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Transition to Virtual Instruction

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Transition to Virtual Instruction

During the spring 2020 academic term, students and instructors were required to transition from in-person instruction to a virtual learning mode. This transition occurred at the mid-point of the semester, moving from an in-person student-teacher interaction to a virtual environment. While this transition was unexpected for students and instructors, it was also an opportunity to understand how student learning outcomes were affected and how students reacted to this change. Both lecture and laboratory sections were evaluated in this study, for both lower-division and upper-division courses. Through a comparative survey, students were asked to evaluate the seven student learning outcomes articulated by the Accreditation Board for Engineering and Technology (ABET) during the in-person and virtual portions of the courses. Survey results showed that students rated their learning outcomes higher for in-person instruction for all course types and levels. The largest difference in how students rated their learning outcomes for before and after the transition to virtual instruction was seen for their ability to function effectively on a team. The smallest difference was seen for their ability to apply engineering design to produce solutions. Additionally, in a time in which our society required social distancing, students expressed that their biggest struggle was that they could not interact with their peers.

Introduction

While virtual instruction has been in practice for over a decade, its effectiveness continues to be investigated [1]. According to Banas et al. [2], distance learning can be traced back to 1892. Several studies conducted a meta-analysis to evaluate the effectiveness of virtual instruction with mixed results [3-6]. The primary benefits of virtual instruction include cost effectiveness [7] and expanding access to post-secondary education on a global scale [8].

Several studies have investigated laboratory courses in a virtual setting. One study from Corter et al. [9] found that remote and simulated laboratories are as effective as hands-on labs in teaching course concepts. Another study by Viegas et al. [10] showed that remote laboratories were useful for basic courses, but not as effective on more advanced courses. While there is growing popularity to offer courses based on virtual instruction, significant challenges remain for engineering education using this format. These challenges include the fundamental need for experimentation and for students to learn through interactions with hardware [11].

Significant scrutiny of virtual instruction is expected to occur during the accreditation process of engineering programs that have incorporated virtual methods into their curriculum. The Accreditation Board for Engineering and Technology (ABET) conducts a review process of degree programs to verify that they meet quality criteria. One such criterion includes student learning outcomes (SLOs) which assess student abilities in areas of conceptual understanding, design skills and teamwork [12]. This criterion will be the main focus of this study.

During the spring 2020 academic term, instructors and students were required to undergo a transition from traditional in-person instruction to a virtual mode during the onset of the COVID-19 global pandemic. The effects of this transition were evaluated in this study with attention to

ABET student learning outcomes before and after the transition, comparisons of the two modes of instruction, and considerations of online tools.

Background

The California State Polytechnic University, Pomona (Cal Poly Pomona) prides itself on its Learn-by-Doing approach for providing students a hands-on methodology to education. In the spring 2020 semester, however, this approach was challenged given the start of the COVID-19 global pandemic that required distance learning. Both lecture and laboratory coursework were transitioned from in-person to virtual instruction. Lecture coursework offered a relatively smooth, more natural conversion to platforms, such as Zoom and Blackboard. However, shifting laboratory experiments to a virtual environment was not as straightforward because students did not have access to necessary laboratory equipment or software licenses. In addition, students in upper-division coursework had the advantage of those students in lower-division courses as they were familiar with the university system and the functions of certain online tools, such as Blackboard. Many students enter the four-year university system after transferring from a junior college, making the lower division courses some of the first courses they encountered at Cal Poly Pomona.

Courses within the Department of Industrial and Manufacturing Engineering at the California State Polytechnic University, Pomona (Cal Poly Pomona) that cover manufacturing processes include both a lecture and a laboratory component. While the lecture component has provided the theoretical concepts of manufacturing processes, the laboratory portion offered hands-on instruction on equipment for casting, machining, metal forming, plastics, and welding. During the laboratory instruction, students would be guided by the instructor to do the laboratory exercises, through which, they would gain a 'feel' for the equipment and its operation. During virtual instruction of a laboratory exercise, students would be provided with relevant videos and/or a description of how the laboratory would be carried out. Laboratory assignment would then be subsequently completed by students to test their knowledge of the exercise.

As an accredited institution, Cal Poly Pomona goes through a six-year cycle for its Accreditation Board for Engineering and Technology (ABET) reviews. Over the six years between reviews, engineering departments collect data on student learning outcomes (SLO). This data is collected to assess student work for the following seven SLOs:

- **SLO 1**: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- **SLO 2**: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- **SLO 3**: an ability to communicate effectively with a range of audiences.
- **SLO 4**: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

- **SLO 5**: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- **SLO 6**: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- **SLO 7**: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

These seven SLOs were the focus of this study. Understanding how student learning outcomes are affected by virtual instruction compared to in-person is significant to all fields of study. Therefore, this work provides a comparison between in-person and virtual instruction through student feedback on their experiences in both environments in a single academic term. The spring 2020 term, while difficult for both students and instructors, provided a unique opportunity for this comparison.

Methods

This study involved two undergraduate courses that covered traditional manufacturing processes at the lower-division level and advanced manufacturing processes and automation at the upper-division level. Both courses had a lecture and laboratory component. Students majoring in mechanical engineering, industrial engineering and manufacturing engineering are required to take these courses. Data was collected anonymously from the two lecture sections (one each from upper- and lower-division) and four laboratory sections (two each from upper- and lower-division). Each of the four laboratory sections comprised of 16-17 students, while the lecture sections for upper- and lower-division had 42 and 37 students, respectively, resulting in feedback from a total of 146 students. The transition from in-person to virtual instruction occurred at the midpoint of the academic term. Therefore, each type of instruction spanned eight weeks of the spring 2020 semester.

Table 1 includes the lecture activities during both instructional environments of the courses. To streamline lecture sessions across the transition, the instructor of both lecture courses continued to provide similar lecture activities for students. These activities included synchronous lectures and in-class assignments to help engage students. In the virtual environment, Blackboard was used to assess student learning. Settings for these assessments included randomized questions, no backtracking, one question at a time, and timed completion. During the assessments, students were required to be on Zoom with their cameras on.

Table 2 shows the topics of laboratories that were conducted during each portion of both the lower- and upper-division laboratory courses. Laboratory activities for the lower-division course were much more hands-on than those of the upper-division course. Concepts such as machining and welding can be understood in theory, but are not completely grasped without the physical interaction with the equipment to learn the nuances of the activity. For example, holding a welding torch at the appropriate distance from the workpiece to achieve a high-quality weld joint is something that is acquired only through trial-and-error in a laboratory setting. Other topics, such as those covered in the programmable logic controller (PLC) and compact mechatronic load (CML) laboratories, involve programming a device that can be simulated remotely.

Table 1: Lecture activities for both in-person and virtual portions of the courses.

Lecture Activity	In-Person	Virtual	Purpose
Lecture	live lectures	synchronous lectures	provide notes that serve as study guide
In-Class Assignment	student groups work to solve problems	breakout rooms for student groups to work on problems	offer student peer interactions to solve problems together
Pre-Quiz	paper quiz at beginning of class session	quiz given on Blackboard prior to class session	assessment tool to hold students accountability for pre-class work
Post-Quiz	paper quiz after covering material in class	quiz given on Blackboard after covering material in class	assessment tool to evaluate student learning of course material
Exam	paper exam after covering several weeks of course materials	exam given on Blackboard covering several weeks of course materials	assessment of student learning of several course concepts

Table 2: Laboratory activities for both in-person and virtual portions of the courses.

Lower-Division Laboratory Course		Upper-Division Laboratory Course	
In-Person	**Virtual**	**In-Person**	**Virtual**
Heat Treatment	CNC G-Coding	Design Lab	PLC III
Casting I	Machining (Mill)	3D Space	CML I
Casting II	Machining (Lathe)	Robotics	CML II
Plastics	Welding I	Logic Gates	CML III
Sheet Metal	Welding II	PLC I	Materials Resource Planning
Dimensional	Design Lab	PLC II	Group Technology

ABET Student Learning Outcomes

To evaluate and compare how effective students found the in-person and virtual instruction portions of the lower- and upper-division lecture and laboratory courses, student surveys were conducted. Student feedback was collected on how they rate their ability to achieve the seven SLOs that ABET has set forth to evaluate programs during their accreditation process, for both the in-person and virtual portions of the courses in this study.

All student surveys conducted in this study used a 5-point Likert scale. The sample size for the entire study was 146. To evaluate the survey data, weighted averages were calculated in which the following weights were applied:

5 = Very Good
4 = Good
3 = Fair
2 = Poor
1 = Very Poor

All courses in this study, including multiple laboratory sections, were taught by the same instructor. Data from multiple laboratory sections are combined to provide a single data sets for comparison. Weighted averages were calculated from the 5-point Likert data to evaluate student feedback through comparisons and differences between the in-person and virtual modes of instruction. Student grades were also examined for each instructional mode.

The Student Experience of Virtual Instruction

To understand student experiences during the transition to virtual instruction, they were asked to provide their biggest struggles and biggest advantages of virtual instruction compared to the in-person environment. In addition to this, students were also asked to indicate which environment they would choose in the future, if they had a choice: in-person or virtual. If a virtual environment was their option, students were also asked if they preferred a synchronous, asynchronous, or hybrid form of instruction delivery.

Online Tools

With the transition to virtual instruction, online tools were utilized to facilitate instruction in a virtual environment. Tools that were used in this study included Blackboard and Zoom. The Blackboard learning management system was used as the primary means for communicating course announcements, post assignments and videos, administer quizzes and exams, and disclose course grades. Students were asked how effective each of these items were through the Blackboard platform.

Zoom was also evaluated by students to determine how effective Zoom sessions were for their learning of course subjects. In addition, students were asked if they attended all Zoom class sessions. If they did not attend, students were asked for their reasons for their absence. Weighted averages were taken of this data for comparison using the following weights:

5 = Very Effective
4 = Somewhat Effective
3 = Neither Effective Nor Ineffective
2 = Somewhat Ineffective
1 = Ineffective

Results and Discussion

ABET Student Learning Outcomes

Data taken from student surveys included their evaluation of the seven ABET student learning outcomes (SLOs) of their experience in an in-person and virtual environment. For each SLO, either in the in-person or virtual environments, the weighted average was taken using the Likert scale. This weighted average data was compiled into plots for lecture and laboratory coursework for both lower- and upper-division courses. A summary of this data was provided in Figures 1. For all courses evaluated in this study, students rated their ability to achieve every SLO lower during virtual instruction than in the in-person environment. In Figures 1, a line was included to indicate the 2 SLOs that fall below this line and received the lowest 2 ratings for virtual instruction for each course type. From this, it was seen that SLOs 3 and 5 were the lowest for all courses. While SLO 3 pertains to the ability to communicate effectively with a range of audiences, SLO 5 concerns a student's ability to function effectively on a team. It was therefore concluded that students perceive a deficiency to develop their abilities to communicate and function on a team in a virtual instruction environment.

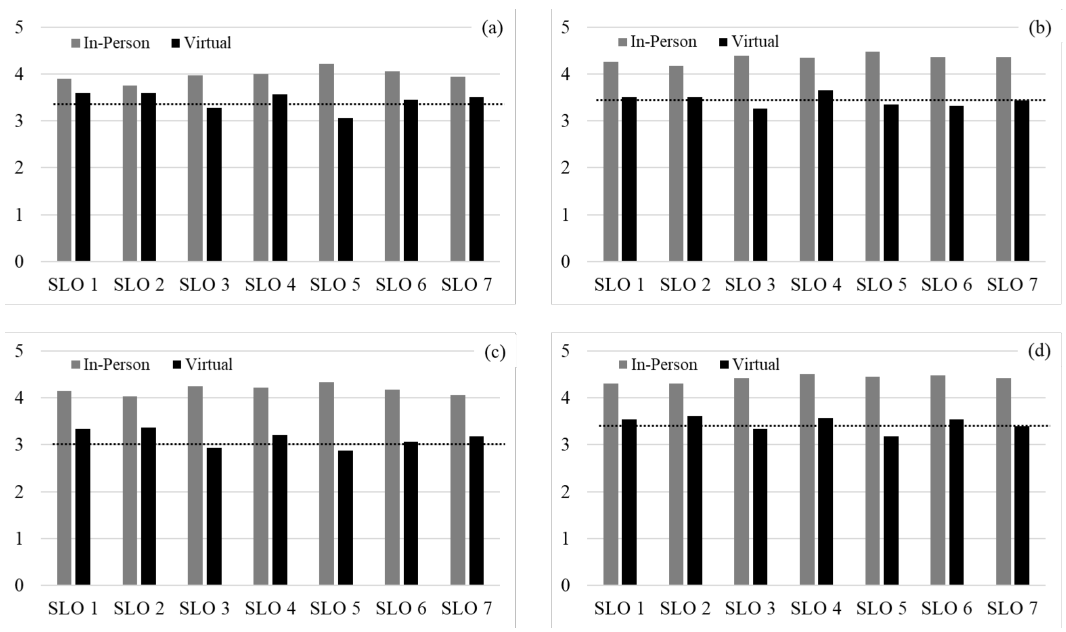

Figure 1: Weighted average data of student feedback of seven ABET student learning outcomes (SLOs) for (a) lower-division lecture, (b) upper-division lecture, (c) lower-division laboratory, and (d) upper-division laboratory courses.

To further compare the student experience in the in-person and virtual environments in terms of student learning outcomes, the difference in the SLO weighted averages for the in-person and virtual environments was taken for each type of course. As the virtual instruction was rated lower for every course type, the value of this difference was always positive. For each course, Figure 2 displayed the difference values plotted against each SLO with lecture, laboratory, lower division, and upper division courses indicated. Difference values larger than unity were observed mainly for SLOs 3 and 5, emphasizing that students perceive a struggle to progress their communication and team skills in a virtual environment. The smallest difference values were seen for the lower-division lecture portion, while the largest difference values were seen for the laboratory portion of that course. This result indicated that the laboratory portion of the lower-division course fared better in the in-person environment as opposed to virtual instruction. For the upper-division course, similar difference values were observed for the lecture and laboratory portions for each SLO. However, since these differences were high, relative to the other courses in this study, this indicated that upper-division coursework, regardless of being a lecture or laboratory setting, was highly affected by virtual instruction. It should also be noted that the smallest differences for all types of courses was seen for SLO 2. This result indicated that while a virtual environment may be necessary, students continue to be able to apply engineering designs to produce solutions.

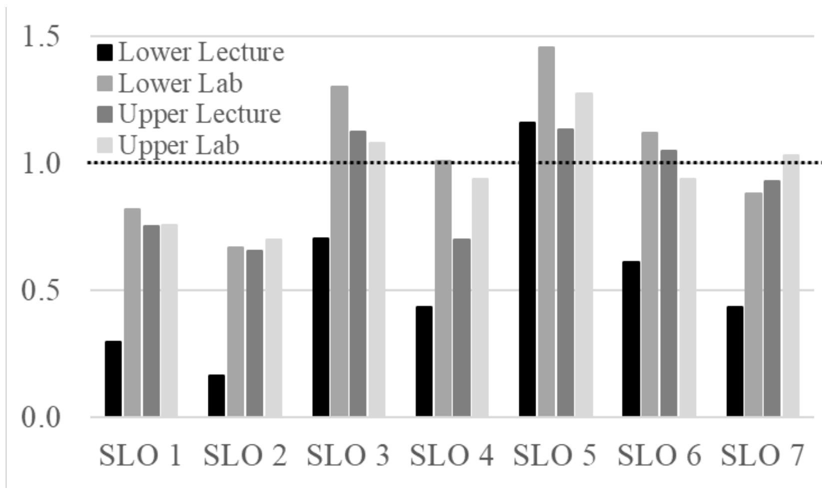

Figure 2: Differences in weighted averages of student learning outcomes (SLOs) between in-person and virtual environments for each course type.

Students have also expressed the need for hands-on learning in their rating of SLO 6. In Figure 2, the highest difference values were observed for SLO 3 and 5. The third highest value was given to SLO 6, which assesses student ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. While the student rating for the lower-division lecture course had a smaller difference for SLO 6, students perceived a larger difference between in-person and virtual instruction for the lower-division laboratory. The content for this course includes manufacturing processes, emphasizing that students require hands-on laboratory exercises to carry out experiments and evaluate data to draw appropriate conclusions.

Student Grades

For an objective evaluation of student learning, quiz and exam grades from lecture courses along with laboratory assignment grades were considered during in-person and virtual instruction formats. Figures 3a and 3b show average quiz and exam grades, respectively, from both in-person and virtual formats for lecture coursework. It is seen that for both the lower- and upper-division courses, students received higher grades in the virtual instruction format. In both formats, the delivery of lecture materials was similar, in the sense that the instructor provided visuals examples and study guide notes during lecture sessions. Quiz grades were averaged for the in-person and virtual portions. For exams, Midterm I was held in-person, while Midterm II and the Final were during the virtual portion. The increased improvement in quiz and exam grades observed for the upper-division lecture course when transitioning from the in-person to the virtual environment was partially attributed to the advanced ability and maturity of these students. The study conducted by Miller et al. [13] showed that student success in online courses is dependent on student ability or maturity to complete tasks with less guidance. In addition, it should be noted that in previous years, exam grades in the upper-division course tended to be higher for Midterm II and the Final exams.

Another key difference was in the administering of quizzes and exams for which proctoring was either in-person or online via Blackboard and Zoom. Since monitoring students for honesty practices, such as not looking for exam solutions in the textbook or from other sources, was difficult during an online exam, the higher grades cannot be attributed to enhanced learning by students. While grades were higher in the virtual format, this result was not necessarily an improvement in student learning. Therefore, further studies are needed to examine how effective online assessments are of student learning, especially when considering that students rated their ability to achieve every ABET student learning outcome lower in the virtual environment.

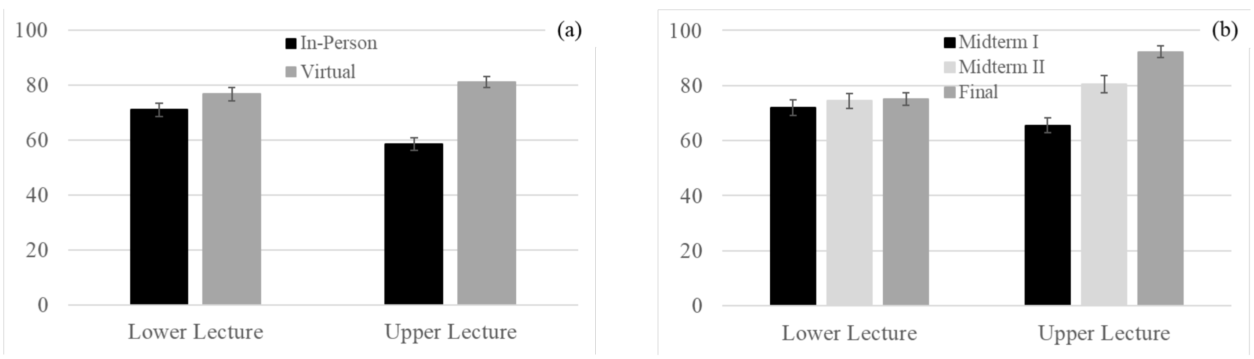

Figure 3: Average quiz and exam grades from in-person and virtual portions of lecture courses.

Similar to lectures, student laboratory assignment grades may not be a good indicator of student learning. Figure 4 shows student grades on laboratory assignments during the in-person and virtual portions of the lower- and upper-division courses. It is seen that the laboratory grades were very similar for both instruction formats. While the theoretical aspect of laboratory practices can be conveyed through lectures and videos, the hands-on portion cannot be provided in a virtual format. Students cannot get a 'feel' for a technique if they are not able to do it themselves. This concept is similar to a child watching a video on how to ride a bicycle and not physically being able to actually ride a bicycle solely from viewing that video. Therefore, performing manufacturing processes, such as casting, machining, metal forming, and welding, cannot be taught through videos, but through practice during laboratory sessions. While students do not become experts through the exercises conducted during the in-person laboratories, they are able to gain a better understanding and 'feel' for how a process works. Through the mistakes that students make during the in-person laboratories, they learn concepts such as the pressure needed to compact sand during casting, the speed at which to turn the knob on a lathe to control the feed rate, the force to apply when bending a piece of sheet metal, and the distance that the torch needs to be from the workpiece during welding. Therefore, student grades are not a good indicator in learning the hands-on aspect of manufacturing processes during laboratory sessions.

While some topics are conducive to virtual instruction, other concepts that require physical practice have no substitute in a virtual environment.

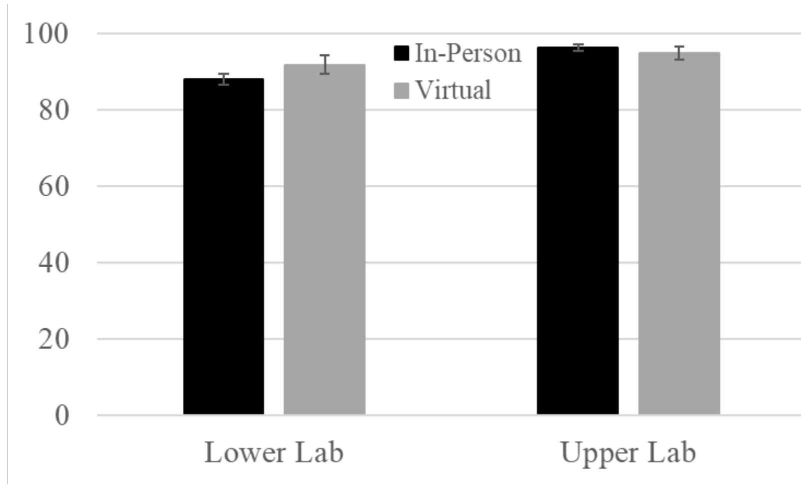

Figure 4: Average assignment grades from in-person and virtual portions of laboratory courses.

The Student Experience of Virtual Instruction

To gain a better understanding of the student experience during the transition between in-person and virtual instruction, students were asked to identify their biggest struggle and biggest advantage that they encountered transitioning to virtual instruction. Figures 5 and 6 showed what students found to be their biggest struggles and biggest advantages, respectively, during their transition to virtual instruction. From Figure 5, it was seen that 25% students struggled the most with their lack of interactions with their peers. Following this, 24% of students struggled with too much screen time. Of the students surveyed, 21% of them had less time for studies, while 10% struggled living at home with their parents. Ten percent of students struggled with an unstable internet connection.

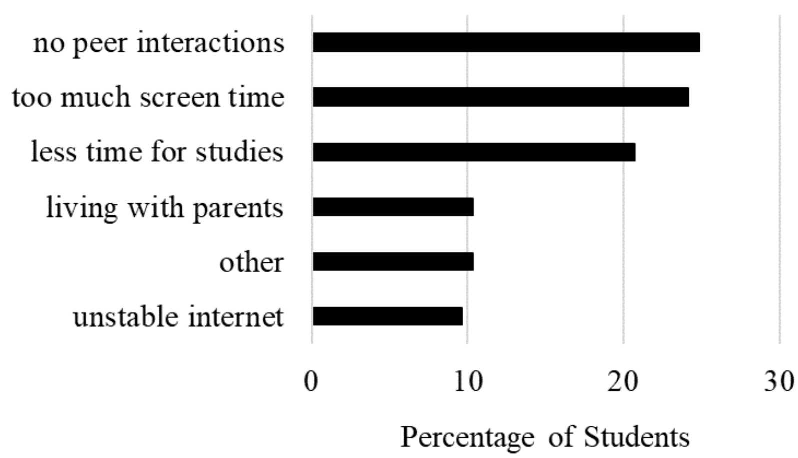

Figure 5: Student's biggest struggles during the transition to virtual instruction.

Figure 6 showed that 58% of students found that no commute was their biggest advantage during the transition to virtual instruction. Twenty-three percent of students saved money while living at home with their parents and 14% found that attending class at home was more comfortable. Of the students surveyed, 4% of students found more time for their studies, while less than 1% found more time for recreation.

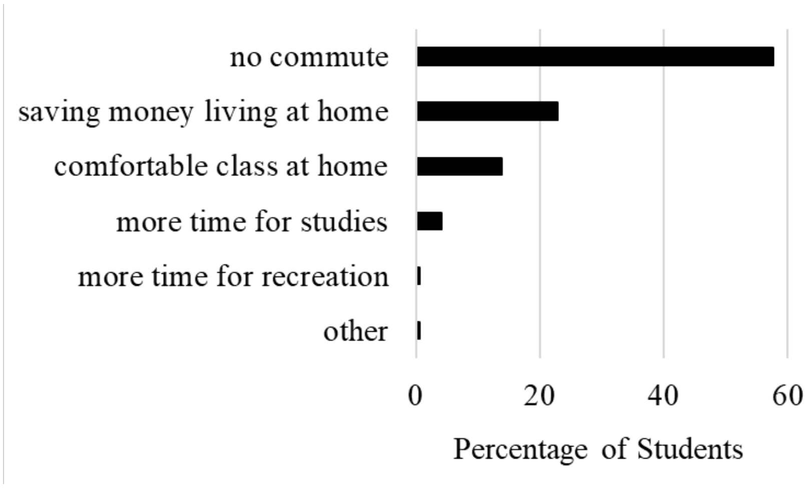

Figure 6: Student’s biggest advantages during the transition to virtual instruction.

To further investigate into the overall student experience of both in-person and virtual instruction, students were asked which mode they would choose, if they had the option in the future. It was seen that 81% of students would choose an in-person learning environment over the less than 20% who would choose virtual instruction. If virtual instruction were offered, 20% of students would choose synchronous, while 14% would choose asynchronous. Nearly 66% would choose a hybrid approach to virtual instruction.

Online Tools

The use of Blackboard was evaluated in this study, specifically for the communication of course announcements, posting of assignments and videos, administration of quizzes and exams, and disclosure of course grades. Table 3 showed the weighted averages for the effective use of each item used on the Blackboard platform. It was seen that all items rated above a weighted average of 4.0, indicating a broad acceptance of the use of Blackboard by students in the virtual environment. Concerning the lowest weighted average for the administration of exams on Blackboard, open-ended feedback from students revealed that Blackboard did not allow them to go back to previous questions during an exam. The backtrack setting was utilized to prevent students from comparing answers during an exam as it is difficult for an instructor to proctor an exam in the virtual environment.

Table 3: Student survey feedback on the effective use of Blackboard.

Item on Blackboard	**Weighted Average**
Assignments	4.63
Announcements	4.58
Grades	4.53
Videos	4.36
Exams	4.13

Figure 7 showed student feedback on the use of the items on Blackboard. It was seen that Blackboard was relatively effective for posting course announcements, assignments, grades, and videos. Although students expressed dissatisfaction for their limited movement through an exam in the virtual environment, 81% of students felt that administering exams through Blackboard was effective.

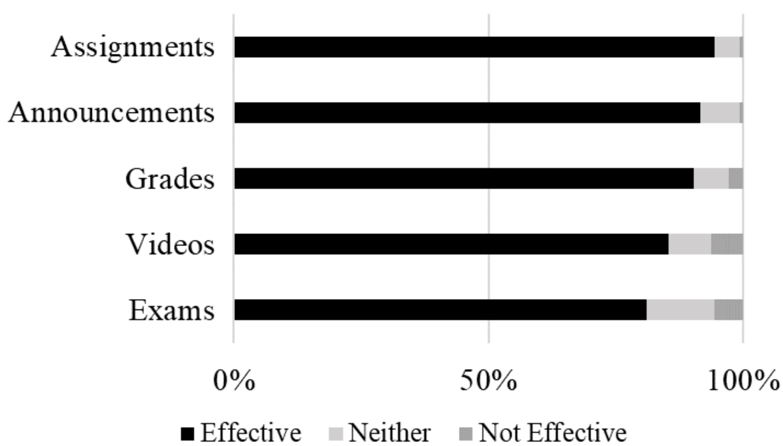

Figure 7: Effective use of Blackboard.

Students were asked if they attended each Zoom session during the virtual instruction portion of the courses. Figure 8 showed if they attended all Zoom sessions and their reasons for missing sessions if they did not attend. Of the students surveyed, 78% attended all synchronous Zoom sessions during the virtual portion of the courses. For the 22% of students who missed at least one Zoom class session, reasons included personal circumstances, an unstable internet connection, and the posted materials were enough to gain an understanding for the subjects covered in class. To put these absences into perspective, in the courses evaluated in this study, absences during the in-person portion were less than 10%. The increased absences during the virtual portion of the courses raises an additional concern of attrition for the virtual teaching environment. In the work done by Jaggars and Bailey [14], student grades were comparable for both in-person and virtual instruction. However, these studies found that students enrolled in virtual courses had a higher risk of attrition.

When students were asked if the Zoom class sessions were effective for their learning, 79% felt that the sessions were effective, while 8% did not find them effective. Thirteen percent of students found the sessions neither effective nor ineffective. To put this result into perspective, 63% of students both attended all Zoom class sessions and found them to be effective in learning course materials.

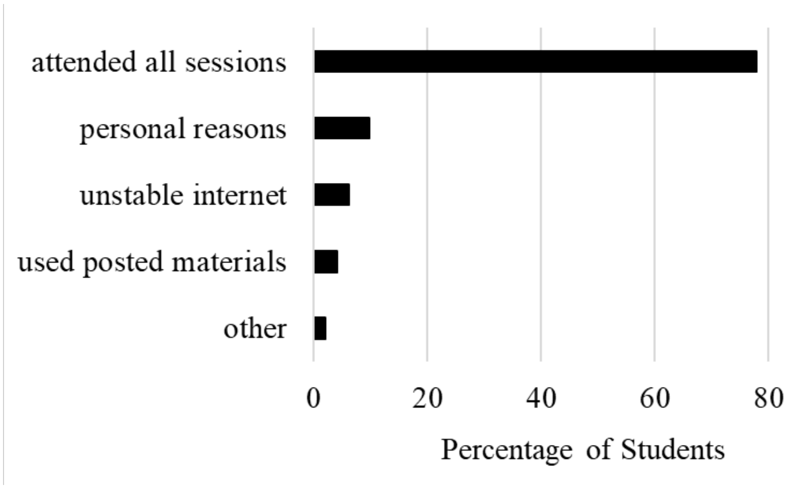

Figure 8: Student attendance on Zoom and their reasons for not attending.

Conclusions

The focus of this study was to provide a comparison between in-person and virtual instruction within the scope of a single academic term. This term was in spring 2020, in which most programs transitioned from in-person to an online environment as a result of the onset of the global COVID-19 pandemic. In this study, both lecture and laboratory courses at the lower- and upper-division were evaluated. Coursework for the lower-division courses included manufacturing processes, while the upper-division courses covered automation.

Students were surveyed to collect their feedback on their perception of the seven ABET student learning outcomes. Results showed that for all courses, all seven SLOs were rated lower for virtual than for in-person instruction. The differences in these ratings showed that SLOs 3 and 5, pertaining to effective communication and functioning on a team, had the highest differences when transitioning from in-person to virtual instruction.

Student grades were also compared for the in-person and online platforms. While grades for quizzes and exams were higher during the virtual instruction timeframe, this may not be an indicator that students had enhanced learning during this mode of instruction. In fact, it is concluded that students need to be held more accountable for their performance during online assessment.

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