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The impacts of virtual teaching technologies on transportation education during the pandemic

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The Impact of Virtual Teaching Technologies on Transportation Education During the COVID-19 Pandemic

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Abstract

The practice of transportation engineering education has evolved substantially over the past few decades. Researchers, engineers, and designers today encounter a wide range of increasingly complicated problems. An urgent problem engineering education currently facing is the COVID-19 pandemic that has changed how engineering education is practiced worldwide. Since the social distancing order was initiated in the United States in March of 2020, universities across the United States have adopted online teaching, and students were forced to take all of their classes online. This research aims to determine the difference in students' engagement and learning experience during online classes compared with on-campus classes, the impact of the current COVID-19 pandemic on transportation engineering education, and the impact of using simulation technologies on students' outcomes in transportation engineering classes. We investigate online teaching's impact on students enrolled in the transportation engineering lab (CE3601L) offered at Cal Poly Pomona using both students' responses to surveys distributed among them and students' grades. The results from the statistical analysis models implemented in this research showed that students show more improvement during online classes; the COVID-19 pandemic had adverse effects on students' engagement, and the use of simulation technologies during transportation classes affected students' engagement levels and grades positively

1. Introduction

The task of transportation engineering, as stated by the Institute of Transportation Engineering (ITE) Committee (1990), is not only "to do various activities associated with current practice" but also to "provide … with the tools necessary to solve new problems that arise". One of the main problems the engineering sector is facing is the COVID-19 pandemic. Due to the lockdown order issued in March of 2020, universities worldwide converted to online teaching. The conversion effect was most evident with classes that have never been taught online and with labs requiring students' presence in class during the lab session for their success.

Many engineering courses, including transportation engineering, are accompanied by labs that have never been offered online before the pandemic. Such labs required implementing a new teaching structure that would accommodate the unique circumstances and ensure that students get the same level of education they would get if they took on-campus classes.

Virtual teaching does not compare to face-to-face teaching, especially with the limited time instructors were given to prepare for the online classes. Previous studies reveal the time requirement needed to complete a highway design is tremendous [8,10], and entry-level engineers lack significant exposure to highway design methodologies [8,11]. This lack of highway design exposure is existent with face-to-face teaching. Thus, one of the main obstacles of the online conversion was creating a class structure that ensures students have sufficient highway design exposure.

A new class structure was created for the highway design class offered at CPP. The new structure steers away from the off-the-shelf methodologies that have been primarily implemented in transportation engineering teaching. The knowledge in practice today will not be sufficient to handle the complicated problems arising with the fast evolution of transportation systems, particularly in highway design [5]. Integrating the emerging vehicular and advanced technologies will be critical to motivate highway engineering design [4,14]. To remedy these problems and meet the fast-evolving market needs, the highway design methods need to be more rigorously structured and technically focused.

However, the traditional approach to highway design does not expose engineers to the myriad of challenging issues they would face in practice. As indicated by a survey conducted by Mason Ref. [10], the number of highway engineers has decreased despite increasing demand from industry[1], and "the growth rate has been decreasing with the passage of each decade and is expected to continue to do so in the future" [14]. As highway design problems are not going away, fresh ideas need to be brought into the field. Therefore, a new simulation-based teaching system such as the use of vitual and segmented reality technologies is needed to better prepare students for their future careers as professional engineers.

By implementing a new engineering teaching system that considers the continually evolving technologies emerging in the engineering field, students can advance highway design and perfect it. Without such a teaching system, students will not be able to get their transportation classes full experience, whether it be given online or face-to-face. Only then, the impact of any emergency events such as the COVID-19 pandemic can be minimized.

2. Literature Review

Transportation engineering classes have been mainly offered face-to-face at universities across the globe. According to Carlos Prado da Silva et al. Ref. [12], undergraduate engineering education, including transportation engineering, is based on three subjects. The three subjects were identified as the definition of learning outcome that is measured based on the theoretical and practical knowledge offered during each class, the specifications of both teaching and learning methods used in each engineering class, and the final evaluation of students learning outcome. This means that the different methods used when teaching engineering classes are critical in determining these classes' actual outcomes.

Engineering projects and hands-on experience are some of the top prospects used in engineering education as they help young engineering students prepare for their future careers. Jiaqi Luo et al. Ref. [9] find out that the quality of transportation education is improved tremendously when it incorporates the innovative CDIO (Conceive, Design, Implement, Operate) framework. Hence, the physical implementation of theoretical engineering concepts through project-based learning is crucial to enhance students learning outcome in engineering classes as intervention implementation in engineering education in general and transportation engineering in particular improved students' cognitive skills, self-efficacy, teamwork, and communication skills [3]. The importance of project experience is one of the main reasons why labs often accompany engineering classes at universities.

Due to the variety of the equipment and software needed for the successful implementation of engineering labs, universities often offer such classes on campus and rarely opt for providing them online. However, with the widespread of the COVID-19 virus and the stay-at-home order, universities had to abruptly convert to online teaching for all offered classes, including engineering labs. Although the conversion to online learning or distance programs have some benefits, such as allowing students to learn and take classes at their convenience, online learning is accompanied by many challenges, such as the lack of online tools needed to create the on-campus class experience at home [15], the lack of teacher training and the adaptation level to the abrupt conversion [7], and the inequality in learning opportunities due to inequality in household learning environments [6].

A case study based on classes offered at Peking University during the COVID-19 pandemic suggests that virtual education can be improved during the pandemic through the implementation of five high-impact principles in online teaching: maintaining high relevance between online instructional design and class learning, creating effective delivery methods for the information offered during online classes, creating a platform where students are provided adequate support and assistance from faculty, encouraging students’ participation in class to improve the depth of student learning, and creating a teaching framework that can deal with unexpected incidents should they arise during online classes [2].

3. Survey Design

In this research, data were collected from five transportation engineering labs that implemented a variety of technologies, including online textbooks, tutorial videos, online aiding resources, 3D design programs, and virtual reality during their online class sessions. Data were collected in different periods of the semester to test the student's understanding of highway design and engagement level during their online lab. Two of the labs in the study were offered on-campus before the online conversion, while the other three were offered online.

Students were asked to complete two projects during the on-campus transportation engineering classes by the end of the semester. The first project required students to design a highway interchange using both MicroStation and InRoads while referring to Caltrans Highway Design Manual (HDM). The second project required students to perform a traffic study on an intersection to improve its Level of Service (LOS). The online classes followed the same structure as the on-campus classes with the addition of a 3rd project that required students to recreate their highway interchange design using Infraworks, a 3D modeling design software. Moreover, students who took the online classes were given project tutorials, additional online resources, and software tutorials to help them with their assignments.

To achieve this study's objectives, online surveys targeted to students taking the transportation engineering lab (CE3601L) offered at CPP during the Spring and Fall semesters of 2020 were used. A total of four surveys were distributed among students for each semester. Two surveys tackled the subject of student's classes in general, whether they were online or on-campus, while the other two focused on the highway design lab. All surveys were distributed to the same group of students and had a panel or longitudinal design as they mainly aimed to report progress in student's engagement and learning curve in both their highway design class and their other classes over the entire semester.

General Questionnaire survey: Students were given two surveys that tackled the subject of online and on-campus classes. One survey was distributed at the beginning of the semester, while the other was distributed at the end of the semester. Surveys distributed during the online classes were designed to collect additional information about students' experience and engagement level with their online classes during the COVID-19 pandemic.

At the beginning of the semester, students were asked general questions about their expectations for the upcoming semester, their desired input, the amount of effort they expect to put into their classes, the information they expect to gain from their classes, and the pros and cons off online teaching based of their expected behavior during the semester. They were also asked about their expected experience with online classes and how it might be different from their experience with on-campus classes, their thoughts about the classes they were taking during the semester, their ability to study and work from their home environment, and the effectiveness of the technology that might be implemented in their classes. Moreover, students were asked specific questions that tackled the subject of the COVID-19 pandemic and their expected behavior and class outcome during the Fall semester of 2020. All of the previously mentioned questions were presented to students as statements, and students were encouraged to pick their agreement level on a scale ranging from “strongly agree” to “strongly disagree”.

At the end of the survey, students were asked to scale their enthusiasm toward the online semester and the amount of effort they expect to put into their classes during the Fall semester of 2020. These questions encouraged students to pick a scale from 1 to 5, with one being the lowest and five being the highest. Along with the questions mentioned above, students were also given open-ended questions to express their feelings about the online semester and to write down any comments or suggestions that would make the semester less stressful for them.

At the end of the semester, students were given a survey that follows the same design as the one given to them at the beginning of the semester. The second survey contains similar choices as the first survey. In the second survey, students were asked about the outcome of their online classes and their overall experience with online teaching over the entire semester. The questions in this survey were designed to collect information about students' progress during the online semester and the change in students' opinions and behavior toward online teaching by comparing their answers before starting their online classes with their answers after they completed them.

Transportation Engineering Lab: Like the online classes' surveys, students were given two surveys over the semester, of which one was distributed at the beginning of the semester while the other was distributed at the end of the semester. Both surveys were designed to collect information about students' engagement level, learning experience, class progress, and outcome in the transportation engineering class.

The first survey collected students' demographic data such as ethnicity, gender, and household income. It contained questions about students' work backgrounds, such as their work experience in engineering companies, engineering software they used at work, and the type of engineering companies they worked at. This survey contained a section about students' school background, their acquired knowledge in transportation engineering from classes they took before, the engineering field they hope to expand on and work at after they graduate, and their opinions about working in transportation engineering after graduating. Moreover, the survey asked students about their expected knowledge they hope to acquire from the class, their proficiency level in the engineering programs taught in the class, and the online teaching tools they believe would increase their understanding of the classes' concepts if incorporated into the class. By the end of the survey, students were asked to evaluate their enthusiasm and expected engagement level in the transportation engineering class on a scale of 1 to 5, with one being the lowest and five being the highest. Most of the survey questions were multiple-choice, with a couple being essay questions that asked about what students hoped to learn from the class.

The second survey was distributed among students at the end of the course after they finished working on all of the assigned projects. This survey collected information about the student's outcome of the course, their proficiency in the software that was taught, their understanding of highway design concepts, their experience with group projects that were assigned to them, their opinions about the amount of communication among each other and between them and the instructor, the effectiveness of the communication technologies used in class such as Zoom, their opinions regarding the online resources that were provided to them by the instructor to help them cope with the new learning environment, and their opinion about different technologies such as Virtual Reality and Augmented Reality (AR/VR) technologies that might increase their understanding of highway design if incorporated in the class structure. At the end of the survey, students were asked to evaluate their progress in the class and their understanding of the class concepts on a scale from 1 to 5, with one being the lowest and five being the highest. Most of the questions in this survey were multiple-choice questions, with a couple being essay questions that asked students about their opinions of the class, their general comments, and what they hoped to see in the class when they registered for it.

4. Data Analysis

The survey was distributed among engineering students enrolled in the transportation engineering labs during the Spring and Fall semesters of 2020. Students enrolled in the labs during the Spring semester 2020 took half on-campus and the other half online, and students enrolled during the Fall semester 2020 took the entire class online.

Data Statistics

A total of 149 students from 5 transportation engineering lab courses over the two semesters were involved in this study. Surveys were divided into sections in which each section tackled a specific subject that was different from the others.

Demographic Data: The demographic data and students; background information was collected through the survey questionnaire. Students were asked about their gender, ethnicity, income, and whether they were first-generation college students or not. Most of the students taking the transportation engineering lab were males (73.46%), and only 26.54% were females. Figure 1 shows the make-up of the ethnicity: Hispanic or Latino (40.00%), Asian and Pacific Islander (25.71 %), White (22.86%), and Black or African American (2.14 %), and others (9.29%). 56.43% of the students identified as first-generation college students. As shown in

Figure 2, the distribution of the household income is: above $75k (38.17%), between $50k and $75k (17.99%), between $25k and $50k (26.46%), and less than $25k (19.42%).

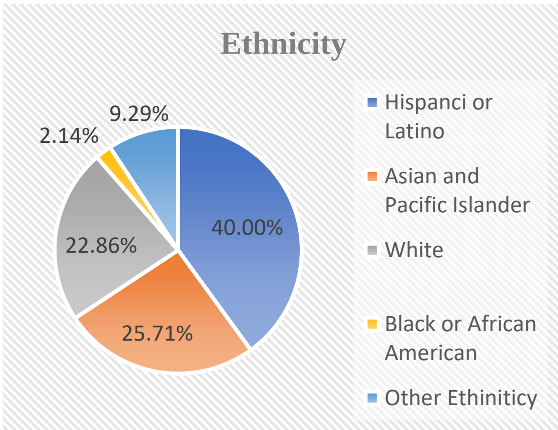

Figure 1: Survey Participants' ethnicity data

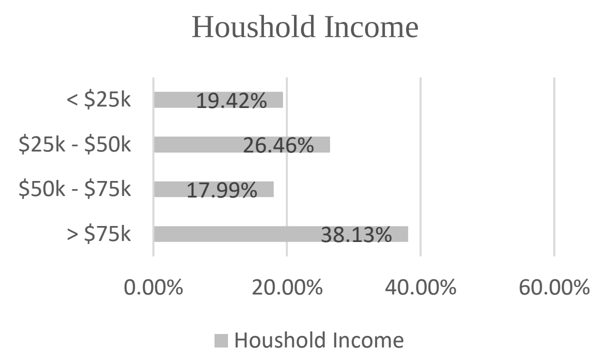

Figure 2: Survey particiants' household income

Work Experience: Students were asked about their work experience in engineering companies before and during taking the class. They were also asked about whether they have ever used both MicroStation and InRoads during work or not. Responses (Figure 3) show that only 28.57% of the students had previously worked in engineering companies before, and only 7.86% of them were still working in engineering companies at the time they took the class. Only 7.86% of students with work experience used MicroStation during their work, and 1.19% used InRoads, as seen in Figures 4.

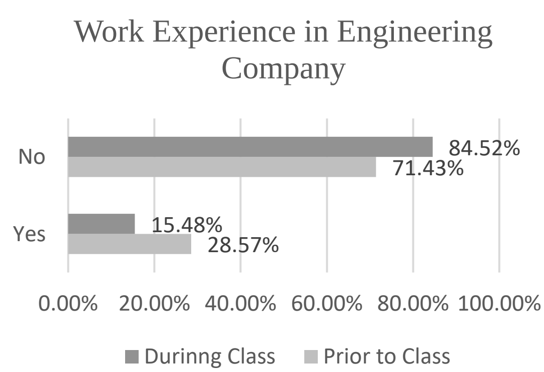

Figure 3: Participants' work experience in engineering companies

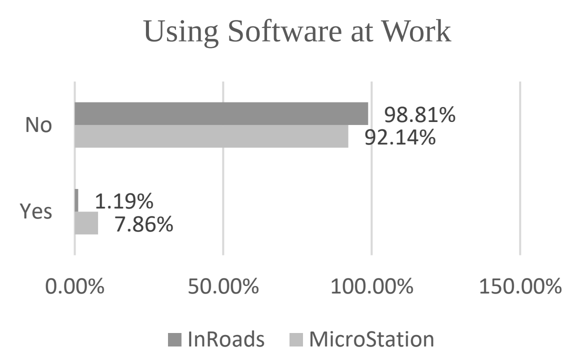

Figure 4: Survey participants' usage of MicroStation and InRoads during work

School Experience: Students were asked about their experience in transportation engineering courses at CPP before taking the transportation engineering lab. Moreover, students were asked if they have ever used both MicroStation and InRoads in previous classes. Most students (97.62%) said that the transportation engineering lab was their first experience with highway design, and 2.38% of students reported having taken other transportation classes before. As shown in Figure 5, 66.67% of the students reported to have used MicroStation in previous classes, but only 8.33% reported to have used InRoads.

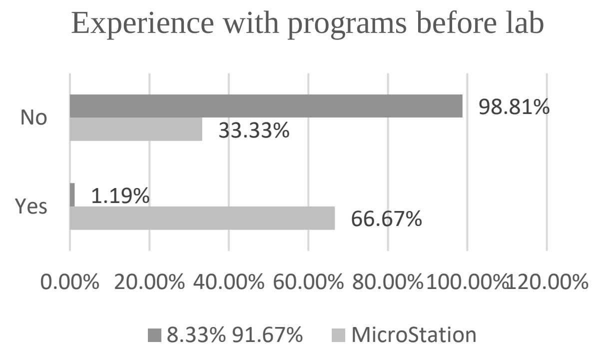

Figure 5: Survey participants' experience of MicroStation and InRoads before the course

Interest in Transportation: When students were asked about whether they have interest in transportation engineering or not, most of the students who took the class (54.76%) said yes, 17.86% said no, and 27.38% were not sure and took the class to learn more about it. When students were asked whether they prefer to work in transportation after graduating, 23.91% said yes, 29.71% said no, and 46.38% were not sure.

Hypothesis Testing

Students were given tests throughout the semester to obtain numerical data to fully understand the impact of the virtual transportation engineering lab in comparison with its on-campus counterpart. Moreover, students were asked to complete surveys that asked about their opinions in the online transportation engineering lab compared to the other engineering labs they took on-campus before the online conversion.

Quiz grades and survey responses were used to test the three hypotheses determined in the research. The comparison between the average quiz grades for different transportation engineering labs and taught by the same instructor is shown in Table 1. Two of the labs were taught on-campus, and three were taught online. In all five labs, quizzes were open book and student’s were allowed to use outside material to complete their quizzes in the limited time they were provided and thus, students in both on-campus and online labs had similar setting during taking their quizzes. Interestingly, the online labs' average quiz grades are higher than those of the on-campus labs.

Table 1: A summary of the quiz grades

	On-campus Lab - Spring 2020		Online Lab - Fall 2020		
	Class 1	Class 2	Class 3	Class 4	Class 5
Avg per Semester	78.71	59.95	78.82	77.35	87.35
Avg per class type	69.33		81.17		

The hypotheses below were tested to determine the impact of the virtual teaching technologies used in the transportation engineering lab courses.

Hypothesis 1: H_{01}: Students show better improvement during online classes.

To better understand the correlation between student's quiz grades to their respective labs, the chi-square test was used to test the significance of the class type, i.e., on-campus vs. online, on students' grades in all labs. The chi-square test analysis showed that the class type (on-campus vs online) significantly relate to student's quiz grades. The probability of the chi-square test statistic for quiz grades ($X^2 = 99.153$) was $p = 0.000$ ($< .05$) as seen in Table 2. Since the p-value is less than our chosen significance level ($\alpha = 0.05$), there is an association between the type of lab and the labs' quiz grades.

Table 2: A summary of Chi-Square test results

	Quiz grades	
	Chi-Square	P-value
Lab type (on-campus vs. online)	99.153	0.000*

*Significance at $\alpha = 0.05$

Students from both on-campus and online labs were also compared according to their reported proficiency at the end of the semester in the programs taught to them during lab. As mentioned before, most of the students taking the lab from the five labs had no experience working with InRoads, and a small percentage of them had either beginner or intermediate proficiency in MicroStation at the beginning of the classes. When comparing the proficiency at the end of the semester, students who took the class online had better progress in MicroStation and InRoads than students who took the class on-campus.

As seen in Figure 6, the majority of students who took the highway design class On-campus reported having a beginners understanding of MicroStation by the end of the class (41.82%), 38.28% of students reported having an intermediate understanding of the program, 3.64% reported to have become proficient in the program by the end of the class, and 16.36% of the students reported that they still have no experience in the program by the end of the class. As for students who took the online classes, most students (59.52%) reported to have an intermediate understanding of MicroStation by the end of the semester, 34.52% said they have a beginner understanding of the program, and 5.95% have proficient understanding by the end of the semester as seen in Figure 7.

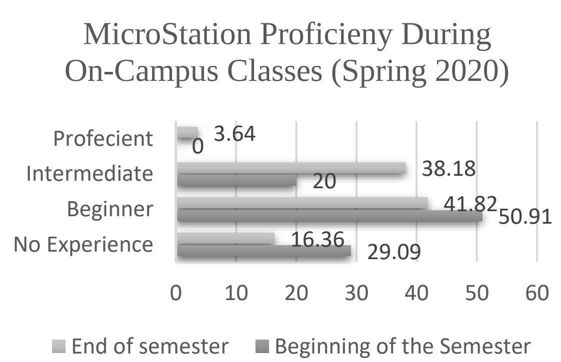

Figure 6: Students' profeciency in MicroStation st the beginning and end of the semester during on-campus classes

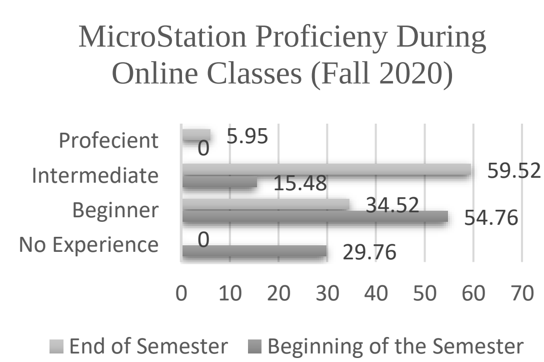

Figure 7: Students' proficiency in MicroStation at the beginning and end of the semester during online classes

As seen in Figure 8, most students who took the highway design class on-campus reported to have no experience in InRoads by the end of the class (58.18%), 21.82% of students reported having a beginners understanding of the program, 18.18% reported having intermediate understanding, and 1.82% reported to have become proficient in the program by the end of the semester. As for students who took the online classes, most students (54.76%) reported having an intermediate understanding of InRoads by the end of the semester; 41.67% said they have beginner understanding of the program; 2.38% have proficient understanding. Only 1.19% reported to still have no experience in the program by the end of the semester, as seen in Figure 9.

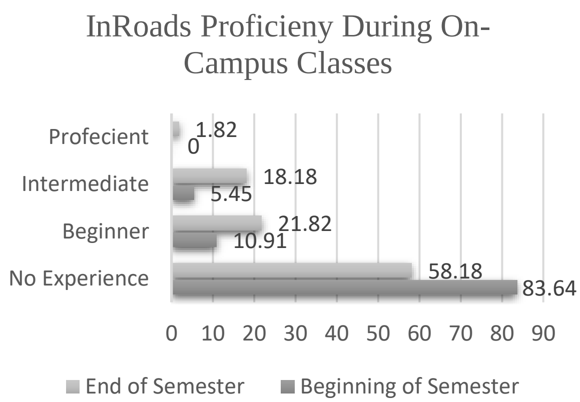

Figure 8: Students' proiciency in InRoads at the beginning and end of the semester during on-campus classes

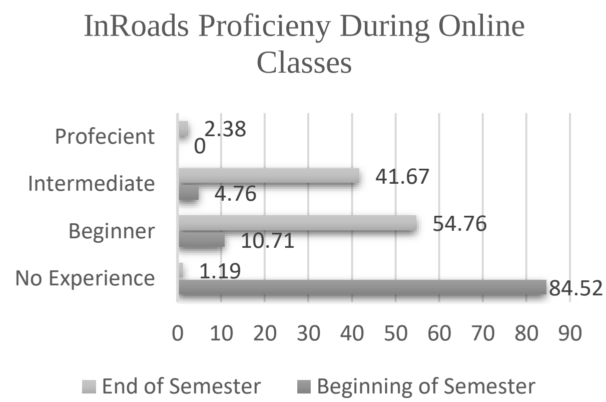

Figure 9: Students' proficiency in InRoads at the beginning and end of the semester during online classes

As seen in Figures 6,7,8, and 9, Students taking the online classes show more progress in MicroStation and InRoads than students taking the class on-campus. By the end of the semester, around 16.36% reported still having no experience in MicroStation and 58.18% reported still having no experience in InRoads by the end of the semester. On the other hand, no students (0%) reported having no MicroStation experience, and only 1.19% of students reported having no experience in InRoads by the end of the online semester.

The chi-square test was used to determine whether the type of class (on-campus vs. online) has any significance on the difference in program proficiency reported by students at the end of each semester. The chi-square test analysis showed that the class teaching type, on-campus and online, significantly relates to student's progress in both MicroStation and InRoads. The probability of the chi-square test statistic for MicroStation progress ($X^2 = 17.392$) was $p = 0.001$ ($< .05$) and the probability of the chi-square test statistic for MicroStation progress ($X^2 = 61.205$) was $p = 0.000$ ($< .05$) as seen in Table 3. Since the p-value is less than our chosen significance level ($\alpha = 0.05$), there is an association between the type of class and students' progress in both MicroStation and InRoads.

Table 3: A summary of Chi-Square test results

	MicroStation Progress	
	Chi-Square	P-value
Class type (on-campus vs. online)	17.392	0.001*
	InRoads Progress	
	Chi-Square	P-value
	61.205	0.000*

*Significance difference at $\alpha = 0.05$

Based on the results of the chi-square tests conducted and the evident difference in students progress in both on-campus and online classes, it is concluded that students show more improvement, in both the theoretical knowledge measured through quizzes and technical knowledge measure through software progress, during online classes in comparison with on-campus classes and thus, the first hypothesis is accepted.

The results obtained from testing the first hypothesis might be due to the amount of extra effort students put toward their online classes compared to their on-campus classes, which allowed them to perform better than if they had taken the same classes on-campus. When students were given the statement "I needed to put more effort to complete my assignments during online classes", 36.76% of the students strongly agree with the statement, 39.71% agreed, 14.71% were neutral, 7.35% disagreed, and only 1,47% strongly disagreed as seen in Figure 10. Moreover, when students were asked to scale the amount of effort students put toward their online classes during the semester on a scale from 1 to 5, with 1 being the lowest and 5 being the highest, most students (45.59%) chose 5, 33.82% chose scale 4, 13.24% chose scale 3, 5.88% chose scale 2, and only 1.47% chose scale 1, as seen in Figure 11.

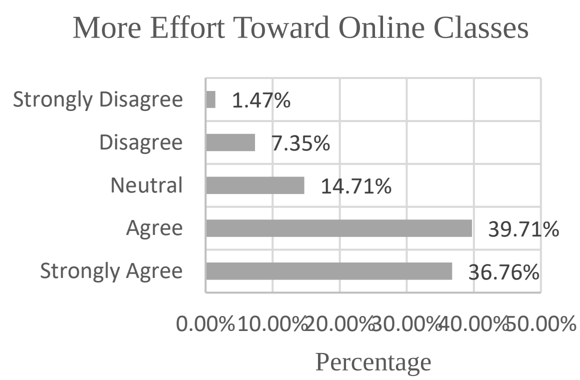

Figure 10: "I need to put more effort to cmplete my assignments during online classes"

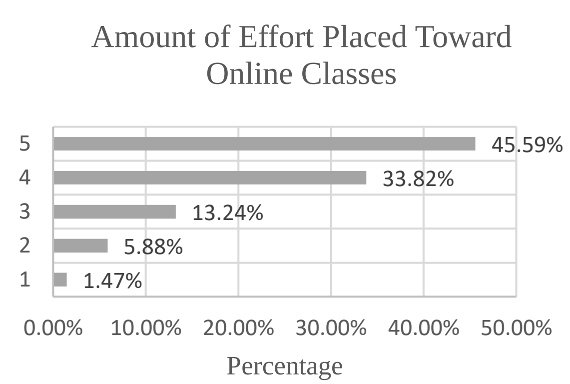

Figure 11: Scale of the amount of effort placed by students toward their onlilne classes

Hypothesis 2: H_{02}: COVID-19 did not affect students learning experience during online classes.

To test this hypothesis, a total of 105 responses collected from surveys distributed to students along with quiz scores that belong to students who took the three online classes during the Fall semester 2020 were analyzed.

At the end of the semester, students were given a survey that aimed to detect students' experience with online classes over the course of the Fall 2020 semester. The survey contained questions about students' experience with COVID-19 events and their opinions of how COVID-19 affected their performance during the online semester.

When students were asked about their stress levels due to COVID-19, Most students (52.94%) strongly agreed with the fact that COVID-19 increased their stress levels during the Spring of 2020 online semester, 20.59% agreed, 17.65% were neutral, 5.88% disagreed, and 2.94% strongly disagreed and believed that COVID-19 did not increase their stress levels during the online semester. Results can be seen in Figure 12.

When students were asked about their learning experience and how it was affected due to COVID-19, around 26.47% of students strongly agreed with the fact that COVID-19 affected their learning experience during the Fall of 2020 online semester, most students (42.65%) agreed, 22.06% were neutral, 5.88% disagreed, and 1.94% strongly agreed to believe that COVID-19 did not affect their learning experience during the online semester as seen in Figure 13.

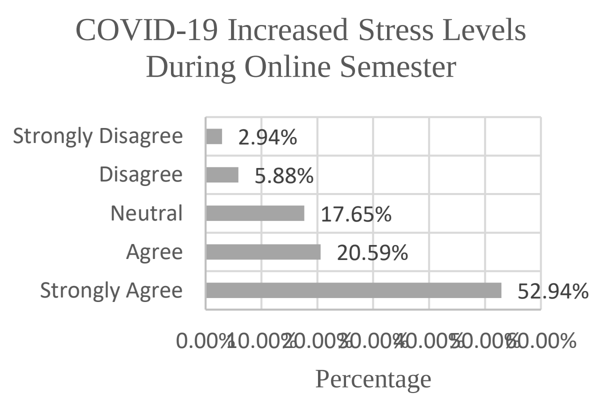

Figure 12: Increased Stress Levels due to COVID-19

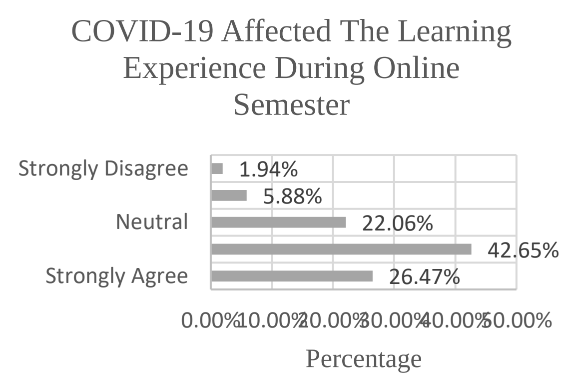

Figure 13: COVID-19 Affected Students' Learning Experience

When students were asked about their overall progress in their online classes and how it was affected due to COVID-19, around 20.59% of students strongly agreed with the fact that COVID-19 affected their overall progress during the Fall of 2020 online semester, the majority of students (41.18%) agreed, 23.53% were neutral, 11.76% disagreed, and 2.94% strongly agreed to believe that COVID-19 did not affect their overall progress during the online semester as seen in Figure 14.

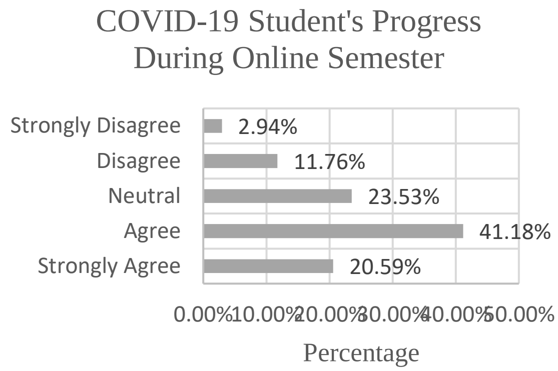

Figure 14: COVID-19 Affected Students' Progress

Further analysis on the significance of students' answers to the previously mentioned three questions to their respective quiz grades using the chi-square test was conducted. The chi-square test analysis showed that Students' answers to three questions significantly relate to students' quiz grades. The probability of the chi-square test statistic for COVID-19 increasing stress level ($X^2 = 120.833$) was $p = 0.012$ ($< .05$), the probability of the chi-square test statistic for COVID-19 affecting students learning experience ($X^2 = 140.069$) was $p = 0.000$ ($< .05$), and the probability of the chi-square test statistic for affected overall students' progress ($X^2 = 125.517$) was $p = 0.005$ ($< .05$)as seen in Table 4. Since the p-value is less than our chosen significance level ($\alpha - 0.05$), we conclude an association between increased stress levels due to COVID-19, the pandemic's effect on students' progress and learning experience, and students' quiz grades.

Table 4: A summary of Chi-Square test results

	Quiz Grades	
	Chi-Square	P-Value
Increased Stress Level	120.833	0.012*
Affected Learning Experience	140.069	0.000*
Affected Overall Progress	125.517	0.005*

*Significance difference at $\alpha = 0.05$

Both the results from students' survey responses and the significance of their responses to their respective quiz grades prove the effect of COVID-19 on students' learning experience and improvement during the online Fall of 2020 semester; thus, we reject the second hypothesis.

Hypothesis 3: H_{03}: Simulation teaching techniques did not affect student's improvement during class.

Different simulation technologies were used during the online highway transportation engineering classes. Students' grades, progress in the software they learned during class, their responses in the surveys distributed among them, and their opinion regarding the technologies used during online classes were used to test this hypothesis.

Students taking the transportation engineering online classes were taught three design software. Data seen in Figures 7 and 9 above show students' progress in both MicroStation and InRoads. In addition to the previously mentioned software, students were also taught how to use Infraworks to create a 3D highway interchange. At the beginning of the class, most of the students (84.52%) had no experience in using Infraworks; however, by the end of the semester, most of the students had beginner, intermediate and proficient understanding of how to use the program and navigate through it (54,76%, 41.67%, and 2.38% respectively). Only 1.19% still had no experience of how to use the program, as seen in Figure 15.

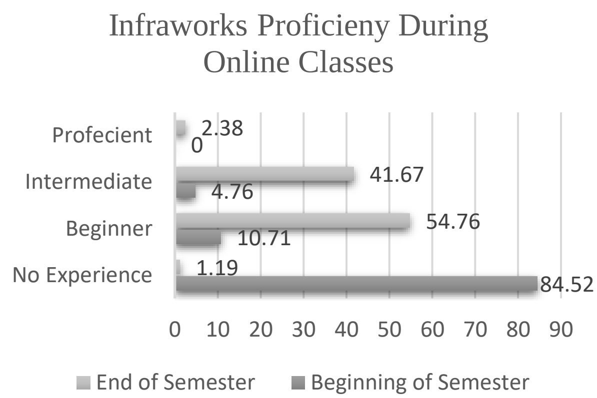

Figure 15: Students' profeciency in Infraworks at the beginning and end of the semester during online classes

The chi-square test was used to analyze the significance of using MicroStation, InRoads, and Infraworks on students' grades during the Fall of 2020 semester. The chi-square test analysis showed that only students' knowledge in using the software InRoads has a significant relation to students' class grades. The probability of the chi-square test statistic for InRoads knowledge ($X^2 = 167.981$) was $p = 0.007$ ($< .05$). On the other hand, the test results show that students' knowledge in MicroStation and Infraworks has no significance in their respective grades. The probability of the chi-square test statistic for MicroStation knowledge ($X^2 = 87.250$) was $p = 0.383$ ($> .05$), and the probability of the chi-square test statistic for Infraworks knowledge ($X^2 = 95.778$) was $p = 0.729$ ($> .05$)as seen in Table 5. Since the p-value for only InRoads knowledge is less than our chosen significance level ($\alpha = 0.05$), we conclude that there is an association between InRoads knowledge and students Final Class grades.

Table 5: A summary of Chi-Square test results

	Final Grades	
	Chi-Square	P-Value
MicroStation Experience	87.250	0.383
InRoads Experience	167.981	0.007*
Infraworks Experience	95.778	0.729

*Significance difference at $\alpha = 0.05$

Students were given additional online resources to aid them in their online classes. When students were asked whether these resources were helpful or not, most students (94.05%) answered yes, and only 5.95% answered no, suggesting that the additional online resources used in the class were not helpful. When students were asked whether the 3D model they created in Infraworks helped visualize their interchange, the majority (90.48%) answered yes, and 9.52% answered not. Most students who took the survey (66.67%) believe that the use of Augmented

Reality and Virtual Reality (AR/VR) technologies might help them in understanding highway design better if such technologies were implemented in the class, 27.38% were not sure about whether it will help or not, and 5.95% believe such technologies will not help.

The chi-square test was used to determine the significance of the additional resources provided for students during the online transportation engineering classes on their respective quiz grades. As seen in Table 6, the probability of the chi-square test statistic for resources ($X^2 = 37.641$) was $p = 0.02$ ($< .05$), the probability of the chi-square test statistic for the 3-dimensional Infraworks model ($X^2 = 43.452$) was $p = 0.398$ ($> .05$), and the probability of the chi-square test statistic for using AR/VR technologies ($X^2 = 77.010$) was $p = 0.693$ ($> .05$). Since the p-value is less than our chosen significance level ($\alpha - 0.05$) only for online resources, there is an association between the additional resources provided to students and their grades.

Table 6: A summary of Chi-Square test results

	Final Grades	
	Chi-Square	P-Value
Resources Used	37.641	0.02*
Infraworks model helped visualize created interchange	43.452	0.398
AR/VR help understand highway design	77.010	0.693

*Significance difference at $\alpha = 0.05$

The above-listed students' survey responses and the chi-square test results show that simulation technologies used during online classes affected students' progress or outcome from the class, and thus, we reject the third hypothesis.

5. Conclusions

In conclusion, five transportation engineering classes offered at CPP and taught by the same instructors were selected for this study. Two classes were taught on-campus during the Spring semester 2020, and three were taught online during the Fall semester 2020. With the conversion to online classes, the highway design class structure was adjusted to take into consideration the lack of face-to-face interactions between the instructor and the students who are taking the transportation engineering classes. Moreover, additional material was added to the online class to ensure that students can understand the concepts presented to them. Surveys designed to measure students' progress and engagement levels in their classes were distributed to all classes involved in this study. Additional surveys that tackled online teaching during the COVID-19 pandemic were distributed among the three transportation engineering classes offered during the Fall semester 2020. Data collected from the surveys along with students' grades were statistically analyzed to test the three hypotheses raised in this research. Results showed that students taking the online classes showed better progress and engagement than students taking the on-campus classes due to the use of additional simulation technologies during online classes, even though students' engagement level during their online classes was affected by the COVID-19 pandemic.

It is important to note that the results should be interpreted with caution due to the small sample size. Thus, the future study recommendations are to increase the sample size, create a comparison study between online classes and on-campus classes with the same structure, and widen the study's scope to include other simulation technologies such as Augmented and Virtual Reality (AR/VR).

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