning environment. We believe the pandemic has provided an opportunity to move some of the courses to a flipped classroom model and the labs to a more flexible model that can include delivery outside the set schedule time using equipment such as Analog Discovery. Our experience has also revealed how virtual teams and online teaching can be improved.

Finally, like other institutions, we observed an enrollment drop during the pandemic. The general assumption was that the decline was related to the delivery preferences of students, and by moving to a face-to-face format, the enrollment will recover. This turned out to be not an entirely correct assumption. Furthermore, even after switching to a face-to-face delivery format, many students requested distance/online delivery options. We intend to investigate this incidence further.

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