2018 ASEE ANNUAL CONFERENCE & EXPOSITION
JUNE 24–27, 2018
SALT PALACE CONVENTION CENTER
SALT LAKE CITY, UT

Paper ID #22968

A Comparative Study of Distance Education and Face-to-Face Lab Students

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ABSTRACT

There is a broad consensus in Science, Technology, Engineering and Mathematics (STEM) academia and accreditation bodies that engineering and engineering technology courses with intensive lab activities can be delivered online. There is ample prior research that assessed the pedagogical effectiveness of lab intensive course delivered in a distance education format. Yet, ABET (Accreditation Board for Engineering and Technology) has only a handful of listed accredited online engineering and technology programs at its website. In an effort to increase accessibility to non-traditional students seeking to advance their career in Electrical Engineering Technology, a new online Electrical Engineering Technology program was recently launched. The development and delivery of the lab component of Digital Fundamentals, one of the courses in this program, is presented. Several research questions were asked prior to and during the development of the program. These questions were as follows: i) Can online courses be delivered while maintaining rigorous accreditation standards? ii) Can teamwork be encouraged and maintained in an online setting? iii) Can the integrity of the assessment processes be preserved? And iv) can the pedagogical effectiveness of the lab experiences be evaluated?

A study of two groups of students in a Digital Fundamentals lab-based course is presented. Both groups of students completed identical experiments and differed only in the environment and test equipment used to conduct the experiments. The on-campus students completed the labs in the regular semester in the physical laboratory facility on campus. The online (distance education) students also completed the lab in the regular semester during the same time period as the on-campus students. However, the online students used breadboards and miniaturized test equipment and portable power supplies. Both groups were supplied with the same components such as integrated circuit chips. Both groups were assigned lab partners and encouraged to work in pairs. The online group utilized webcams and video conferencing software to collaborate with their lab partners. In this paper, we present the findings of this study with respect to the aforementioned research questions. We also compare the performance of both groups.

INTRODUCTION

In academia and industry, online learning has become very popular[1,2]. There are various educational research projects that have demonstrated the pedagogical effectiveness of online learning. The Science, Technology, Engineering and Mathematics (STEM) academia has also demonstrated through prior research and projects that lab activities can be delivered online[3-11]. However, very few lab-intensive STEM programs are offered in their entirety online. To increase accessibility for working adults, a new online Electrical Engineering Technology (EET) program was launched in the Fall 2017 semester. This paper presents the results of a comparative study of two groups of students (online and on-campus) doing the same lab-intensive course. The course is Digital Fundamentals, a 200-level core requirement of the EET curriculum. Four important research questions were posed:

i. Can online courses be delivered while maintaining rigorous accreditation standards?
ii. Can teamwork be encouraged and maintained in an online setting?
iii. Can the integrity of assessment processes be preserved?
iv. Can the pedagogical effectiveness of the lab experiences be evaluated?

METHODOLOGY

Two groups of students were studied: an on-campus (traditional) group and an online group. Both groups were registered and attended the same Digital Fundamentals course in Fall 2017. The course instructor, lab instructor/teaching assistant, curriculum and course content were the same for both groups. The course rubric was identical except for the assessment of the lab. For the on-campus course, the students conducted the experiments in the physical laboratory on a weekly basis. The online students conducted the same labs at home using miniaturized test instruments and a breadboard. While the on-campus group were expected to conduct the experiments under direct supervision during the 2 hours lab period each week, the online students completed the lab at their leisure during the course of the week. To document their findings the on-campus students submitted a lab report on the completion of each experiment, while the online students submitted a 2 to 5 minutes Youtube-like video explaining their experiment, along with a completed online lab-form. The web form included fields such as: name, title, lab partner, results, etc. They could also attach additional files that may contain handwritten calculations or circuit diagrams. Both groups were divided to work in pairs with a lab partner but must submit videos and web forms or lab reports individually. All labs were submitted via the Desire to Learn (D2L) learning management system.

The traditional course lectures were delivered face-to-face using PowerPoint and the whiteboard as the main teaching tools. The online lectures were delivered via interactive multimedia that included voice-over PowerPoint lectures, animations, virtual whiteboard, and whiteboard applications such as ShowMe. The 4 credits course has a lab component and was delivered by the instructor, who was assisted by a graduate student/teaching assistant (TA). The online course was delivered in an asynchronous format; however, tutorials were delivered in real-time on a weekly basis. The TA interacted with the students via Zoom videoconferencing and webinar application. Through this medium, the TA was able to do the following: share videos via webcam, share Zoom's inbuilt whiteboard feature, share a computer screen, or share files. Utilization of the whiteboard was encouraged, since this facilitated a very interactive and visually stimulating way to clarify difficult concepts and to solve mathematical or design problems. The TA was available six hours per week for tutorial sessions, consisting of three 2-hour sessions in the evenings and on weekends. The tutorial sessions were optional for the students, who were allowed to attend for any amount of time. However, the TA was always available in accordance with the posted schedule. Likewise, the TA was available six hours each week to attend to the needs of traditional students during on-campus office hours.

From prior work the instructors realized the importance of immediate feedback and collaboration in the online environment, especially when working on lab activities. Each student was assigned a lab partner and encouraged to collaborate with his/her lab partner via the university-provided Zoom videoconferencing software. The lab instructor, who was also a graduate student, was also available for 6 hours (three 2-hour slots per week) to interact via Zoom in real-time with students who were having issues with their labs. The lab instructor used an adjustable dual camera system that facilities high definition (HD) quality video sharing. A typical lab session consisted of the lab instructor sharing a particular circuit arrangement on the breadboard to explain how the circuit should be correctly wired. In-turn students would share, via their webcam, their breadboard circuits and discuss their lab related issues.

Sample labs

Two sample labs are provided below. These are two summaries of the actual hands-on activities in the sequence of experiments both groups of students performed.

EXPERIMENT 1

Number Systems

Objective

The objective of the lab is to convert binary or BCD numbers to decimal. Each group will construct a portion of a digital system that decodes a BCD number and displays it on a seven-segment display.

Procedure

1. Datasheets can be found online using Google. You must enter the part number, found on top of each component, to obtain the appropriate pinouts. Draw a schematic with all pins labeled, it will help you as you are applying the circuit to your breadboard.
2. Begin by designing the circuit in Figure 1. It consists of a four-switch system; each switch represents a bit of a binary number. Connect the components seen in Figure 1 to your breadboard. Double-check the polarity of the LEDs. After wiring the circuit, connect the power and test each switch to see that it lights an LED.
3. Remove the power and add the second circuit, shown in Figure 2. Make sure you place a 330Ω limiting resistor between each output of the decoder and each input to the MAN-74. Additionally, place a pull up resistor to +5 Volts; this assures a solid HIGH on both the lamp test (LT) and the Blink enable (BI). The latch enable (LE) should be tied to ground.
4. When you have completed the wiring, apply power and test the circuit. Use the binary numbers in the table provided as your input. The last six codes are invalid BCD codes; however, you can set the combinations in binary and observe the display. It will show a blank display or a unique display for each of the invalid codes. Complete the table by recording the numerical appearance of the seven-segment display in the output column.

Figure 1

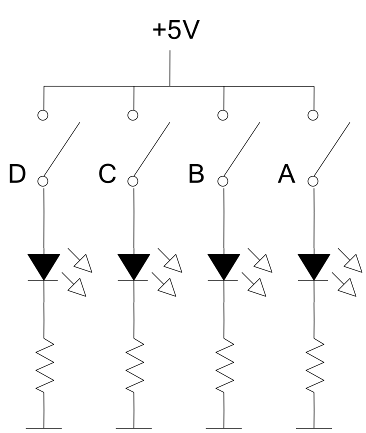
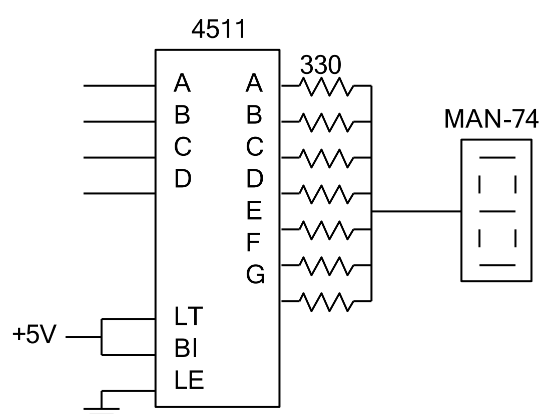


Figure 2



Inputs		Output
Binary Number	BCD Number	Man-74 Display
0000		
0001		
0010		
0011		
0100		
0101		
0110		
0111		
1000		
1001		
1010	Invalid	
1011	Invalid	
1100	Invalid	
1101	Invalid	
1110	Invalid	
1111	Invalid	

Questions

1. Assume the switches are set to 1000, but the display shows a zero. What are three possible causes for this error?

2. Looking at the possible causes of error from question 1, how would you go about troubleshooting the problem?

3. Explain the difference between binary and BCD.

4. Why do we tie the lamp test (LT) and blink enable (BI) to +5V, and the latch enable (LE) to ground?

Apparatus

330Ω Resistors (11)
Man-74 Seven-Segment Display
LEDs (4)
4511 BCD to Seven Segment IC
DC Power Supply
Digital Multimeter

EXPERIMENT 5

Seat Belt Warning System

Objective

The purpose of this experiment is to design a seat-belt alarm system that uses an LED as an indicator when the seat-belt is unfastened. The design specifications involve examining four (4) sensors or inputs. The LED will illuminate when various combinations of the inputs assume certain states.

Procedure

1. The first sensor (Sensor A) is a switch that indicates whether a key is in the ignition. Additionally, the switch will produce a LOW (while the key is in). The driver's seat also has a switch (Sensor B) that closes and produces a LOW when the driver's seat is occupied. The driver's seat belt has a switch (Sensor C) that produces a LOW when the driver's seat belt is fastened. The passenger's seat also has a compound sensor (Sensor D) that monitors both the passenger seat and its seat belt. It produces a LOW when the passenger seat is occupied and the passenger seat belt is fastened. If the passenger seat is occupied but its seat belt is not fastened, then it produces a HIGH.

2. The seat belt alarm (LED) should indicate when an alarm condition exists. An alarm condition exists if a key is in the ignition AND either (1) the driver's seat is occupied but the seat belt is unfastened, OR (2) the passenger's seat is occupied and the seat belt is unfastened. Your task is to design a digital circuit that uses the LED to warn of these alarm conditions.

3. Viewed as a black box, your system has 4 inputs, and one output. You can test your design by simply grounding the input for a 0 or placing the input at +5V for a HIGH.

4. The report for this lab should be very extensive in explaining how you designed your circuit. Discuss any problems you had and how you fixed them or expected to fix them.

Apparatus

Dipswitch
4011 (NAND) IC
74LS04 (NOT) IC
74LS32 (OR) IC
LED
DC Power Supply
Digital Multimeter

Current assessment methods

Both group of students were assessed using the same test instruments. Students were assessed through un-proctored weekly quizzes and homework, and proctored mid-term and comprehensive final examinations. The proctoring was done online via monitoring and lockdown browser software applications. Certain protocols were put in place to ensure that the integrity of the examination process was not compromised. These include the following: i) students were required to present a current photo ID in front of the webcam prior to starting the exam, ii) students were required to take a self photo, using the webcam, immediately prior to beginning testing, iii) students were required to conduct a panoramic scan of the entire room with the webcam before beginning the exam, and iv) no one else above the age of fourteen was allowed in the room during testing.

RESULTS and DISCUSSION

To arrive at the results of the comparative study we addressed the previously mentioned research questions individually.

Can online courses be delivered while maintaining rigorous accreditation standards?

In order to address this question we will utilize ABET's general criteria (See Table 1). Please note that the course was delivered using the same faculty and student outcomes. Additionally, there were no modifications in the admission nor graduation process. Therefore, the following criteria were unaffected by the introduction of the course: Students, Program Educational Objectives, Continuous Improvement, Curriculum, Faculty, and Institutional Support. As a result, we will focus on Student Outcomes and Facilities. This course is used to evaluate Student Outcome c- "an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes." Based on students' performance in the lab they overwhelming satisfied this criterion (See Table 2). Additionally, the overall performance in the homework and proctored exams showed that the online students performed as well or better than the traditional students. Also, to satisfy criterion 7- Facilities, we ensured that the tools used were modern and appropriate and students were given sufficient guidance via online videos and real-time videoconferencing sessions.

Table 1. Summary of ABET's General Criteria

General Criterion	Description
1. Students	"Student performance must be evaluated. Student progress must be monitored to foster success in attaining student outcomes, thereby enabling graduates to attain program educational objectives. Students must be advised regarding curriculum and career matters."
2. Program Educational Objectives	"The program must have published program educational objectives that are consistent with the mission of the institution, the needs of the program's various constituencies, and these criteria."
3. Student Outcomes	"a. an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities; b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies; c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes; d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;

	e. an ability to function effectively as a member or leader on a technical team; f. an ability to identify, analyze, and solve broadly-defined engineering technology problems; g. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature; h. an understanding of the need for and an ability to engage in self-directed continuing professional development; i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity; j. a knowledge of the impact of engineering technology solutions in a societal and global context; and k. a commitment to quality, timeliness, and continuous improvement."
4. Continuous Improvement	"The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained."
5. Curriculum	The curriculum must effectively develop the following subject areas in support of student outcomes and program educational objectives: Mathematics, Technical Content, Physical and Natural Science, The Integration of Content, Cooperative Education, and Advisory Committee.
6. Faculty	"Each faculty member teaching in the program must have expertise and educational background consistent with the contributions to the program expected from the faculty member."
7. Facilities	i. Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning. ii. Modern tools, equipment, computing resources, and laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes and to support program needs. iii. Students must be provided appropriate guidance regarding the use of the tools, equipment, computing resources, and laboratories available to the program.
8. Institutional Support	"Institutional support and leadership must be adequate to ensure the quality and continuity of the program."

Can teamwork be encouraged and maintained in an online setting?

Initially, it was determined that online students should work in pairs while doing experiments, like their on-campus counterpart, in order to encourage teamwork. However, while all online students were assigned a partner through an open process that encouraged students' input and facilitated preferences, less than 70% of the online students frequently collaborated with their partner. This was determined via a post-course survey. Reasons stated for non-frequent communication were mainly personal and scheduling issues. Informal survey (questioning) by the course instructor during the semester shed some light that the collaboration was not at the level he would have preferred. The instructor decided that the best approach might be simply to provide the opportunity to collaborate and encourage the students to do so, rather than attempting to enforce cooperation. Hence, while existing technology allowed real-time collaboration for students even while doing hands-on activities, students may find it challenging to do this frequently. In the future, incentives will be explored in order to enhance the degree to which the online students collaborate; since, teamwork is an essential element of the curriculum.

Can the integrity of assessment processes be preserved?

It was determined that using a lockdown browser and monitoring (proctoring) software via webcam was very effective in preserving the integrity of the assessment process. Human review of the recorded sessions showed very little, if any, evidence of cheating. Also, there was a strong correlation with student's performance in the homework and unproctored quizzes and the proctored exams.

Can the pedagogical effectiveness of the lab experiences be evaluated?

The online students' performances in their experiments were comparable to the traditional students (See Table 2). Also, it was determined through the student-lab instructor interaction that the online students in general had a better grasp of the experiments than the traditional students. This we believe is due to the fact that although the online students had partners, each student were required to do the lab and record the functional experiment, which was normally a working circuit. While the traditional student worked almost entirely, with the exception of individually report, with his/her partner and was not required to individually explain the experimental process and results via video.

Table 2. On-Campus versus Off-Campus Average Grading Comparison

	Homework	Labwork	Examinations
On-Campus	90.19%	97.37%	76.25%
Off-Campus	86.54%	96.46%	81.25%

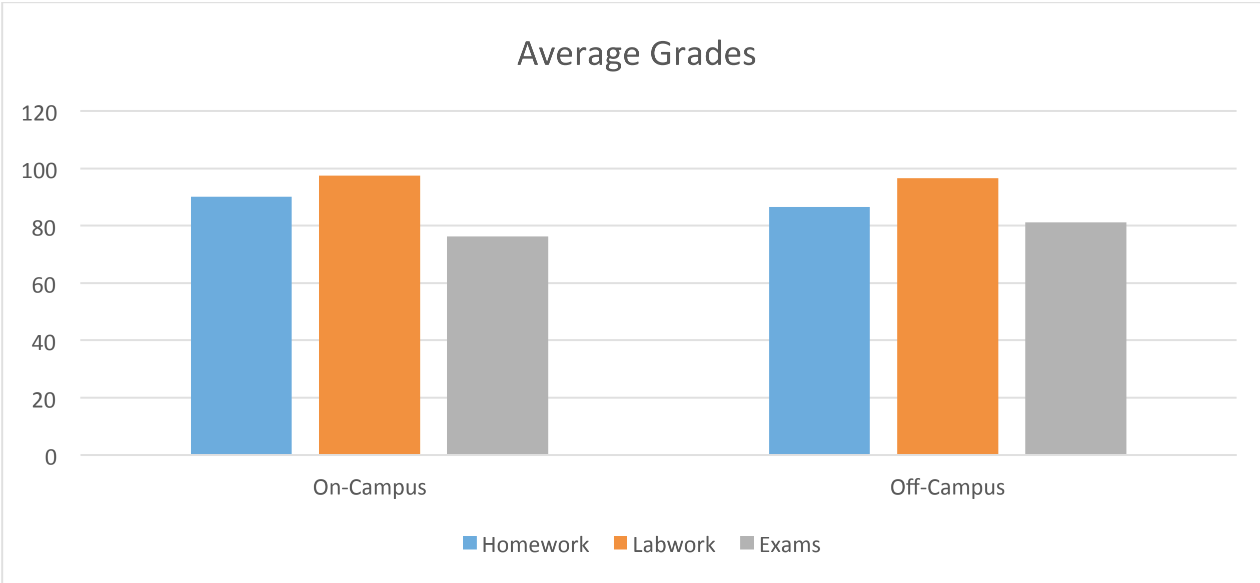


Figure 1. Average Grade Comparison

CONCLUSION

This study successfully answered the four important research questions that were posed. Demonstrating that lab intensive engineering and engineering technology courses can be delivered online while maintaining ABET's accreditation criteria and important academic standards. Neither the rigor nor the quality of the course needed to be compromised. There is some inherent difficulty in establishing frequent collaboration among online lab partners. However, incentives for cooperation can potentially encourage teamwork. Our research suggests that the optimal approach may be to provide opportunities for collaboration rather than forcing cooperation. This is recommended because the non-traditional student is typically highly motivated but oftentimes prefer to work according to his/her own schedule that may not coincide with his/her partner's schedule. Through computer based monitoring and a lockdown browser we believe that the integrity of the assessment process can be preserved. Lastly, the online students' performance was as good as traditional (on-campus) students. This provides some evidence that conducting the labs and attending the lectures in the distance education format were as pedagogically effective.

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