Development and Implementation of Experiment Centric Active Learning Experiments/Activities in Transportation During the Pandemic and Beyond

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ABSTRACT

The COVID-19 pandemic forced many colleges and universities to remain on a completely online or remote educational learning for more than a year; however, due to distraction, lack of motivation or engagement, and other internal/external pandemic contributing factors, learners could not pay attention 100% to the learning process. Additionally, given that transportation classes are very hands-on, students could not do the experiment from home due to limited resources available, thereby hampering all three phases of learner interactions. The limitation of the implementation of physical, hands-on laboratory exercises during the pandemic further exacerbated students' actualization of the critical Accreditation Board for Engineering and Technology (ABET) outcomes in transportation: An ability to develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgment to draw conclusions. Subsequently, this paper highlights the development and implementation of experiment centric pedagogy (ECP) home-based active learning experiments in three transportation courses: Introduction to Transportation Systems, Traffic Engineering, and Highway Engineering during the pandemic. Quantitative and qualitative student success key constructs data was collected in conjunction with the execution of classroom observation protocols that measure active learning in these transportation courses. The results reveal a significant difference between the pre, and post- tests of key constructs associated with student success, such as motivation, critical thinking, curiosity, collaboration, and metacognition. The results of the Classroom Observation Protocol for Undergraduate STEM (COPUS) show more active student engagement when ECP is implemented.

Keywords: Experiment Centric Pedagogy, Transportation, Pandemic, Motivation

INTRODUCTION

Due to recent pandemic events, many institutions have shifted to completely online or virtual learning platforms. However, this unplanned shift resulted in unforeseen challenges in transportation learning as transportation is an applied science that requires hands-on activities and the application of transportation concepts to solve real-life problems. The growing concern was how students would be able to achieve the Accreditation Board for Engineering and Technology (ABET) learning outcome that is directly related to experimentations (an ability to develop and conduct experiments or test hypotheses, analyze and interpret data and use scientific judgment to draw conclusions) without access to the physical laboratory facilities and equipment. Consequently, during the pandemic, because of these limitations, hands-off virtual lab simulations were adopted by many institutions. However, given the nature of students at the authors' institution who learn best via hands-on activities, hands-off virtual lab activities will not promote effective students' engagement and satisfaction.

The provision of authentic laboratory and real-world problem-solving learning experience has been a challenge for online/virtual learning *(1,2)*. Mackay and Fisher's (1) observations revealed that there is a significant level of dissatisfaction with online engineering teaching, thus warranting a need for tremendous improvement in the delivery methodology *(1)*. The traditional approach fails to engage students and is too abstract, imparts a sense of boredom and lack of motivation to the students *(3)*. Equally, Lepper opined that students' motivation is highly dependent upon how best to relate the subject with the real world *(4)*. Aziz and Islam noted that skepticism is widespread in the academic community regarding online courses in engineering largely due to the perceived difficulties in implementing hands-on labs *(3)*. Consequently, to bridge the gap between concepts and practical hands-on skills during the pandemic, experiment centric pedagogy was adopted in transportation engineering to engage students. Experiment centric pedagogy (ECP), a hands-on learner-centered teaching technique that utilizes cheap, portable instrumentations, has been successfully implemented to increase students' engagement and motivation in the electrical engineering field at 13 historically black universities *(5)*. ECP integrates problem-based activities and constructivist instruction by using a hands-on mobile multi-function instrument that is designed to replace larger laboratory equipment *(5)* . The hands-on mobile instrument enables the students to practice previously acquired knowledge outside the classroom with their peers or independently. The uniqueness of ECP devices is that it can be easily utilized at different learning settings; in the classroom for demonstration by the instructor, in the laboratory and at home by students to conduct homework. The portability and cost-effectiveness of ECP devices facilitated the ease of adoption at home for students during the pandemic. ECP is also hinged on embodied learning where bodily activity is integrated into learning tasks with a view of developing metacognitive skills and expertise that enhances critical thinking, which promotes students active participation in rendering and deeply understanding scientific concepts *(6,7)*. The use of instrumentations in other STEM fields facilitates the adoption of ECP in these fields. Although ECP has been successfully implemented in electrical engineering, it has never been implemented in the field of transportation.

The paper presents the development and implementation of ECP in the transportation field to increase students' motivation and achievement during the pandemic. To demonstrate the efficacy of ECP in transportation, home-based active learning experiments were developed and implemented in three transportation courses: Introduction to Transportation Systems, Traffic Engineering, and Highway Engineering. Following are the research questions that guided the study:

1. Does the Experimental Centric Pedagogy (ECP) enhance student learning, motivation, and curiosity in transportation?
2. How is ECP integrated and customized to meet the learning objectives of coursework within the transportation field?

To answer these questions, concepts and subjects where electronic instrumentations are used to make scientific measurements in the transportation field are carefully identified. In the transportation engineering field, electronic instrumentations are very essential in testing and understanding transportation concepts. Subsequently, the reasoning for the adoption of ECP in transportation engineering. After the identification of these concepts, experiments that utilize the electronic instrumentations are then developed and implemented. Since the ECP devices are cheap and portable, the devices and the laboratories kits are then shipped to the students. Videos and detailed laboratory procedures were provided to the students. In order to effectively engage the students, a synchronously online laboratory experimentation pedagogy that effectively engages the students while conducting the home-based hands-on laboratory exercise was implemented. The Motivated Strategies for Learning Questionnaire (MSLQ) tool *(8-10)* and Litman and Spielberger curiosity assessment instruments *(11)* were used to measure key constructs associated with student success, such as motivation, epistemic and perceptual curiosity, and self-efficacy. Student success was measured by the academic performance of the ECP students compared to the academic performance without ECP.

LITERATURE REVIEW

In order to effectively and efficiently implement ECP in Transportation, various learning theories must be considered. Learning theories describe different learning processes and models that can be integrated into classrooms. The result of this provides instructors with better teaching methods. In addition, the proper implementation of learning theory results in increased motivation and engagement in students. Furthermore, the fundamentals of ECP and the classroom observation protocol are implemented to effectively integrate ECP in Transportation.

Kolb's Learning Cycle

This learning cycle includes reflective observation (watching), conceptualization (thinking), active experimentation (ECP testing), and concrete experiences (doing). This theory includes two major concepts:

a) How students learn through concrete experiences (experimentation) to thinking processes (results/data/analysis).
b) How students internalize information through active experimentation (ECP testing/re-testing, reflecting on activities, collaborating with peers).

This learning cycle is composed of four steps: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). These four steps can be further elaborated as CE being the "feeling" aspect, RO being the "reflecting" aspect, AC being the "thinking" aspect, and AE being the "acting" aspect (12). The Kolb's Learning Cycle model is further defined in Figure 1. Instructors who implement the Kolb's Learning Cycle tend to produce more student achievement and overall material retention. Kolb's Learning Cycle is based upon his experiential learning theory (ELT) (13). The definition of ELT is: "...the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience” (12). Since individuals tend to synthesize information in different ways, four learning styles have developed over time: diverger, converger, accommodator, and assimilator. A diverger specializes in CE/RO and tends to gain insight from a number of different viewpoints. An assimilator concentrates in AC/RO and creates a theoretical framework on the basis of that gained insight. A converger specializes in AC/AE and normally tests relevant theories. An accommodator specializes in CE/AE and analyzes test results to formulate new methodologies (12). Kolb’s experiential learning theory is implemented in this study through students conducting experimentation to relate it to real-world applications and expand their knowledge. Students and their peers in ECP look at things from different perspectives and learn best by observing and brainstorming ECP experiments/activities. Kolb’s experiential learning cycle implements constructivist and embodied learning theories through students collaborating with students and conducting experiments. The constructivism learning theory articulates that students need to engage in social interaction and collaboration in order to expand their knowledge. These experiences help students to improve their own methodologies (14). Embodied learning “emphasizes the role of the body and bodily engagement in learning” (15). The Kolb’s Learning Cycle is implemented in ECP through active learning processes.

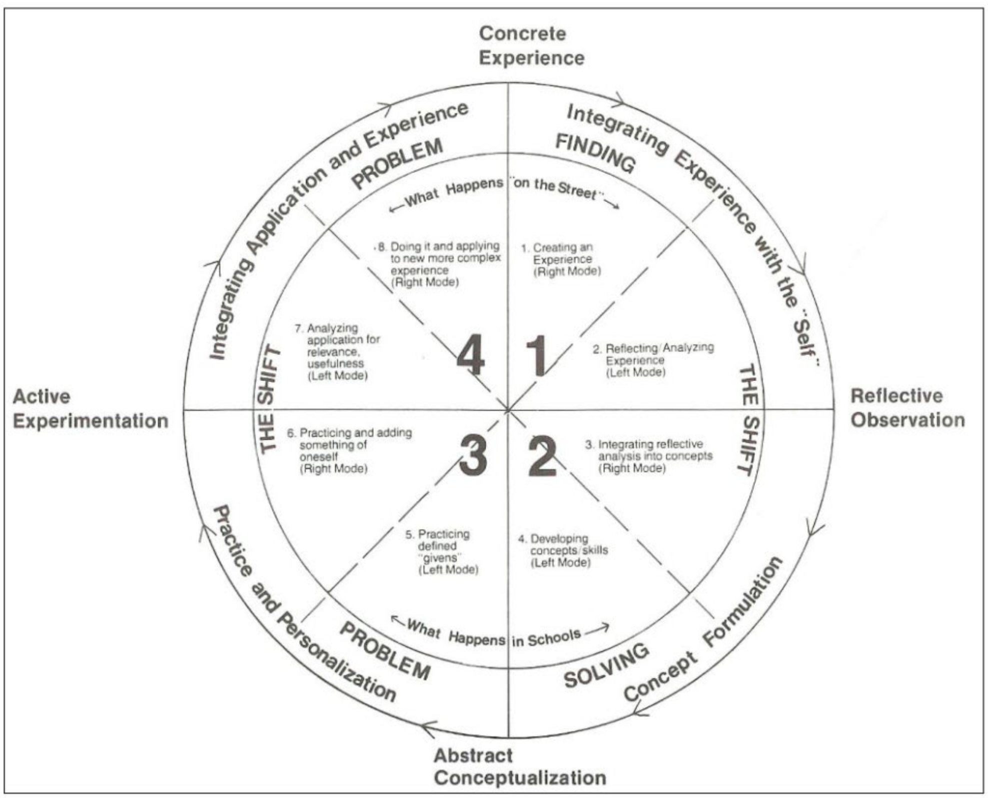


FIGURE 1 Kolb's Learning Cycle Model (13)

Experimeny-Centric Pedagogy (ECP)

Experiment-centric pedagogy (ECP) is an active, hands-on pedagogical approach that emphasizes that students get physically involved in the learning process through experimentation. This experimentation helps students relate the theory that they are learning to real-life applications. Through students learning these applications, they are better prepared for the real world (16). In addition, students and their peers learn best by working with practical applications in ECP. By working on ideas and abstract ECP concepts, students learn a wide range of information in a logical format. During the experimentation process, students make use of portable devices such as Analog Devices Active Learning Module (ADALM1000) and ADALM2000 (M2K). During the coronavirus pandemic, some students also made use of mobile phone applications to perform experiments in the comfort of their home. The fundamentals of ECP are further discussed in Figure 2. The figure reveals the four learning processes, whereby learning commences in the experimental phase. In a Noise Measurements Experiment conducted in a highway engineering class, students learn the fundamentals of noise measurement as it relates to transportation. After learning this information, students conduct a practical experiment with their peers to further understand the significance. Students learn different skills and experiences to expand their knowledge. In addition, students learn the importance of collaboration, open-mindedness, and goal setting. The progression of the instructor's teaching and the students' learning is documented by the Classroom Observation Protocol for Undergraduate STEM (COPUS). The results of the classroom observation show evidence of engagement.

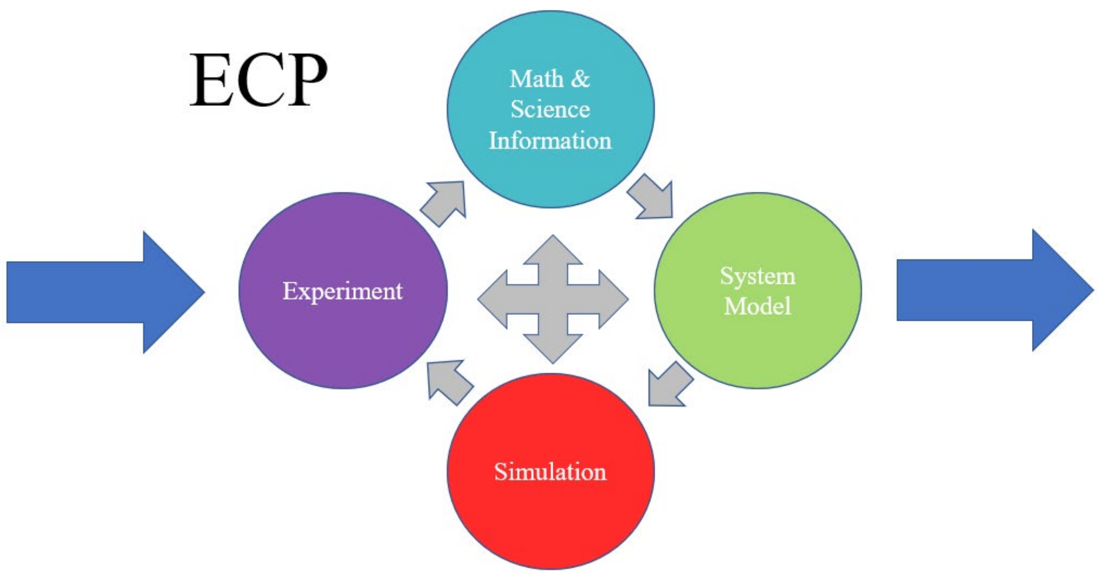


FIGURE 2 The fundamentals of experiment-centric pedagogy *(17)*

Classroom Observation Protocol for Undergraduate STEM (COPUS)

Smith et al 2013 (18), developed a new observation protocol known as the Classroom Observation Protocol for Undergraduate STEM (COPUS) that can be used to reliably characterize how faculty and students are spending their time in the classroom. COPUS is also a pedagogical validated evaluation tool that can provide feedback to instructors about the effectiveness of their teaching techniques, in-order to identify professional development needs. The classroom observation contains 25 codes in only two categories ("What the students are doing" and What the instructor is doing") and can be reliably used by university faculty.

DETAILS OF THE TRANSPORTATION COURSES

There were several transportation courses taught between the Fall 2020 and Fall 2021 academic semesters. Some instructors implemented ECP in their classes while others did not implement ECP. The courses that did not implement ECP served as a control group. The control group was compared to ECP courses.

Introduction to Transportation Systems

This is an introductory course that explains basic strategies and concepts of transportation systems; it addresses key issues relating to different aspects of transportation, including logistics, management, engineering, and planning. Noise measuring is important in most transportation projects. For example, a new road or traffic diversion would increase or divert the noise from one area to the other area. In this regard, the ECP was implemented in this course in Spring 2021 and Fall 2021 using a decibel meter app. The decibel meter app that is available on both android and IOS versions of devices. To familiarize students with the application of the decibel metering in the real-world project, students were required to record the volume of their television for approximately two minutes at different volume levels. They were to take note of their maximum, minimum, and average decibel levels. Such an experiment provided the students with the application of the ECP regarding the assessment of the noise impact of different types of vehicles, different pavement types, graded roadways, and other variables.

Traffic Engineering

In this course, the students are to learn the concept of level of service, traffic flow theory, analysis and collection of traffic data, capacity analysis of uninterrupted and interrupted flows, traffic control devices, countermeasures, and accident analysis, traffic impact studies, pedestrian, and parking facilities analysis (19). The traffic flow experiment and car speed detection experiment was originally proposed to be implimented in Fall 2021 in this course, however, due to logistics reasons it could not be imlplemented. The students are supposed to learn the fundamentals of traffic flow theory which is the relationship between flow (q), density (k), and speed (u). Figure 3 shows the relationship between flow, speed, and density.

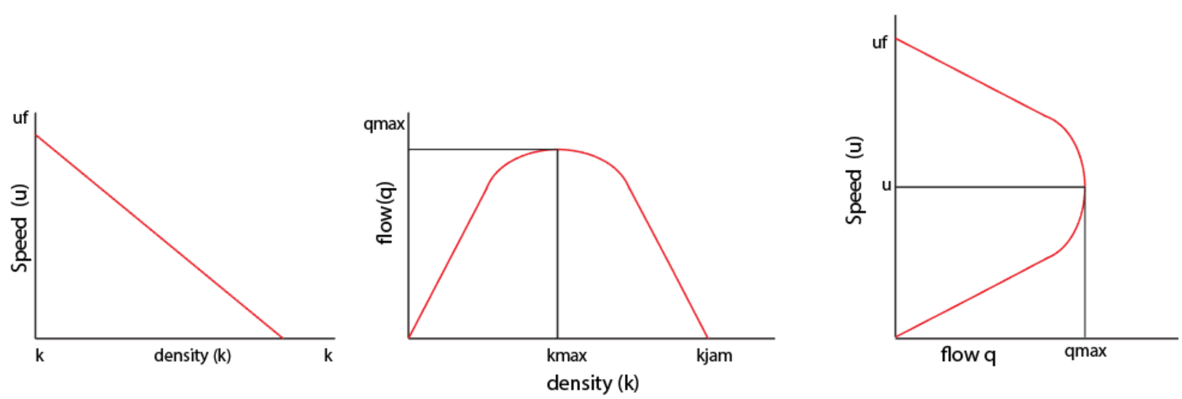


FIGURE 3 Fundamental Flow Diagram

From this experiment, students will understand why speed decreases when there is a high density of cars on the road and vice versa (speed and density). Regarding the relationship between flow and density, students will understand that when there is a low density, additional vehicles on the observed roadway stretch increase the flow, but as density increases to a critical number, additional cars will decrease the flow of vehicles (flow and density).

This experiment was supposed to be conducted with pneumatic tubes and a car speed detection sensor. These should be mounted close to the campus, the sensors will be used to collect data during peak periods and off-peak periods in the day and in the evening. Students will plot the traffic flow diagram based on their data and compare traffic flow during peak periods and off-peak periods.

Highway Engineering

This course gives students a general background of highway engineering and it introduces them to basic principles, methodologies, and processes that are essential to highway design. Students will have a general understanding of earthwork, highway alignment, drainage design, construction surveys, highway materials, intersection design, pavement thickness design, and design of asphalt mixtures at the end of this course. (Chavis, Syllabus for TRSS 415_Fall 2020, 2020[20]). In order to design sound barriers, there must be a better understanding of traffic noise; hence the sound experiment was implemented so that students can be able to relate the transportation sound concept to real-life situations. Students also performed the soil moisture content determination for better understanding for highway materials and earthworks.

METHODOLOGY

Concepts and subjects where electronic instrumentations can be used to make scientific measurements in explaining principles guiding such concepts were identified in the transportation field. After the identification of these concepts, experiments that utilize the electronic instrumentation are then developed and implemented. Details of the experiments and the implementation are shown under the experiments section. In each of the courses a well-developed course structure with modules where ECP can be easily implemented was developed. The ECP course structure with well-aligned course components are divided into four parts, as described in Figure 4 below.

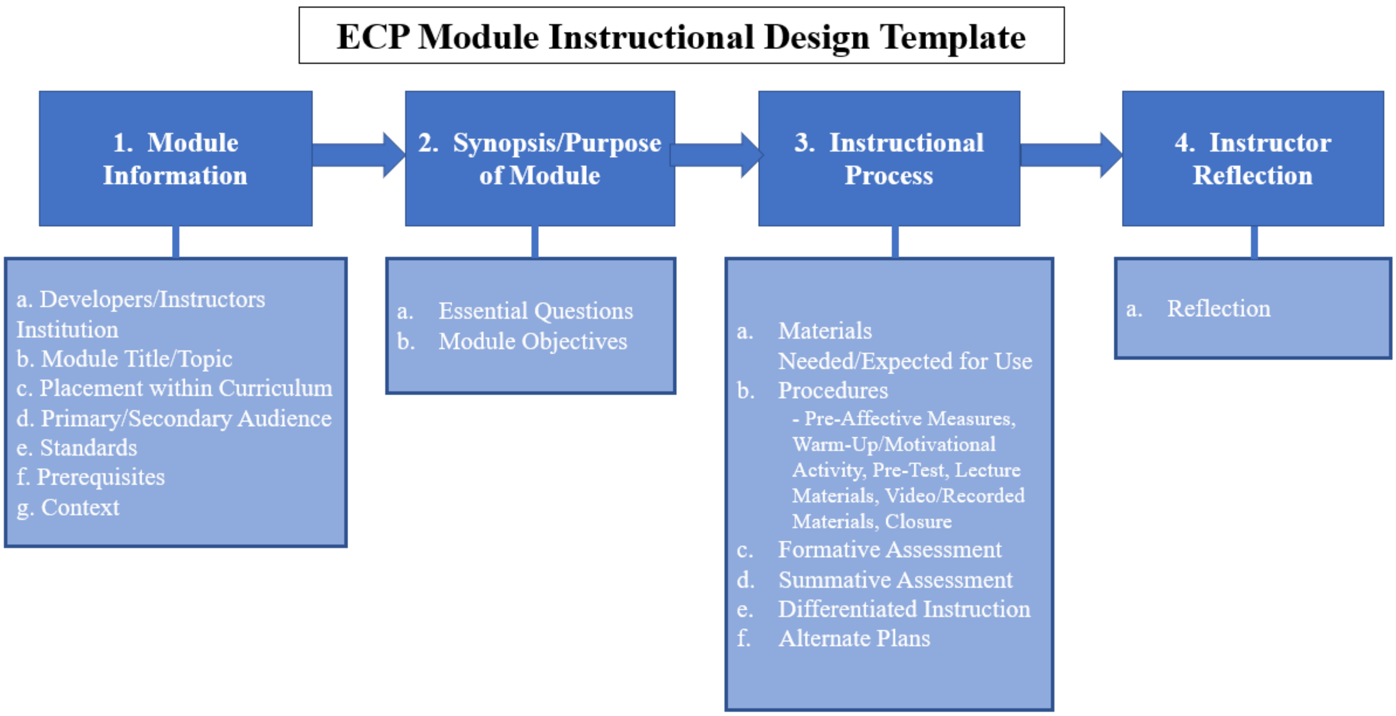


FIGURE 4 – ECP Module Instructional Design Template

Quantitative and qualitative data are collected before and after each module. Validated MSLQ and Curiosity assessment tools were used to evaluate students' engagement and motivation, while student success was measured by the academic performance of the ECP students compared to the academic performance without ECP. The MSLQ measure includes two distinct scales, motivational and learning goals. The motivational scale includes three components: value, expectancy, and affective. The value section includes goal orientation for intrinsic and extrinsic, and task value, while the expectancy section includes control beliefs, self-efficacy. The affection section includes test anxiety. The MLSQ measure was utilized to assess the effectiveness of the implementation of ECP. The learning goals scale of the MSLQ is further separated into cognitive and resource management strategies components. The cognitive section includes items for rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation. The resource management strategies include items for: time and study environment, effort regulation, peer learning, and help-seeking. When pre and post-data are collected to show positive gains, we would expect increases particularly in intrinsic goal orientation, task value, control beliefs, and self-efficacy with reduced test anxiety from the motivational scale. As well as increases in critical thinking, metacognitive self-regulation, peer learning goals scale particularly as a function of the active learning strategies and the implementation of ECP *(8, 9, 12)*. The MSLQ uses a 7-point Likert-type scale with statements related to the key constructs.

The Littman and Spielberger curiosity assessment tool on the other hand measures students' level of curiosity (11). The tool is divided into two categories: Epistemic Curiosity and Perceptual Curiosity. Epistemic Curiosity (EC) is curiosity that stems from one's motivation to know, to gather knowledge, and to fill in "gaps" in one's knowledge. In contrast, Perceptual Curiosity (PC) is curiosity that leads to increased perceptual experiences of the individual. The curiosity assessment tool is based on a 4-point Likert-type scale. A descriptive analysis is conducted in order to determine the significance of the pre and post-test results of all the key constructs.

In the highway engineering class in Fall 2020, all the students were African American male. Thirteen percent of the 15 students that responded to the survey were in their junior year, while the rest were seniors. However, in the introduction to transportation systems class, 41.81% of the respondents (N=34) were male and 58.82% were female; 88.24% reported ethnicity as African American, 3% White/Caucasian 9% reported as other racial group. Overall, 9% of the students were freshmen, 35% sophomore, 18% junior, and the remaining 38% of the students reported that the were seniors.

The Classroom Observation Protocol for Undergraduate STEM or COPUS developed by Smith et al.(18) was used to measure student engagement during the implementation of ECP.

Experiments

Noise Measurements Experiment

In Fall 2020, the sound experiment was conducted in the highway engineering class. The experiment involved the use of ADALM 1000 (M1K), an analog sound sensor, three jump wires, and a laptop or personal computer. Figure 5 shows the experiment components.

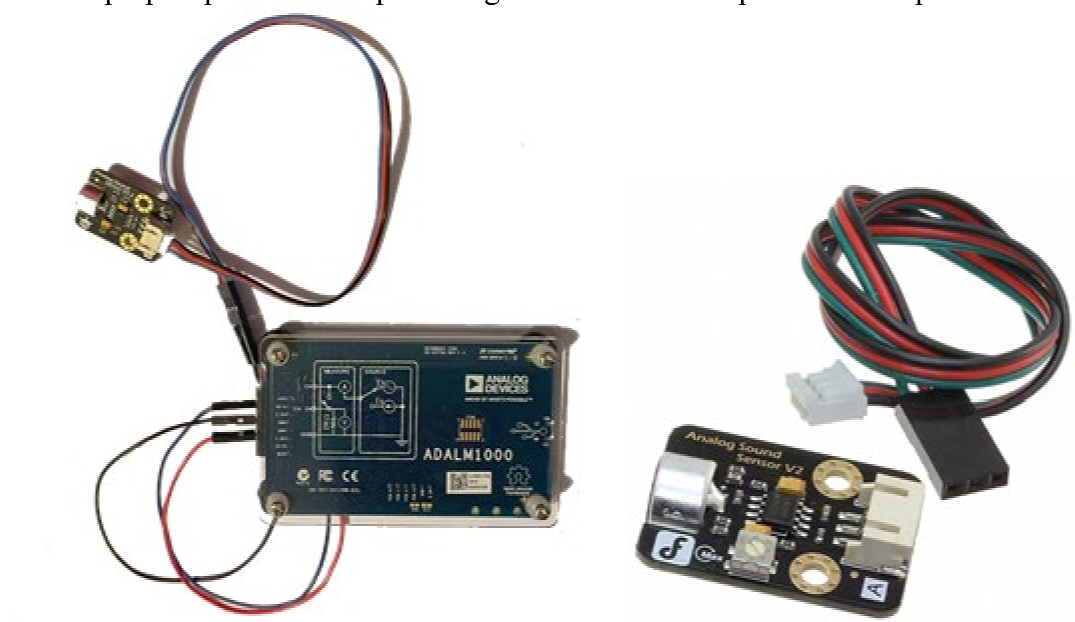


FIGURE5: The Noise Experiment Set Up

Before the experiment was introduced in class, the students were taught about the fundamental concepts of sound, which include loudness, duration, frequency, and subjectivity. They were shown the different decibel levels for different scenarios. Since noise pollution is very prevalent in urban and densely populated communities, mitigation is necessary. Noise pollution consists of unwanted sounds that can negatively affect psychological health. These negative effects can lead to stress responses, sleep disturbances, and adverse economic effects. To address the effects of noise pollution, noise barriers have been created to absorb and alleviate noise leaks. Noise barrier walls can be implemented in highway traffic and residential areas *(21).* This noise measurement experiment will help students better understand the planning and design of noise barriers in highway corridors that are situated in densely populated communities. Figure 6 shows the effect that traffic volume, speed, and vehicle type has on noise. Students were able to understand the noise model that governs the observation in Figure 6. Sound data was collected both indoor and outdoor. The voltage reading from ADALM 100 was converted to decibel by using Equation 1.

Gain (dB)= $20Log_{10}(V_{out} \div V_{in})$ (1)

where $V_{out}$is the output voltage, and V_{in} is 5 volts which is the input voltage.

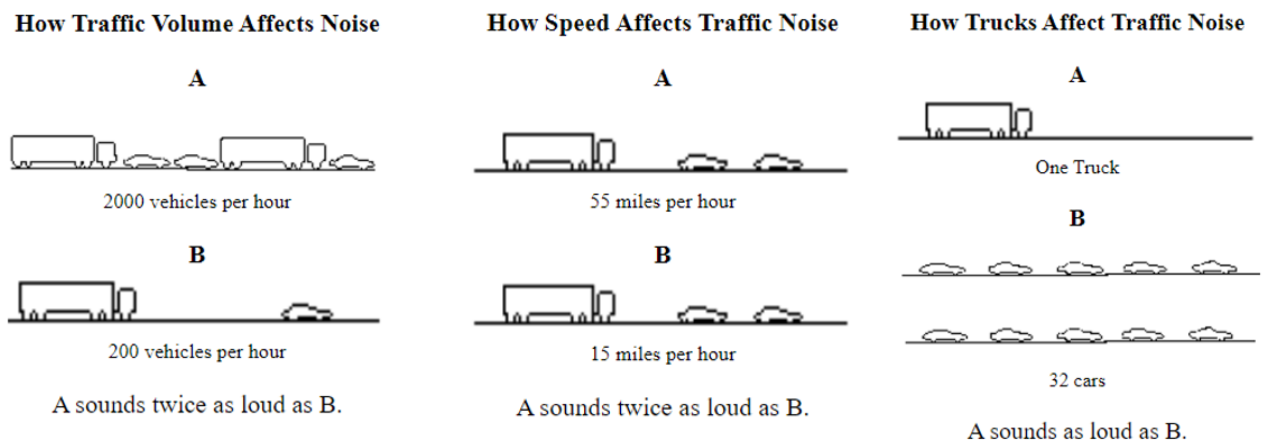


FIGURE 6 The effect of volume, speed and vehicle type on Noise (22)

Moisture Content Determination

Soil moisture content is an essential parameter to determine the quality of highway contruction and pavement performance. Soil moisture content is defined as the ratio of the weight of water to the weight of the dry soil. It is normally expressed as a percentage. Soil moisture content affects the soil's electrical conductivity (EC), which can help to determine the important physical and chemical properties of the soil (23). The soil sensor measures the soil electrical conductivity and the data collected can then be used to determine the moisture content. The soil moisture sensor (Figure 7b) has 3.3V to 5V user-supplied power, with output voltage signal of 0-4.2 volt and a current of 3mA. Moisture content data is collected using the ADALM 100 (ALICE desktop) with the appropriate transfer function (Figure 7c). Six prepared samples of varying soil moisture were used to calibrate the sensor (Figure 7a). The experiment could not be implemented as it was difficult to obtain results; however in Fall 2021, we have utilized a microcontroller called Arduino UNO, which is a digital system compared to ADALM 1000 that is an analog system. Arduino UNO has enabled us to produce consistent results similar to Drake, (23) results. Moisture content can affect the structural performance and behavior of roadway pavement. This knowledge is also very important for compaction control in highway construction. Another application of moisture content determination is material quality determination and control.

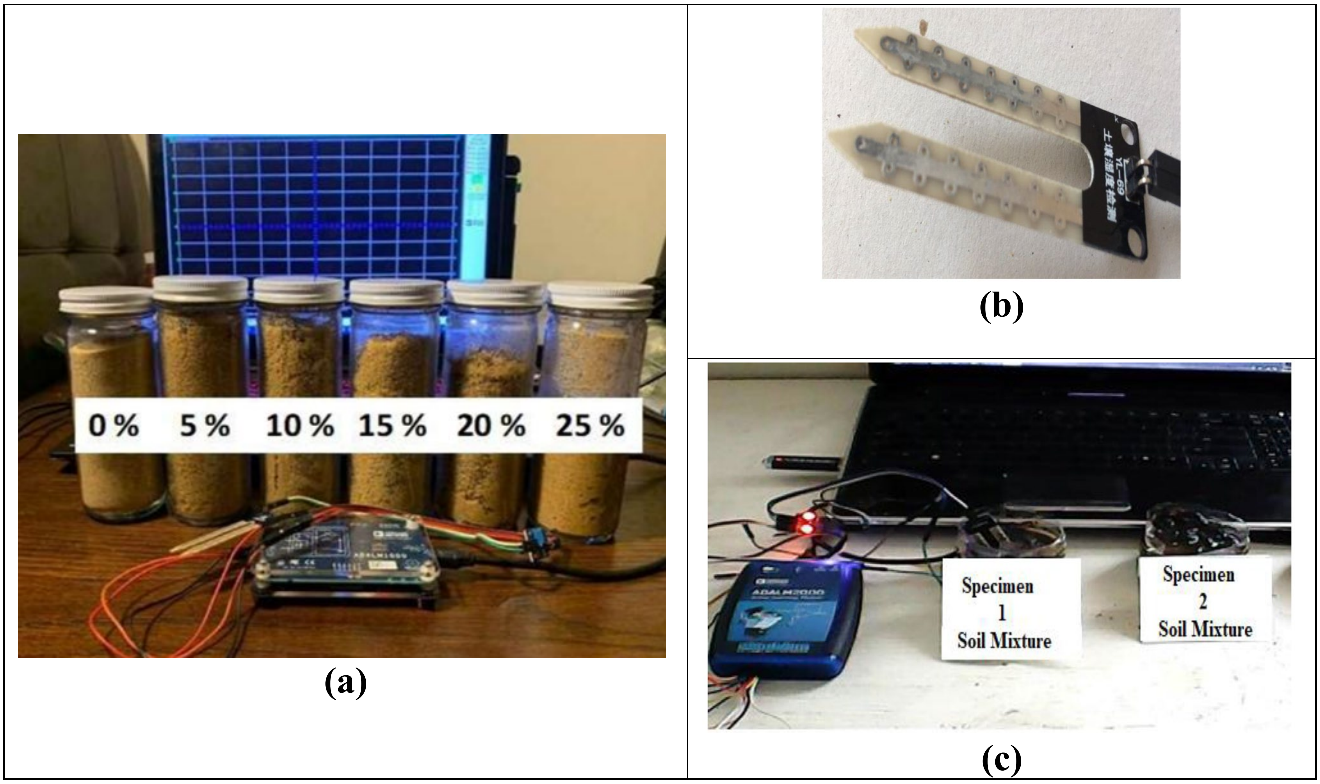


FIGURE 7 (a) Sample Specimens used to calibrate the soil moisture sensor (b) Soil moisture sensor (c) Experimental set of the moisture content determination with ADALM 1000

RESULTS AND DISCUSSION

This section presents the impact of ECP on student learning and key constructs associated with students with student success, such as motivation, epistemic and perceptual curiosity and self-efficacy. The results from the MSLQ and the Curiosity scale for the pre- and post-tests when ECP was implemented in the Highway Engineering course in Fall 2020 are shown in Tables 1 and 2 respectively. Overall, the most notable pre to post changes in participants' perspective occurred in sub areas of Metacognition and Peer Learning collaboration. One of the most consistent changes from pre to post was within the construct of Metacognition, the item "If course materials are difficult to understand, I change the way I read the material" with a percentage change of 28.6, another subarea similar change was Peer Learning item "When studying for this course, I often try to explain the materials to a classmate or a friend." A negative direction was observed in the areas of Intrinsic Goal Orientation, Task Value, Expectancy Component, Critical Thinking, Deprivation Epistemic Curiosity: "The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible" (-2.4%); "It is important for me to learn the course material in this class" (-9%); "I believe I will receive an excellent grade in this class" (-5.4%); "I expect to do well in this class" (-4.8%); "I often find myself questioning things I hear or read in this course" (-0.5%) and "I feel frustrated if I can't figure out the solution to a problem, so I work harder to solve it" (-4.9%). The above trends are visually represented in Figure 8 and 9 respectively. On the other hand, Figures 10 and 11 show the results of the pre- and post- tests of students' constructs in Spring 2021. A comparison of the construct gains due to the implementation of ECP in Fall 2020 and

Spring 2021 is shown in Figure 12. The impact of ECP is more pronounced in Fall 2020 than Spring 2021 for most constructs except for Peer Learning (PL1, PL2,), Intrinsic Goal (IGO3) and Critical Thinking (CTI). This trend may likely due to the majority of the non-STEM majors offering the introduction to transportation systems course.

TABLE 1 Changes in Student Motivation Constructs: Pre and Post Test Fall 2020

Items	Construct**	Code	Pre % n=15	Post % n=15	% Change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation (IOG 1)	IGO 1	53.3	72.8	19.5
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation (IOG 2)	IGO 2	66.7	72.8	6.1
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible	Intrinsic Goal Orientation (IOG3)	IGO3	93.3	90.9	-2.4
It is important for me to learn the course material in this class.	Task Value	TV1	100	91.0	-9.0
I am very interested in the content area of this course.	Task Value	TV2	60.0	72.8	12.8
I like the subject matter of this course.	Task Value	TV3	80.0	91.0	11.0
I believe I will receive an excellent grade in this class.	Expectancy Component	EC1	60.0	54.6	-5.4
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	EC2	73.3	81.9	8.6
I expect to do well in this class.	Expectancy Component	EC3	86.7	81.9	-4.8
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	TA1	86.7	91.0	4.3
I feel my heart beating fast when I take an exam.	Test Anxiety	TA2	60.0	63.7	3.7
I often find myself questioning things I hear or read in this course.	Critical Thinking	CT1	73.3	72.8	-0.5
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	CT2	66.7	72.8	6.1
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives	Critical Thinking	CT3	66.7	81.9	15.2
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Metacognition	MC1	93.3	100.0	6.7

If course materials are difficult to understand, I change the way I read the material.	Metacognition	MC2	53.3	81.9	28.6
Before I study new course material thoroughly, I often skim it to see how it is organized.	Metacognition	MC3	73.3	81.9	8.6
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	Metacognition	MC3	86.7	91.0	4.3
When studying for this course, I often try to explain the material to a classmate or a friend	Peer Learning	PL1	53.3	81.9	28.6
I try to work with other students from this class to complete the course assignments.	Peer Learning	PL2	66.7	81.9	15.2
When studying for this course, I often set aside time to discuss the course materials with a group of students from the class.	Peer Learning	PL3	60.0	81.9	21.9

** %Agree =5,6, & 7 where 1= Not at all true of me, 7=Very true of me

Table 2: Changes in Student Curiosity Scale: Pre and Post Test Fall 2020

Items	Construct*	Code	Pre % n=15	Post % n=15	% Change
I enjoy exploring new ideas	Interest Epistemic Curiosity Scale	IEC1	93.3	100	6.7
I enjoy learning about subjects that are unfamiliar to me	Interest Epistemic Curiosity Scale	IEC2	73.3	81.8	8.5
I find it fascinating to learn new information	Interest Epistemic Curiosity Scale	IEC3	86.6	91	4.4
When I learn something new, I would like to find out more about it	Interest Epistemic Curiosity Scale	IEC4	73.4	100	26.6
I enjoy discussing abstract concepts	Interest Epistemic Curiosity Scale	IEC5	66.7	72.8	6.1
Difficult conceptual problems can keep me awake all night thinking about solutions	Deprivation Epistemic Curiosity Scale	DECS1	46.7	90.9	44.2
I can spend hours on a single problem because I just can't rest without knowing the answer	Deprivation Epistemic Curiosity Scale	DECS2	66.7	72.7	6
I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it	Deprivation Epistemic Curiosity Scale	DECS3	86.7	81.8	-4.9
I brood for a long time in an attempt to solve some fundamental problems	Deprivation Epistemic Curiosity Scale	DECS4	66.7	72.8	6.1
I work like a fiend at problems that I feel must be solved	Deprivation Epistemic Curiosity Scale	DECS5	60	81.9	21.9

* %Agree =Always and Often with 4-Likert scale

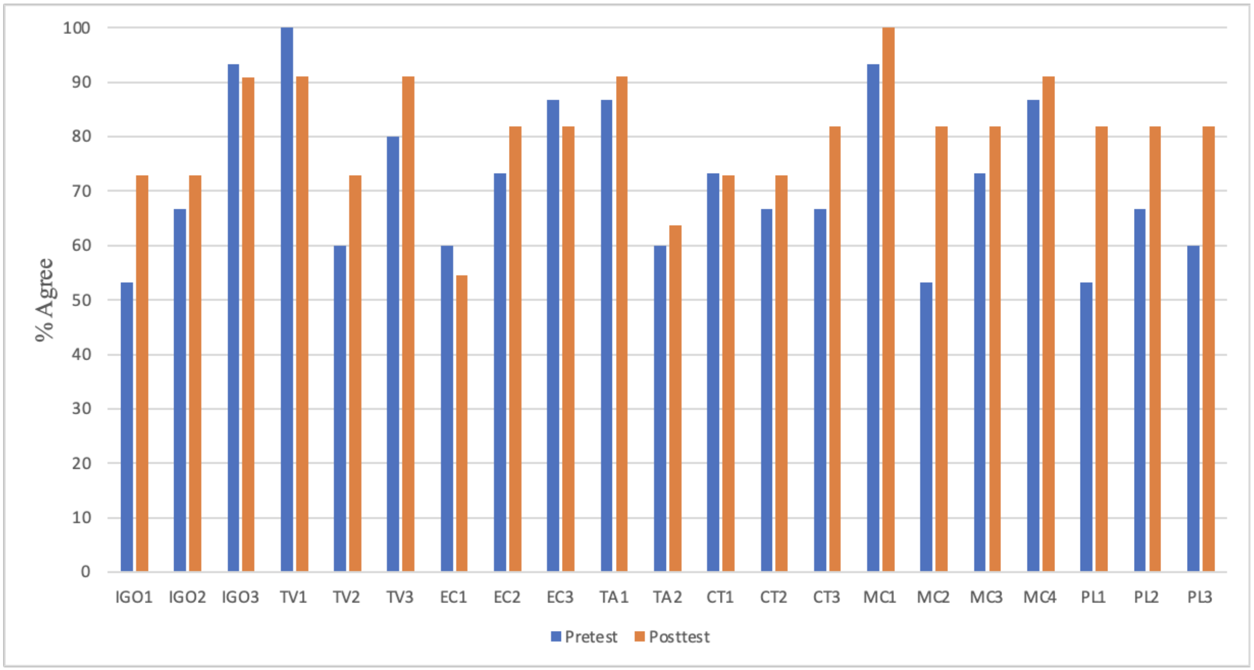


FIGURE 8: Pre-Post Test Student Motivation Fall 2020

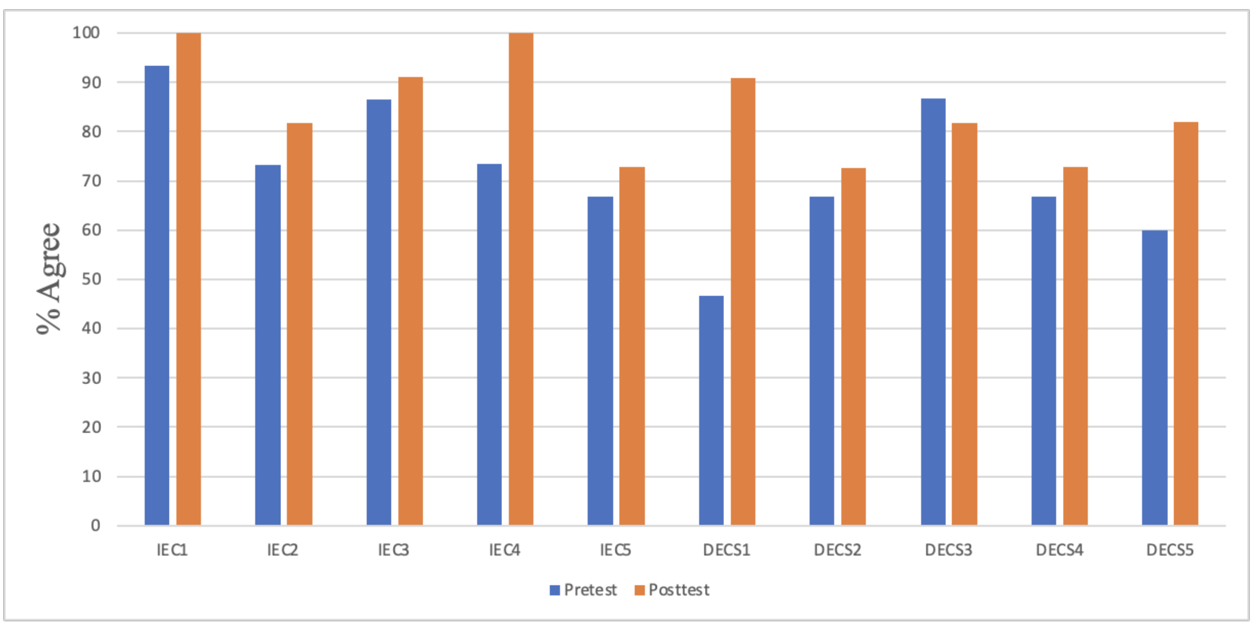


FIGURE 9: Curiosity Scale - Fall 2020

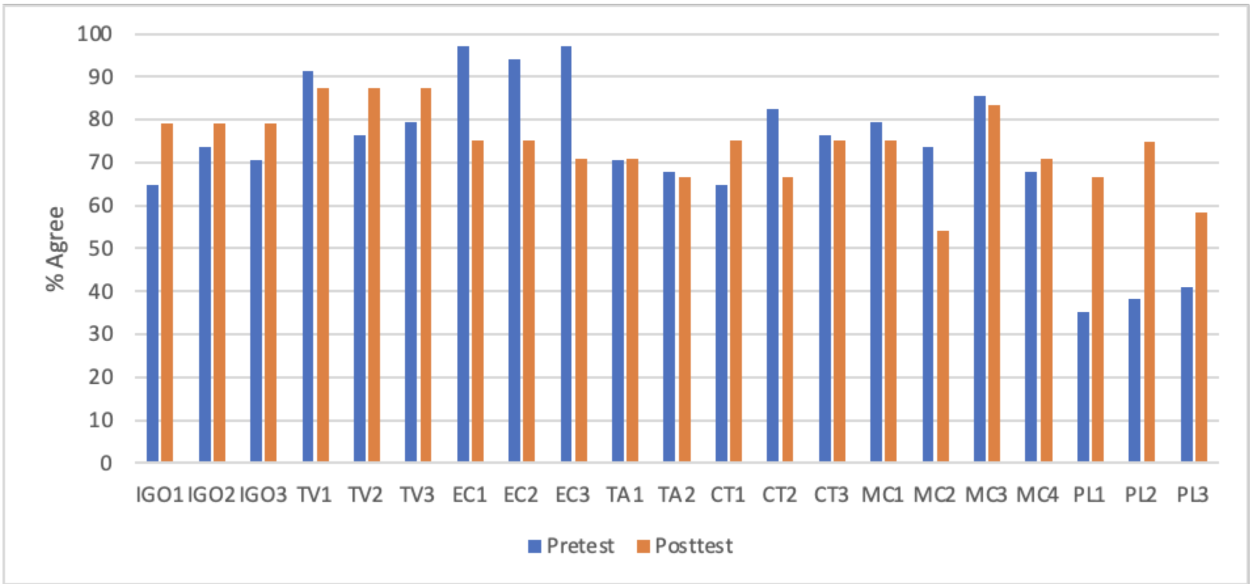


FIGURE 10: Pre-Post Test Student Motivation Spring 2021

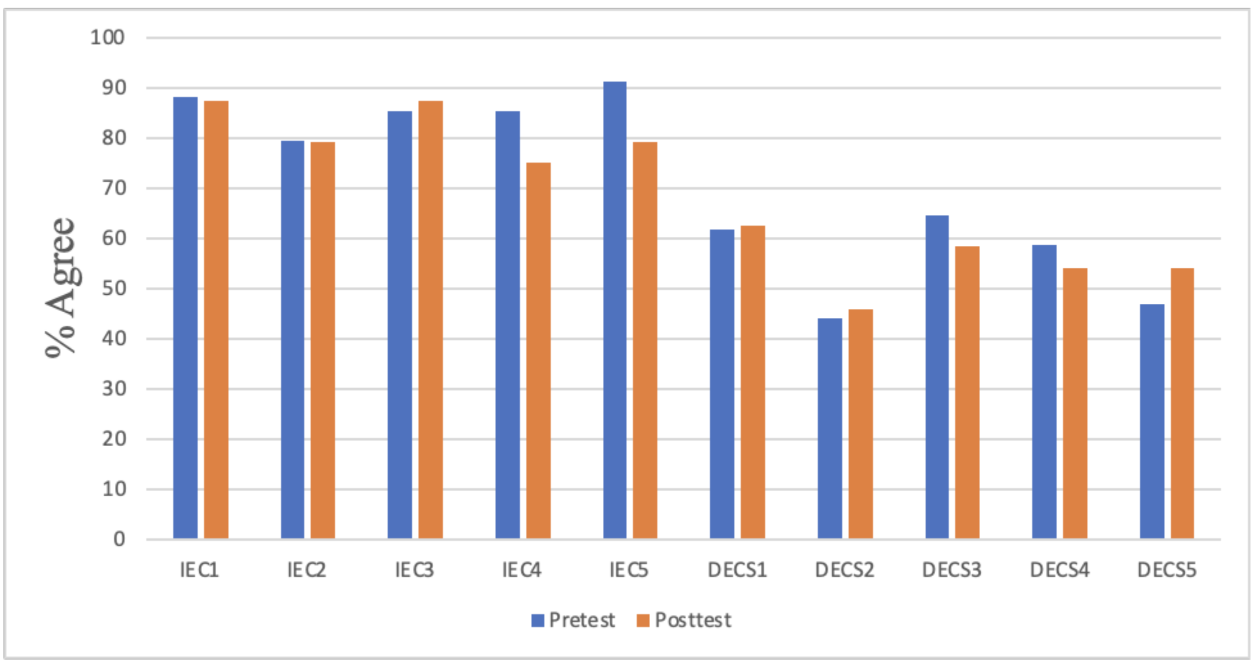


FIGURE 11: Curiosity Scale-Spring 2021

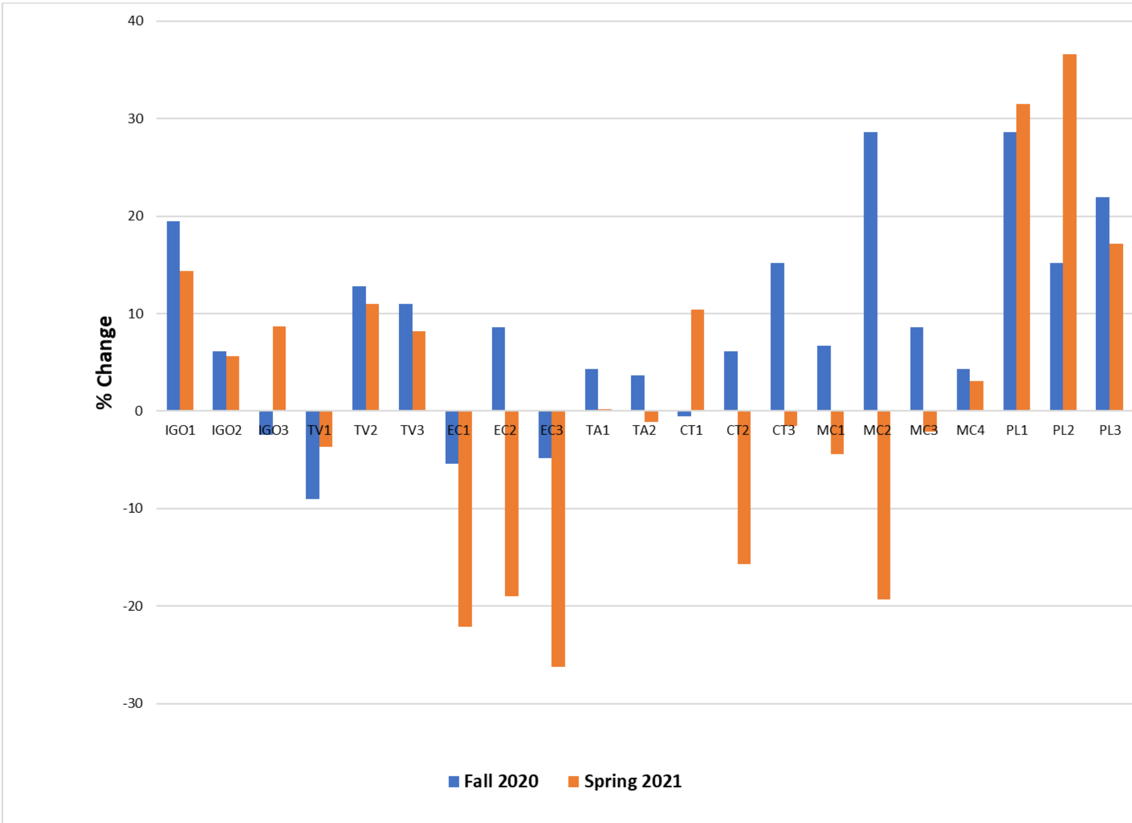


FIGURE 12: Student Motivation % Change between Fall 2020 and Spring 2022

Table 3a shows the results of the descriptive analysis conducted on pre-and post-test results of the survey of the key constructs, when ECP was implemented in the highway engineering class in Fall 2020 and in the introduction to transportation system class in Spring 2021 respectively. While in Fall 2021 ECP was implemented both in the introduction to transportation systems class and the highway engineering class. In Fall 2020, 15 students participated in the pre-test and 11 students participated in the post-test and in Spring 2021, 34 students participated in the pre-test while 24 students participated in the post-test. In the introduction to transportation systems class (TRRS 301) in Fall 2021, 32 students participated in the pre-test while 26 participated in the post-test. However, in the Highway Engineering class (TRRS 415) where the moisture content experiment was conducted , 8students participated in the pre-test and 7 participated in the post-test. Figure 3b shows the results of the Fall 2021 ECP implementation. The results of the descriptive analysis were compared with the outcome of ECP in all the five STEM disciplines combined (Biology, Chemistry, Civil Engineering, Industry Engineering, Physics and Transportation). The sample size of the participants for the pre and post are shown in the table. The result clearly shows that in Fall 2020 that there are improvement in students' motivation levels in six constructs: (Intrinsic goal orientation (post (5.528)> pre (5.289)); Task value(post (5.917)> pre(5.222)); Expectancy Component (post (5.500)> (5.222)); Critical Thinking (post (5.500)> pre(5.133)), Metacognition (post (5.979)> pre(5.383)); Peer Learning (post (5.444)> pre(4.556));

Interest Epistemic Curiosity Scale[1] (post (2.327)>pre (1.787)). However, test anxiety is supposed to reduce because of the intervention, but the results reveal an increase in test anxiety. The mean value for the test anxiety construct dropped when ECP was implemented in Spring 2021 in the TRSS 301 ((post (1.960) < pre(2.120) difference -1.740). The implementation of ECP only witnessed improvement in Intrinsic goal orientation, task Value, interest epistemic curiosity and deprivation epistemic curiosity constructs respectively in Spring 2021. Paired-sample t-test analysis was conducted in order to determine the significance difference between the pre- and post-mean of the scores (p-value of < 0.05 indicates a significance difference). Significance difference is only observed in the Metacognition and Peer learning constructs in Fall 2020 semester while in Spring 2021 there was significant improvement in Task Value, Expectancy, Test anxiety and interest epistemic curiosity key constructs of students as a result of the implementation of ECP. The above trends are similar to what was observed when ECP was implemented in the electrical engineering field at 13 HBCUs [5]. Table 3b shows the results of all the descriptive analysis conducted on pre-and post-test for the ECP courses combined in Fall 2020, Spring 2021 and Fall 2021 respectively. The cummalitive number of students that responded to the pre-test was 89 while post test was 68, thus sufficient to make statistical inference. Overall there is a significance difference in the epistemic curiosity scale with p=0.0375 between the pre and post tests.

From the Qualitative results following were expressed by the students:

"It was very interesting seeing how the Analog Device (M1k-ADALM 1000) worked. It was very simple and it was intriguing to see how decibel waves formed with sound"

"We used the instrument to capture sounds from outside and in our room. I thought it was an interesting experiment since it was simple and very easy to use from home"

"The use of the device was simple after instruction and fairly understandable"

"We used the sound decibel app in my transportation class to record the level of noise for different locations and at different times. It was cool finding out the differences in the level of noise for different sounds."

"The decibel: finding the db decibel's was very interesting and enlightening during this course. Learning how to upload the device and the information obtained was a bit challenging. I realized how very effective this instrument is for various uses".

"It was a good experience for me. I didn't think the app that we had to use for our project would work but it actually did work and it was pretty cool once you got the hang of it and knew you were doing".

"My class experience with using phone apps was very interesting and it opened my horizons by using new and different apps and introducing me to the measurement of source decibels."

"The overall experience using the phone app was insightful. It allowed me to better understand and determine safe vs unsafe sound ranges based on the sources. As well as how other factors contribute to sound/noise levels. "

"I enjoyed my class experience greatly.. my professor always kept us engaged and was very creative with fun but challenging assignments. "

[1] Based of a 4-point likert scale

"The Arduino was used to simulate different soil states with given properties to generate the necessary data for the understanding and analysis of soil properties."

"During this experiment the goal was to measure the soil moisture through utilizing the Arduino software. "

"it was a good experiment that exposed me to a soil moisture sensor"

Students equally commented positively about the impact of ECP on learning during the pandemic on the faculty evaluation that are usually provided at the end of the semester. Example of such comments when students were asked to give some successful remote instruction experiences in the course evaluation is given below:

"The lab assignment was very enjoyable"

The instructor of the highway engineering has been teaching this course for the past three consecutive sessions, subsequently, Figure 13a shows the grade distribution in Highway Engineering for the Fall 2018 to Fall 2020. Generally, in the School of Engineering, students are given letter grades of A, B, C, and F respectively. The percentage of students that failed the class seems to be highest in Fall 2019, when ECP was not implemented.

However, there is no significance difference for the students' performance between Fall 2021 and Fall 2018.

In the Higway Engineering class (TRSS 415) in Fall 201, the students were assessed on how they are meeting the ABET Outcome 6 on design, conduct and interpretation of experiments using the following performance criteria: (6.1) Describes the hypothesis being tested, (6.2) Formulates adequate simulation or exeperiment to test hypothesis, (6.)3 Accepts reasonable variance between numerical or experimental results and predictions of hypothesis (A) (analysis), (6.4) Understands the functions and limitations of the computer or laboratory tool/equipment used, (6.5) Organizes experimental or simulation data mathematically or graphically to interpret it (I), (6.7) Recognizes the relation in precision between input and output data (I) and (6.8) Determines sources of error performs error analysis on results (A). The outcome assessment rubrics used have performance scales of unsatisfactory, developing, satisfactory and exemplary respectively. For the targeted performance to be met at least 75% of students must be either at the satisfactory or exemplary scale. This means that less than 25% must fall under unstatisfactory and developing scales respectively. Figure 13b shows the results of the outcome assessment. More than seventy five percent of students in the class met the targeted performance for the performance indicator 6.1, 6.2 and 6.5 respectively, while students did not meet the targeted performance in the rest of the performce criteria.

Table 3a Descriptive analysis of pre-and post-test results of Fall 2020 and Spring 2021

		Intrinsic goal* orientation		**Task Value***		**Expectancy* Component**		**Test Anxiety***		**Critical Thinking***		**Metacognition***		**Peer Learning/ Collaboration***		**Interest **Epistemic Curiosity Scale**	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
FALL 2020																	
TRS PrN=15	Mean	5.289	5.528	5.667	5.917	5.222	5.500	5.300	5.750	5.133	5.500	5.383	5.979	4.556	5.444	1.787	2.327
PsN=11	SD	0.506	0.039		0.136		0.245		0.250		0.068		0.069		0.039	0.735	0.728
	Δ	+0.239		+0.2500		+0.278		+0.450		+0.367		+0.596		+0.888		+0.540	
	P-Val	0.573		0.505		0.419		0.429		0.070		0.046		0.013		0.075	
ALL	Mean	5.387	5.283	5.770	5.459	5.676	5.315	5.581	5.324	5.063	5.158	5.394	5.388	4.528	5.085	1.734	2.589
PrN=259	SD	0.258	0.058	0.292	0.177	0.135	0.085	0.089	0.076	0.038	0.034	0.164	0.063	0.170	0.076	0.658	0.956
PsN=169	Δ	-0.104		-0.311		-0.361		-0.257		+0.095		-0.006		+0.557		+0.855	
	P-Val	0.630		0.281		0.042		0.163		0.059		0.954		0.028		0.000	
TRS	**SPRING 2021**																
PrN=34	Mean	3.460	4.140	2.580	5.690	5.750	1.800	4.680	2.940	4.160	3.060	4.590	2.750	3.550	3.860	1.677	2.433
PsN=24	SD	1.290	1.800	1.230	0.880	1.380	0.760	2.120	1.960	1.370	1.120	1.530	1.170	1.720	1.800	SD	1.290
	Δ	+0.680		+3.110		-3.950		-1.740		-1.100		-1.840		+0.310		0.757	
ALL	P-Val	0.081		0.000		0.000		0.001		0.001		0.000		0.466		0.000	
PrN=264	Mean	3.010	3.560	2.610	5.650	5.310	2.370	4.650	3.050	4.510	3.110	4.850	2.710	4.090	4.440	1.803	2.421
PsN=158	SD	1.460	1.630	1.500	0.800	1.600	1.390	1.850	1.740	1.470	1.350	1.410	1.180	1.630	1.630	0.706	0.956
	Δ	+0.550		+3.040		-2.940		-1.600		-1.400		-2.140		+0.350		0.618	
	P-Val	0.000		0.000		0.000		0.000		0.000		0.000		0.013		0.000	

*1-7 Likert Scale
** 1-4 Likert Scale
PrN Sample size for Pre-test
PrS Sample Size for Post-test
SD Standard Deviation
Δ Difference Between Pre-and Post-Test
P-Val T-test result <0.05 is significant

Table 3b Descriptive analysis of pre-and post-test results of Fall 2021 and Combination of Fall 2020 to Fall 2021

		Intrinsic goal* orientation		Task Value*		Expectancy* Component		Test Anxiety*		Critical Thinking*		Metacognition*		Peer Learning/ Collaboration*		Interest **Epistemic Curiosity Scale	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
FALL 2021																	
TRS PrN=40	Mean	5.289	3.917	4.180	3.878			3.201	2.192	3.281	2.500	2.641	2.423	5.849	3.769		
	SD	1.941	1.516	0.935	0.771			2.039	0.749	1.339	0.662	1.164	0.588	1.713	1.095		
PsN=33	Δ	+1.583		-0.302				-1.009		-0.781		-0.218		-2.080			
	P-Val	0.609		0.0615				0.020		0.009		0.404		0.002			
ALL PrN=315 PsN=364	Mean	2.837		2.324	1.561	2.423		2.597	2.339	3.099	2.445	2.621	2.359	3.782	2.911		
	SD	1.213		1.263	0.422	1.348		1.700	0.936	1.251	0.929	1.147	0.814	1.674	1.328		
	Δ			-0.763				-0.258		-0.654		-0.262		-0.871			
	P-Val			0.000				0.016		0.000		0.001		0.000			
	FALL 2020, Spring 2021 & Fall 2021 Combined																
TRS PrN=89 PsN=68	Mean	4.679	4.528	4.142	5.162	5.486	3.650	4.394	3.627	4.191	3.687	4.205	3.790	4.652	4.358	1.732	2.380
	SD	1.246	1.118	1.083	0.596	1.380	0.503	2.079	0.987	1.355	0.617	1.355	0.609	1.717	0.978	0.735	1.009
	Δ	-0.151		+1.020		-1.836		-0.767		-0.504		-0.415		-0.294		+0.648	
	P-Val	0.421		0.189		0.209		0.150		0.027		0.018		0.160		0.0375	

*1-7 Likert Scale
** 1-4 Likert Scale
PrN Sample size for Pre-test
PrS Sample Size for Post-test
SD Standard Deviation
Δ Difference Between Pre-and Post-Test
P-Val T-test result <0.05 is significant
Blank space means there is no data at the time of report

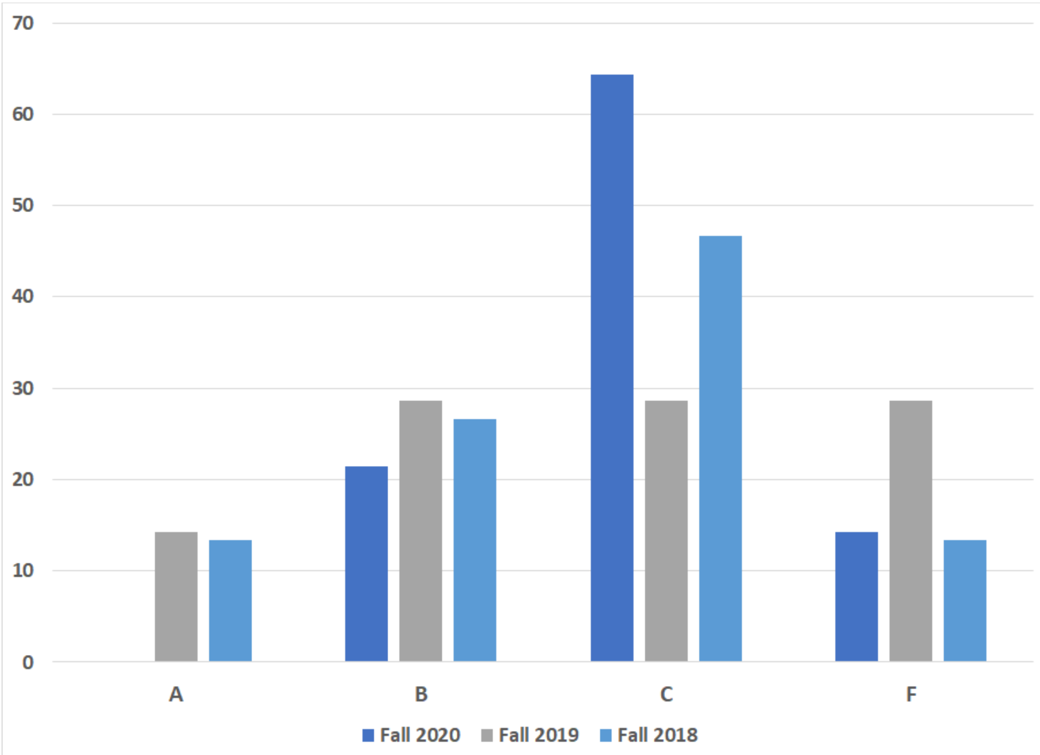
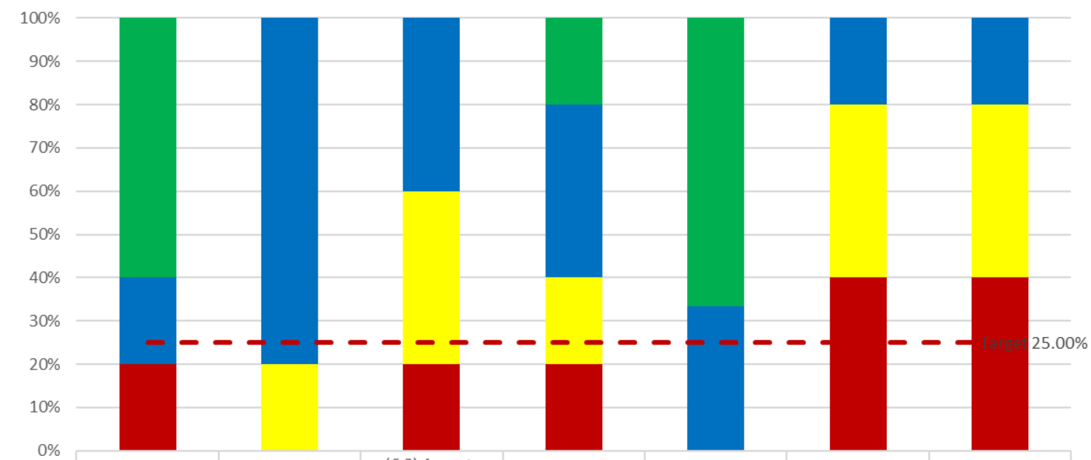


FIGURE 13a: Grades Distribution in Highway Engineering (Fall 2018 to Fall 2020)



	(6.1) Describes the hypothesis being tested. (D)	(6.2) Formulates adequate simulation or experiment and hypothesis (D) (synthesis)	(6.3) Accepts reasonable variance between numerical or experimental results and predictions of hypothesis (A) (analysis)	(6.4) Understands the functions and limitations of the computer or laboratory tool/equipment used(C) (comprehension)	(6.5) Uses laboratory tool/equipment or computer simulation correctly (c)	(6.7) Recognizes the relation in precision between input and output data (I)	(6.8) Determines sources of error performs error analysis on results (A)
Exemplary	60.00%	0.00%	0.00%	20.00%	66.67%	0.00%	0.00%
Satisfactory	20.00%	80.00%	40.00%	40.00%	33.33%	20.00%	20.00%
Developing	0.00%	20.00%	40.00%	20.00%	0.00%	40.00%	40.00%
Unsatisfactory	20.00%	0.00%	20.00%	20.00%	0.00%	40.00%	40.00%
Target	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%

FIGURE 13b: Outcome Assessment Result for Highway Engineering Class in Fall 2021

Classroom Observation

Highway Engineering

The lab session was very interactive and it was clearly observed that the students were effectively engaged, they were excited about the experiment as well as highly inquisitive about the procedures. In addition, they were very curious and mostly exchanged question and answer with the instructor the whole session and were not cognizant of the time. They really appreciated the introduction of the sensor and were very motivated in the upcoming results they will record during the assigned tasks. Figure 14 shows the results of the COPUS, the results reveal that ECP is highly engaging as students spent 84% of the class time on hands on activities, while simultaneously 92% of the class time was spent by students asking questions. Figure 14 equally reveals the contrast between students behavior with and without ECP. The rest of the characteristics of student's behavior clearly shows that the students were highly motivated with ECP. From Figure 15 it clearly shows that the instructor only lectures 8% of the class time, while most of the time was spent on highly interactive pedagogy activities. The instructor was excited that ECP made students turn on their Zoom cameras. The contrast between instructor attribute with and without ECP is also shown in the figure. A great similarity was seen in the results of the classroom observation when compared with other courses that utilize several active learning instructional practices (Smith et al 2013 [18] and Velasco et al 2016 [26]. Another class was observed when the instructor was not implementing, Figure 15 clearly shows the different between ECP pedagogy and other teaching technique.

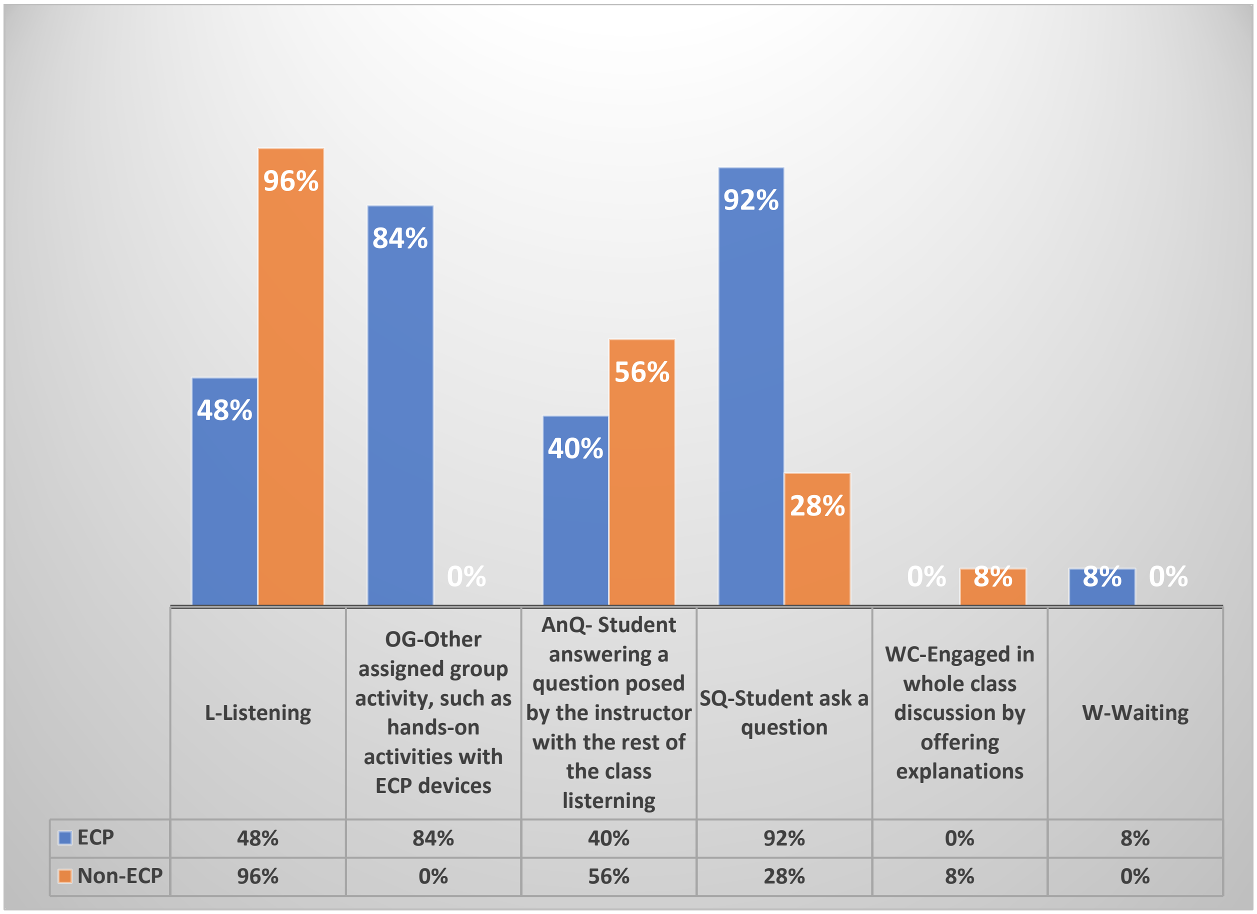


FIGURE 14 – Students' behavior with and without ECP

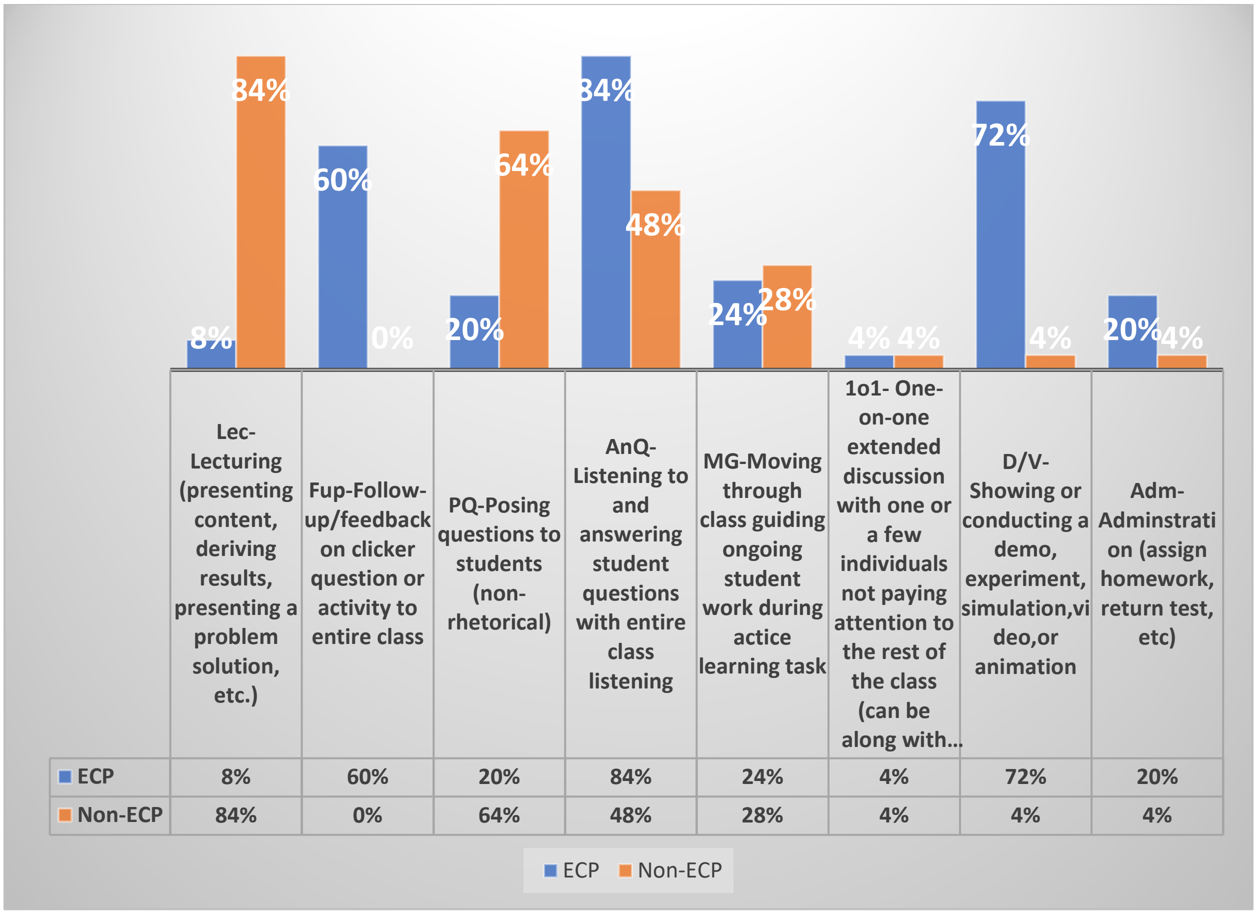


FIGURE 15 – Instructor's behavior with and without ECP

CONCLUSION

Two experiments were developed using the ECP including noise and moisture content. The noise experiment was successffully customized and integrated in the Highway Engineering (TRSS 415) and the Introduction to Transportation Systems (TRSS 301) during the pandemic in Fall 2020 and Spring 2021 respectively, and details are presented. The moisture content experiment has been integrated in Fall 2021. The results reveal a significant difference between the pre- and post-tests of key constructs associated with student success, such as motivation, critical thinking, curiosity, collaboration, and metacognition. The results of the Classroom Observation Protocol for Undergraduate STEM (COPUS) show more active student engagement when ECP is implemented. In the future, more work needs to be done for traffic count and flow studies. In order to investigate the flow and density of the road, the traffic count experiment will be used to track the number of vehicles that pass through a particular road or garage of our choice, while the car speed detection experiment will be used to track how vehicles accelerate or stop at an intersection due to the traffic light. The pneumatic road tubes lay across the roadway to detect the passing vehicles.

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CONTRIBUTIONS

The project team consists of faculty members and trainees (graduate students). Faculty members and trainees developed and implemented the experiments in the existing courses and students helped with collecting data and administering survey studies. Faculty members analyzed and interpertated data to draw conclusions and the entire team worked on writing and editing the manuscript.

REFERENCES

1. Mackay, S. and Fisher, D. (2014). Practical Online Learning and Laboratories for Engineering, Science and Technology, 2nd ed. West Perth, WA, Australia: IDC Technol., 2014
2. Walkington, J., Pemberton, P., and Eastwell, J. (1994). "Practical work in engineering: A challenge for distance education," Distance Educ., vol. 15, no. 1, pp. 160–171, 1994
3. Aziz, A., & Islam, S. N. (2021). Impact of Mixed Pedagogy on Engineering Education. *IEE Transactions on Education, Education, IEEE Transactions on, IEEE Trans. Educ*, *PP*(99), 1–8. https://doi-org.proxyms.researchport.umd.edu/10.1109/TE.2021.3088808
4. Lepper, M (1988) "Motivational considerations in the study of instruction," Cognit. Instr., vol. 5, no. 4, pp. 289–309, 1988
5. Astatke, Y., & Connor, K. A., Newman, D., Attia, J. O., & Nare, O. E. (2016, June), Growing Experimental Centric Learning: The Role of Setting and Instructional Use in Building Student Outcomes Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25427
6. Skulmowski, A., Rey, G.D. (2018). Embodied learning: introducing a taxonomy based on bodily engagement and task integration. *Cogn. Research* 3, 6 (2018). https://doi.org/10.1186/s41235-018-0092-9
7. Smyrnaiou, Z., Sotiriou, M., Georgakopoulou, E., and Papadopoulou, O. (2016). "Connecting embodied learning in educational practice to the realisation of science educational scenarios through performing arts," in Proc. Int. Conf. Inspiring Sci. Educ., Athens, Greece, 2016, pp. 37–45.
8. Pintrich, P. R., Smith, D. A., García, T., & McKeachie, W. J. (1991). A manual for the use of the motivational strategies for learning questionnaire (MSLQ). Ann Arbor, MI: University of Michigan, National Center for Research to Improve Postsecondary Teaching and Learning.
9. Garcia, T., & Pintrich, P.R. (1996). Assessing Students' Motivation and Learning Strategies in theClassroom Context: The Motivated Strategies for Learning Questionnaire.
10. Taylor, R. (2012). Review of the motivated strategies for learning questionnaire (MSLQ) using reliability generalization techniques to assess scale reliability (Doctoral dissertation). Auburn University.

11. Litman, J. A. & Spieldberger, C.D. (2003). Measuring epistemic curiosity and its diversive and specific component. Journal of Personality Assessment, 80(1), 75-86.
12. Li, M., Armstrong, S. J. (2015). The relationship between Kolb's experiential learning styles and Big Five personality traits in international managers. *Personality and Individual Differences, 86*, pp. 422-426. https://doi-org.proxy-ms.researchport.umd.edu/10.1016/j.paid.2015.07.001
13. Weir, J. (2004). *Active Learning in Transportation Engineering Education* (3158525) [Doctoral dissertation, Worcester Polytechnic Institute]. https://drive.google.com/drive/folders/1xQyzHzgEgSOw6Wxgjowjls0m1wP82rOd
14. Adult online education (2018): Investigating learning theories and their application to distance learning. Development and Learning in Organizations, 32(3), 31-34. doi: http://dx.doi.org.proxy-ms.researchport.umd.edu/10.1108/DLO-02-2018-0023
15. Bagher, M. M. (2020). Immersive VR and Embodied Learning: The Role of Embodied Affordances in The Long-term Retention of Semantic Knowledge, *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pp. 537-538, doi: 10.1109/VRW50115.2020.00120
16. Connor, K. A., Gullie, K. A., Newman, D., Chouikha, M. F., Kelly, J. D., et al. (2018). Experiment-Centric Pedagogy – Improving the HBCU Engineering Student Learning Experience, *American Society for Engineering Education, 22775*, https://peer.asee.org/board-26-experiment-centric-pedagogy-improving-the-hbcu-engineering-student-learning-experience.pdf
17. Connor, K.A (2021). ECP Learning Cycle. Kenconnor.org
18. Smith, M. K., Jones, F. H., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A new instrument to characterize university STEM classroom practices. *CBE—Life Sciences Education*, *12*(4), 618-627.
19. Chavis, C. (2020). Syllabus for TRSS 414_Fall 2020. Retrieved from morganstate.instructure: https://morganstate.instructure.com/courses/9997/assignments/syllabus
20. Chavis, C. (2020). Syllabus for TRSS 415_Fall 2020. Retrieved from morganstate.instructure: https://morganstate.instructure.com/courses/13194/assignments/syllabus
21. Deaconu, M., Cican, G., & Cristea L. (2020). Noise Impact Mitigation of Shopping Centres Located near Densely Populated Areas for a Better Quality of Life, *Applied Sciences, 10*(18), 6484, DOI: 10.3390/app10186484
22. Federal Highway Administration, 1980. Highway Traffic Noise. https://www.nonoise.org/library/highway/traffic/traffic.htm
23. Drake, K. (2020). *A Semi-Autonomous Sensor Station for Remote Assessment of Soil Quality in Rooftop Gardens and Agricultural Farmlands.* [Doctoral dissertation, Morgan State University]. https://www.proquest.com/openview/4d7eba84df22665c4e6f1a5a0cc92fb0/1.pdf?pq-origsite=gscholar&cbl=18750&diss=y
24. Velasco, J.B, Knedeisen, A., Xue, D., Vickrey, T.L., Abebe, M., and Stains, M. (2016) "Characterizing Instructional Practices in the Laboratory:The Laboratory Observation Protocol for Undergraduate STEM". Journal of Chemical Education. Vol 93, pp 1191-1203.