2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38681

Utilization of Real-Life Hands-On Pedagogy to Motivate Undergraduate Students in Grasping Transportation Related Concepts

Adebayo Iyanuoluwa Olude, Morgan State University
Dr. Oludare Adegbola Owolabi, P.E., Morgan State University

Adebayo Olude is a doctoral student and research assistant at Morgan State University's Department of Civil Engineering in Baltimore, Maryland. Adebayo formerly worked as a Graduate Research Assistant at Eastern Mediterranean University in North Cyprus, where he earned his master's degree in civil engineering. He also worked as a project Analyst with AgileP3 after graduating with a Bachelor of Engineering (B.Eng) in civil engineering from Covenant University, Nigeria. Adebayo has taught courses in Transportation and Chemistry at Morgan State University as part of his commitment to the STEM profession. He has attended conferences across the Transportation engineering field.

Mr. Pelumi Olaitan Abiodun, Morgan State University

Pelumi Abiodun is a current doctoral student and research assistant at the Department of Civil Engineering, Morgan State University, Baltimore, Maryland. Pelumi got his BSc and MSc degree in Physics from Obafemi Awolowo University, where he also served as a research assistant at the Environmental Pollution Research unit, in Ile-Ife, Nigeria. As part of his contribution to science and engineering, Pelumi has taught as a teaching assistant both at Morgan State University and Obafemi Awolowo University. With a passion to communicate research findings gleaned from experts in the field as he advances his career, Olaitan has attended several in-person and virtual conferences and workshops, and at some of them, made presentations on findings on air pollution, wastewater reuse, and heavy metal contamination.

Hannah Abedoh, Morgan State University
Frank Efe
Dr. Petronella A James, Morgan State University

Dr. Petronella James is a faculty member at Morgan State University in both the Electrical Engineering and Transportation departments. Dr. James has experience in accreditation, program assessment and evaluation process and was recently (2016-2019), the accreditation coordinator for the school of Engineering. Her interest in engineering education emphasizes developing new classroom innovations and assessment techniques and supporting student engagement. Her research interests include broadening participation in STEM, equity and diversity, engineering ethics, online engineering pedagogy, program assessment solutions, transportation planning, transportation impact on quality of life issues, and bicycle access. She is a proud Morgan Alum (2011), having earned a Doctorate in Civil Engineering, with a focus on transportation. Dr. Petronella James earned her Doctor of Engineering (Transportation) and Masters of City & Regional Planning. She completed a B.S. Management Studies, at the University of the West Indies (Mona), Jamaica.

Dr. Celeste Chavis, P.E., Morgan State University

Celeste Chavis is an Associate Professor in the Department of Transportation & Urban Infrastructure Studies in the School of Engineering at Morgan State University in Baltimore, MD. Dr. Chavis is a registered professional engineer in the State of Mary

Dr. Eazaz Sadeghvaziri, Morgan State University

Dr. Eazaz Vaziri is a Postdoctoral Research Associate at the Urban Mobility & Equity Center and an Adjunct Faculty in the Department of Transportation & Urban Infrastructure at Morgan State University. Also, he is an Engineering Postdoctoral Fellow (eFellows) at the American Society for Engineering Education through funding provided by the U.S. National Science Foundation (NSF). He has almost ten years of experience in the Transportation Engineering field and has conducted different research projects. His research interests include connected and autonomous vehicle, micro mobility, equity in transportation, transportation planning, travel pattern analysis, driver behavior analysis, traffic simulation, and traffic safety. He earned his Bachelor of Science in Civil Engineering, his Master of Science in Civil Engineering (Transportation Planning), and his Ph.D. in Civil Engineering (Transportation Engineering). He serves as a member of the Transportation Research Board (TRB) Standing Committee on Workforce Development and Organizational Excellence (AJE15). Also, he serves as a member of the TRB Standing Committee on Rural, Intercity Bus, and Specialized Transportation (AP055). He is a paper reviewer for different TRB committees, and has reviewed, presented, and published numerous research papers. He served the ITE student chapter at Florida International University as Secretary and Membership Chapter for two years. He has been PI/Co-PI for nine research grants funded by state agencies totaling over $1,018,659. He has also worked as a transportation engineer in private companies. Having both academic and industry backgrounds, Dr. Vaziri continues his practical research and works with students and practicing engineers.

Di Yang
Neda Bazyar Shourabi, Pennsylvania State University, Berks Campus
Dr. Mulugeta T. Dugda, Morgan State University
Dr. Krishna Bista,

Krishna Bista is an Associate Professor at Morgan State University, Maryland (USA).

Dr. Jumoke 'Kemi' Ladeji-Osias, Morgan State University

Dr. J. 'Kemi Ladeji-Osias is Professor in the School of Engineering at Morgan State University in Baltimore. She is a rotating Program Director in the Division of Engineering Education from 2021 - 2023.

Utilization of Real-life Hands-on Pedagogy to Motivate Undergraduate Students in Grasping Transportation Related Concepts

Abstract

Real-life hands-on pedagogy adequately grounded in workable social learning theory is a precursor to motivating students to grasp transportation-related concepts. At a historically black university, an evidence-based, experiment-focused, hands-on method of instruction was adopted in the transportation discipline from the fall of 2020 until now. This paper outlines the development and implementation of hands-on pedagogy in the transportation systems discipline from fall 2020 to fall 2022. The Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, García, and McKeachie in 1991 was used to measure key constructs associated with students' success, such as motivation, epistemic and perceptual curiosity, and self-efficacy. Signature assignments were developed to measure student success outcomes from adopting the pedagogy. The results of the MSLQ administered to 44 students impacted by the pedagogy reveal a significant increase in the students' key constructs associated with success. The pedagogy reveals better knowledge gain and classroom engagement than the traditional teaching approach.

Introduction

Historically, concepts in engineering fields have been taught using traditional methods of instruction [1]. In this method, the instructor is the sole provider of knowledge, and students rely on the instructor to explain concepts from the instructional resources [2], [3]. With this method, learners are incapable of total concentration due to the absence of active learning engagements. They can, unfortunately, not relate concepts taught in the classroom to real-life situations [4]. With the emergence of ample evidence against traditional teaching methods in recent times, a large and growing body of literature has recommended alternative teaching methods to improve student achievement in STEM related disciplines [5]–[8].

This alternative approach to traditional instructional methods is hands-on pedagogy. The foundational approach of this method is "learning by doing." It allows students to interact with hands-on learning devices, thereby promoting active participation during classroom teaching. Much of the current literature on hands-on pedagogy suggests that its interactive nature increases students' engagement in engineering disciplines. Ikiriko et al. [9] investigated the impact of a home-based measurement of strain experiment. They found increased student motivational levels in the civil engineering discipline following a pre- and post-experimental survey. According to Chowdhury et al., [10] most engineering programs require hands-on workshop facilities to conduct educational laboratory activities to achieve academic objectives. Hands-on pedagogy achieves better learning outcomes using portable multifunction instruments to substitute larger laboratory instruments [7].

By drawing from the success of hands-on pedagogy in preliminary research, its use may be extrapolated to other disciplines and under-represented student groups in academia. In the United States of America (USA), African American students have a lower enrollment and graduation rate than White students in STEM disciplines [11]. Data from the National Science Foundation confirm that African Americans constitute only 3.9% of all BS Engineering degree graduates in the USA. Evidence suggests that many African American students may leave STEM disciplines due to the intellectual challenges they present, of which transportation studies are a subset [12]. As a result of this challenge, it is expedient to explore contemporary teaching methodologies that offer opportunities to improve African American student retention in STEM fields. Hence, this study was carried out among undergraduates attending one of the Historically Black Colleges and Universities in USA.

Therefore, this study assesses the impact of practical real-life, hands-on teaching methods on undergraduate students' motivation for engagement in transportation-related concepts. This research questions posited for the current study were:

1. Can experiment-centric pedagogy improve undergraduate students' understanding of transportation-related concepts?
2. Does ECP increase the engagement of students in the learning process ?

Experiment-centric pedagogy (ECP) is one of the emerging hands-on pedagogies that actively engage students by utilizing affordable, safe, and portable electronic instrumentation devices in various educational situations (classrooms or laboratories).

ECP is a teaching method that integrates with multiple stem disciplines while measuring student success outcomes. ECP integrates technology with curriculum creation and innovative pedagogies to enable hands-on activities, experiential learning, and group work [13]. Overall, hands-on pedagogy utilizes portable multifunction instruments to substitute larger laboratory instruments to achieve interactive learning and long-term knowledge retention [8]. ECP incorporates problem-based activities and constructive learning methods with a hands-on, portable multifunction instrument intended to substitute for larger laboratory instruments.

This paper details the development and implementation of ECP in teaching transportation-related concepts in a historically black college and university (HBCU).

Theoretical Framework

Learning is fluid and varies from person to person. A piece of essential knowledge for educators is understanding how new abilities are created, new information is gained, and new behaviors, morals, attitudes, and values are acquired. Researchers have conducted various studies to investigate this, guiding academic theorists to develop a variety of hypotheses and models to explain how learning takes place. These learning theories provide explanations of the framework behind how individuals acquire knowledge. This paper discusses one of these theories.

Constructivism Learning Theory:

Constructivism - a theory based on observation and scientific study about how people learn. The theory states that through experience and reflection on various experiences, individuals are guided to construct their understanding and knowledge of the world [11]. Experiment-centered pedagogy integrates problem-based activities and constructivist education by allowing students to actively engage in the learning process by drawing on their prior experiences and understanding to generate new information or understanding.

According to constructivism, learning takes place under the following four assumptions:

1. Learning involves active cognitive processing.
2. Learning is adaptive.
3. Learning is subjective, not objective.
4. Learning involves both social/cultural and individual processes.

Constructivist Learning Theory Using the 5E Model:

In 1987, the Biological Sciences Curriculum Study developed the 5E Learning Model [14], [15]. The model aims to stimulate students in active learning, collaboration, and problem-solving through observations, questions, analyses, and conclusions. This kind of learning is known as active and collaborative learning. The 5E Model is preferred in science education. This is due primarily to its progressive process; knowledge is shared and elaborated to students during learning.

The first stage is the **ENGAGE** stage. At this stage, educators encourage students' participation through various challenges, thus stimulating their interest. The students are captivated by finding solutions to these challenges and, as a result, begin to activate and link prior knowledge of the tasks. After that, students' progress to the second, **EXPLORE** stage. At this stage, prior knowledge is tested, new concepts are gained, and learned concepts are established. The third stage is the **EXPLAIN** stage; students can connect the acquired information to real-world examples as the educator simplifies the ideas and contexts of the subject matter, which previously seemed difficult. The fourth stage **ELABORATE** delves deeper by demonstrating ways previously gained knowledge can be applied to new situations. Upon completing the four phases of the 5E Model, students are equipped with information, hands-on experience, and expertise needed in practical settings. At the final stage, students **EVALUATE** their performances and reflect on the knowledge gained.

Sugiarti et al. [16] presented their findings on the impact of using the 5E model to develop learning materials for Thermochemistry. They presented that the Learning Cycle 5E based STEM learning materials are appropriate to increase students' learning outcomes in studying Thermochemistry. In teaching engineering subject principles in Japan, Yata et al. [17] mentioned that it is critical to have a pedagogy that combines the learning process with activities. Duran and Duran [18] posited strongly that STEM education is best when carried out with an inquiry-based approachh. These reports show that 5E training has a clear advantage in fostering learning process such as the students' critical thinking abilities and peer interactivities. Establishing upon prior experiences, students effectively acquire knowledge facilitating the construction of new knowledge and understanding.

Methodology

Module Design

Figure 1 summarized the well-developed module structure where ECP is implemented and divided into four sections, and which was elaborated by Ladeji-Osias [13].

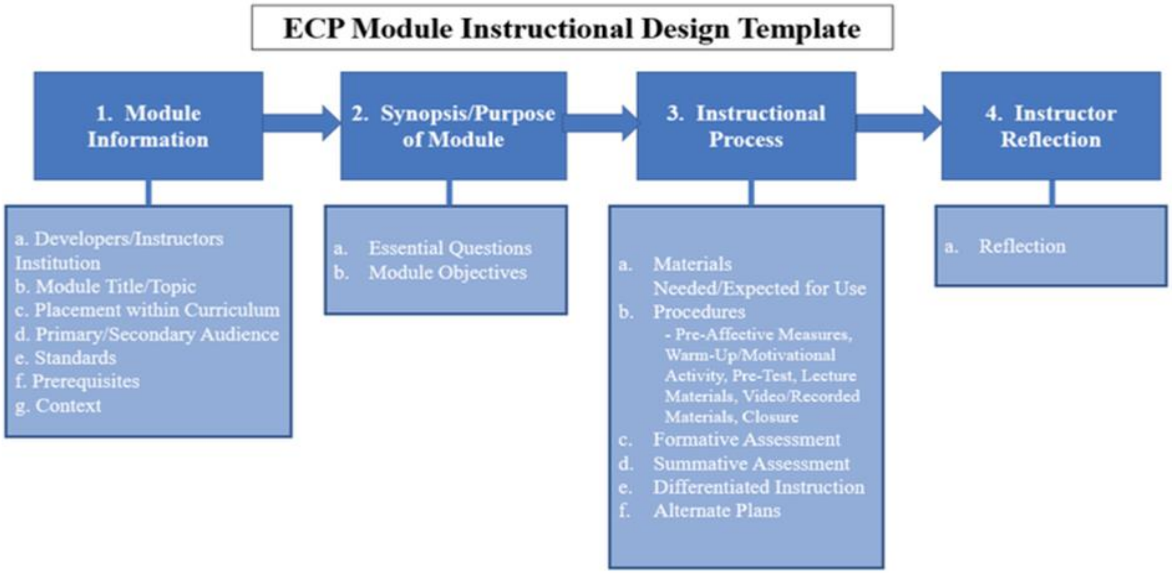


Figure 1: ECP Instructional module design

In the transportation engineering discipline, ECP was implemented in two undergraduate courses: TRSS 301 Introduction to Transportation Systems and TRSS 415 Highway Engineering. The first course is at the junior level. It covers transportation system concepts and strategies, like planning, engineering, management, logistics, and key issues such as physical, economic, social, and environmental aspects. Some topics covered include passenger and freight transportation systems, intermodal connectivity, and traffic control operations. There are about nine modules covered in the introductory course on transportation systems.

At the senior level, five modules were studied in the Highway Engineering course, comprising Principles of Highway Drainage, Soil Properties, Earthwork Calculations, Geometric Design, and Intersection. The course covers the fundamental principles, procedures, and methodologies of roadway design. There are just two hands-on lab experiments in these courses. However, further experiments will be conducted in subsequent semesters.

Methods of Experiments

Sound Measurement Experiment

In the fall of 2020, a sound experiment was conducted during the highway engineering class. The experimentation utilizes a laptop, an analog sound sensor, the ADALM 1000 (M1K), and three jumper wires. This measurement will help students understand sound and compare noise levels at different locations. Figure 1 shows the experimental setup.

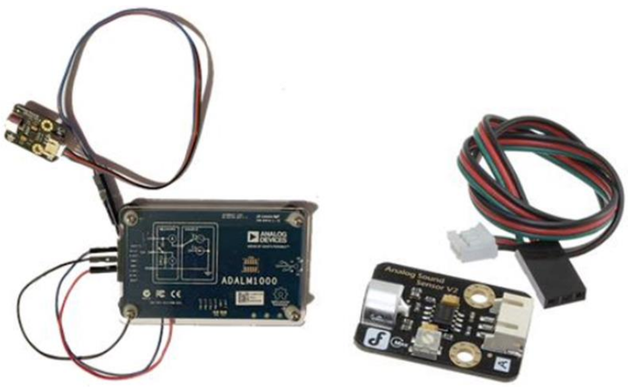


Figure 2: Sound Experiment Setup

Before the commencement of the experiment, students were introduced to fundamental concepts such as frequency, noise, and loudness. They were shown how to measure different sources of sound. The students could relate these concepts to real-life scenarios using the device for noise measurement. Students could also identify, formulate, and solve technical or scientific problems with knowledge of mathematics, science, and technological topics pertinent to this field as part of the learning outcomes. The experiment provides students with a better understanding of noise in planning and developing transportation infrastructure to mitigate the effect of noise on the environment.

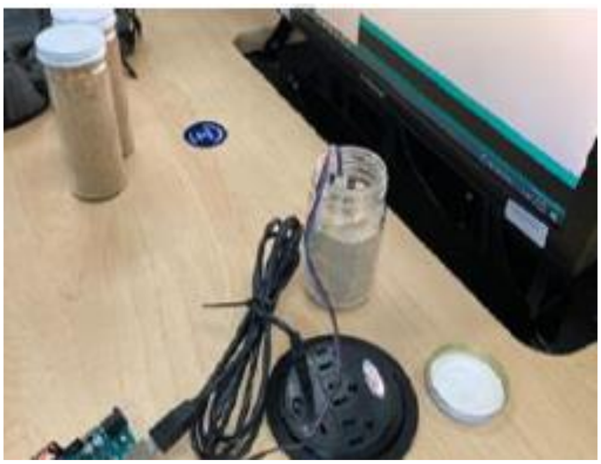
However, in the Fall of 2022, the sound decibel mobile app and a mobile phone were introduced to conduct sound experiments. Tasks were administered to the students to obtain data from different sources of sound with the aid of the mobile app. After performing the tasks, the students analyzed the obtained data. Figure 3 shows the pictorial representation of the mobile apps that were used.

Figure 3: (a) Apple (iPhone) Apps (b) Android Apps

Soil Moisture Experiment

A soil moisture sensor and Arduino were utilized during the implementation. The code for Arduino Uno was uploaded, and the soil sensor measured the moisture content in real time. Ten samples were prepared with varying soil moisture to calibrate the sensor. Students were able to conduct the experiments on the desktops at the computer laboratory with the assistance of an instructor. The Arduino has proven consistent outcomes in other studies for different data capturing and streaming [19]. This experiment is part of the learning module under the Soil Properties section and will help students understand electrical conductivity's characteristics, changes, and effects on the soil. As one of the learning outcomes, students will be able to develop and conduct experiments or test hypotheses, evaluate, and interpret data, and apply scientific judgment to make conclusions.

a. (b)



(c)

Figure 4: (a) Demonstration of the soil moisture test, (b) soil moisture sensor, and (c) soil moisture experimental setup

Data Collection and analysis

This study adopted a pre-post-test design and was carried out in one of the historically black colleges and universities in the United States of America. This is to enable a close investigation of the black population among learners which represents the underrepresented groups of learners in the USA. Following the research questions in this study, the implementation of ECP was conducted in the transportation-related field with the aid of electronic instrumentation to provide answers to the research questions. A quantitative method that revealed the pre- and post-report of students during the class session was obtained from the Motivated Strategies Learning Questionnaires (MSLQ) [20], classroom observation, and signature assignments. A rubric assessment was also used to determine students' understanding of the concepts taught using this pedagogy.

The MSLQ adopted to evaluate the effectiveness of ECP implementation uses a 7-point Likert-type scale consisting of statements that pertain to the core motivation and learning constructs. This widely adopted questionnaire for measuring learners' motivation comprises of the following constructs: intrinsic goal orientation (IGO), extrinsic goal orientation (EGO), task value (TV), expectancy component (EC), peer learning and collaboration (PLC), metacognition (MC), test anxiety (TA). More so, a curiosity tool developed by Littman and Spielberger [21] was also adopted. valuation instrument tool assesses students' curiosity [2]. The tool is categorized into two divisions: interest epistemic curiosity (IEC) and deprivation epistemic curiosity (DEC). EC originates from a desire for knowledge and to learn about innovations. PC, on the other hand, leads to interest in novel perceptual stimulation that inspires visual inquiry. The Curiosity Evaluation Tool utilizes a 4-point Likert scale; examples of the survey questions: "In a class like this, I prefer course material that really challenges me so I can learn new things," and "I like the subject matter of this course." A descriptive analysis was conducted to determine the significance of all constructs for the pre and post-test data.

The classroom activities of both instructor and learners were observed and recorded using Smith et al. [22] Classroom Observation Protocol for Undergraduate STEM or COPUS. COPUS was effectively utilized to characterize how much time the instructor and student spent during class sessions on several class-based activities. This is also a methodologically recognized assessment tool that present teachers with feedback on the effectiveness of their instructional strategies to identify areas for professional growth. The classroom observation assessment comprises 25 indicators and is categorized into two sections, "what the student is doing" and "what the instructor is doing." Examples of such indicators include "listening to Instructors," "lecturing," "other assigned group activity," "posing a question," and "student ask questions."

In analyzing the class observation results, Velasco et al. [23] recommendations of using a bar chart to represent instructor-student behavior, computed in percentages for a 2-minute interval during learning sessions was adopted. The researchers observed student behavior and the appropriation of the indicators to describe the characteristics of verbal interactions. A signature assignment was administered to them to measure the student's performance. A tool was used to measure the change the leaners understanding of concept after the implementation of ECP. The tool is herein called the signature assignment. The signature assignment is a set of question given to the learners to answer before and after the implementation of ECP on the singular concept.

Results and Discussion

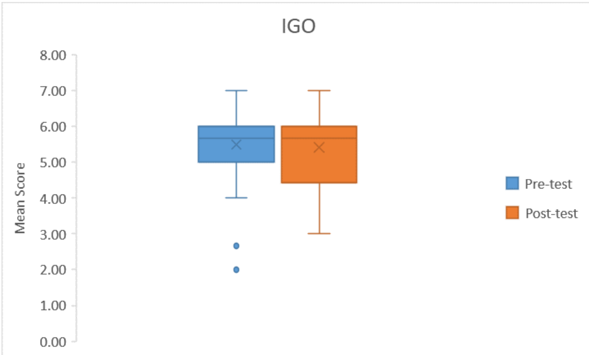
The descriptive results of the MSLQ reveal the pre- and post-test scores, as shown in Table 1 (Fall 2020 and Fall 2022 results combined). There is a significant increase learners' task value and peer learning collaboration constructs ($p<0.05$). Table 1 shows the summary statistics for the pre-test, post-test, z-test, and p-value for students under each construct.

Furthermore, a pictorial representation of the constructs is shown in a box-whisker plot, as shown in Figure 5, revealing mixed results. The task value (TV) and peer learning and collaboration (PLC) constructs reveal a significant difference between test scores. In peer learning and collaboration, post-test scores were higher than the pre-test scores, and this increment was statistically significant. The result justifies McConnell et al. [14], who explain that peer interaction improves students' understanding. Surprisingly, in task value, the pre-test scores were higher than the post-test scores, which was statistically significant; it can be attributed to how the course modules were organized and the implementation process was conducted. Clearly, in Figure 5 (a), (b), (d), (e), (g), (h), and (i), which represent intrinsic goal orientation (IGO), test anxiety (TA), exceptional component (EC), critical thinking (CT), metacognition (MC), interest epistemic curiosity (IEC) and deprivation epistemic curiosity (DEC) respectively show no significant difference in the pre-test and post-test scores. Overall, each construct has room for improvement as ECP is being implemented in subsequent semesters.

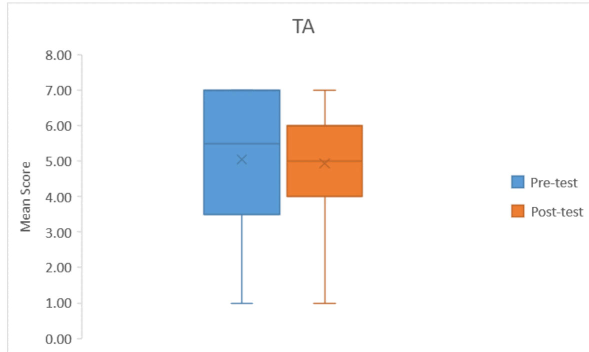
Table 1: Summary of Descriptive Statistics for MSLQ (N=44)

Variables	Pre-test	Post-test	Z test	p-value
Intrinsic Goal Orientation (IGO[a])	5.49±1.1	5.41±1.08	0.35	0.73
Test Value (TV[a])	5.81±1.04	5.29±1.21	2.98	<0.05*
Exceptional Component (EC[a])	5.8±1.21	5.61±1.2	1.35	0.18
Test Anxiety (TA[a])	5.05±1.9	4.93±1.53	0.64	0.52
Critical Thinking (CT[a])	4.89±1.34	5.17±1.2	1.30	0.19
MetaCognition (MC[a])	5.32±1.11	5.43±1.19	0.34	0.73
Peer Learning and Collaboration (PLC[a])	3.69±1.85	4.58±1.84	3.43	<0.05*
Interest Epistemic Curiosity (IEC[b])	3.26±0.64	3.2±0.66	0.89	0.37
Deprivation Epistemic Curiosity (DEC[b])	2.81±0.78	2.8±0.67	0.24	0.81

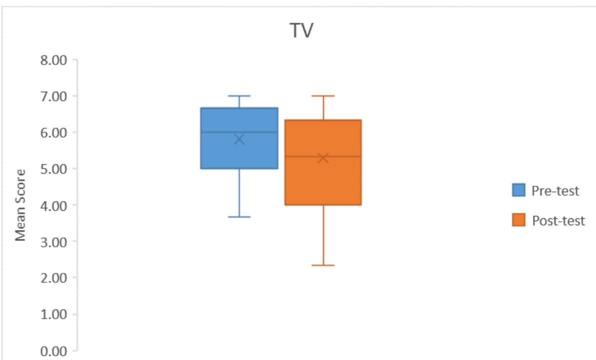
a 1-7 Likert Scale (Note: 1 =not at all true of me, 7 = very true of me)
b 1-4 Likert Scale (Note: 1 =never., 2= sometimes, 3 =often, 4 = always)



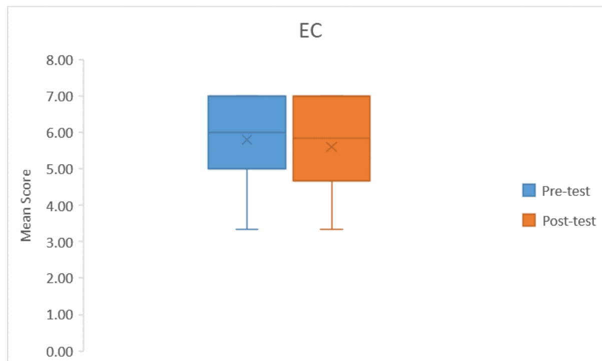
(a) Intrinsic Goal Orientation



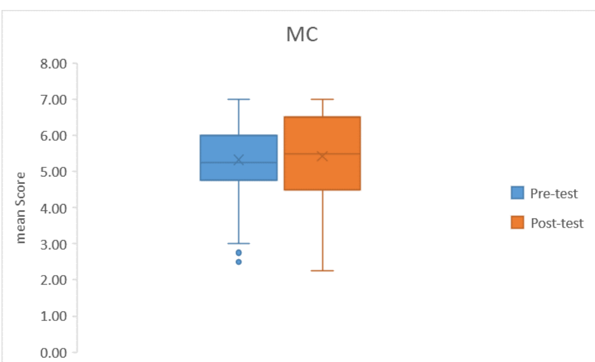
(b) Test Anxiety



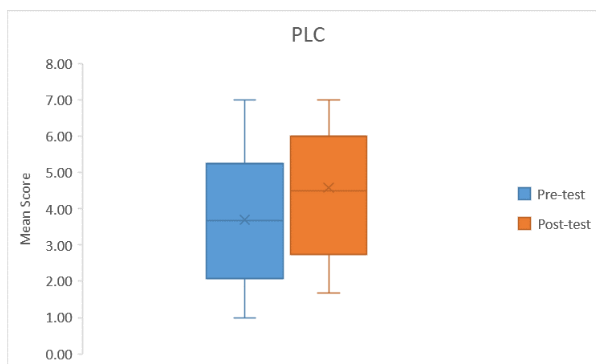
(c) Task Value



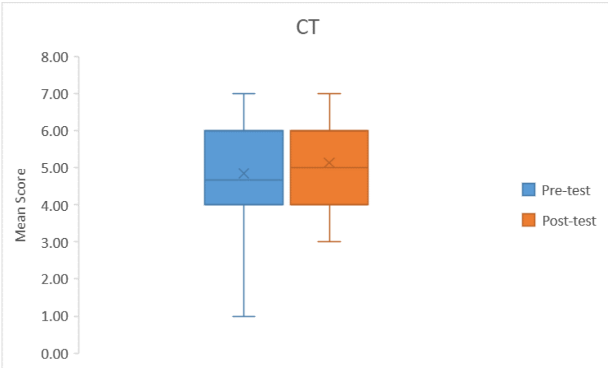
(d) Expectancy Component



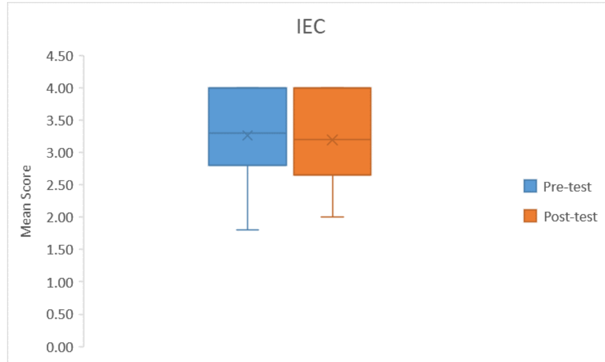
(e) Metacognition



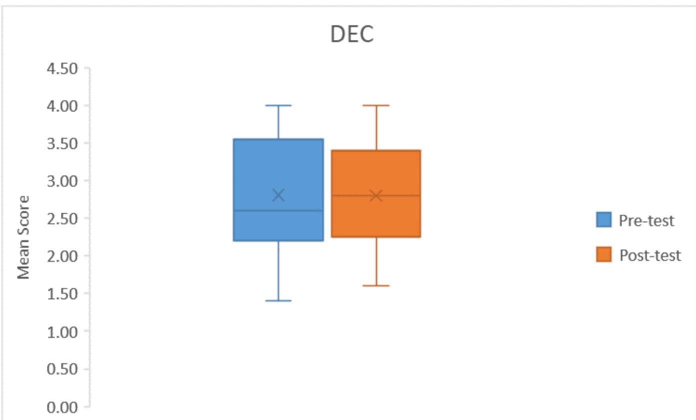
(f) Peer-Learning and Collaboration



(g) Critical Thinking



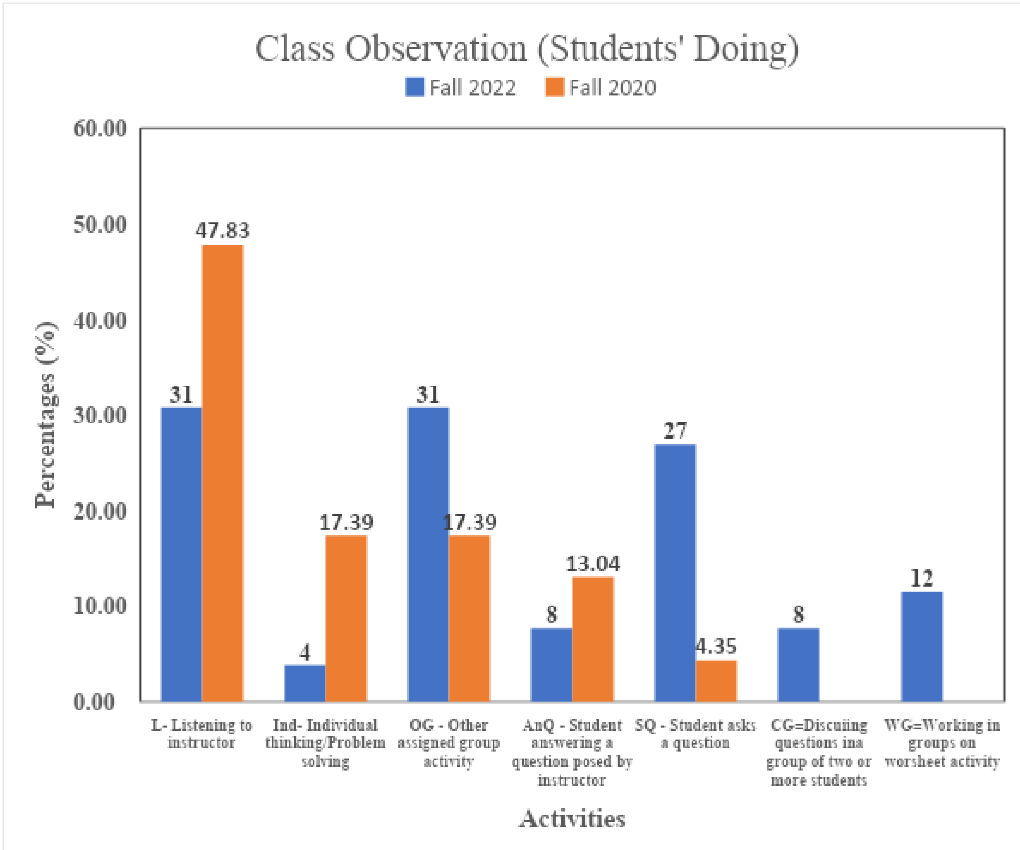
(h) Interest Epistemic Curiosity



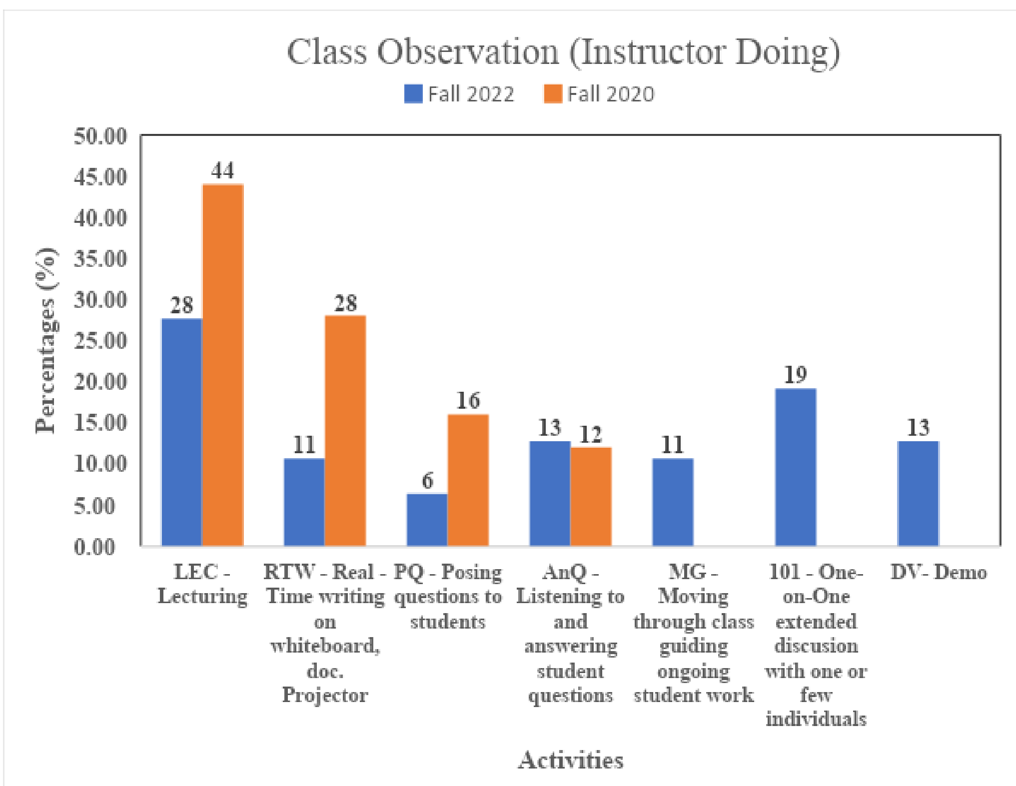
(i) Deprivation Epistemic Curiosity

Figure 5: Statistical comparisons of test scores in transportation courses using a box-whisker plot.

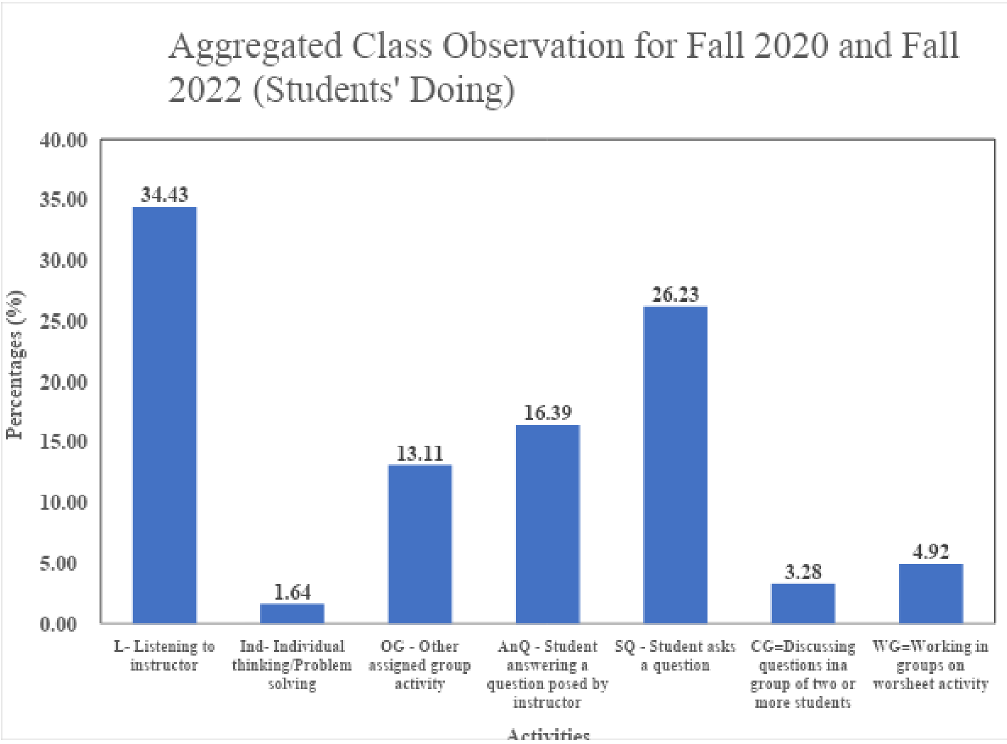
A class observation was conducted to determine the student's learning engagement, and the feedback is shown in Figure 6. The result showed that Students were actively engaged in the assigned activity and eager to learn more about the concepts by asking questions. The comparison of student and instructor behavior shows good engagement with implementing ECP. However, in the Fall of 2022, the comparison between ECP and traditional methods shows distinct engagement with the students, as shown in Figures 6e and 6f, justifying the claim that the traditional approach is too abstract and fails to engage student. Figures 6a and 6b show variations in the Instructor's and Students' behavior during the ECP lab session, which reveal instructor-student interaction and engagement; Figures 6c and 6d reveal the total percentage of activities performed by the instructor and students during lab sessions for Fall 2020 and Fall 2022.


Class Observation (Students' Doing)
Fall 2022
Fall 2020
Percentages (%)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
47.83
31
4
17.39
31
17.39
8
13.04
27
4.35
8
12
L- Listening to instructor
Ind- Individual thinking/Problem solving
OG - Other assigned group activity
AnQ - Student answering a question posed by instructor
SQ - Student asks a question
CG=Discuiing questions ina group of two or more students
WG=Working in groups on worsheet activity
Activities

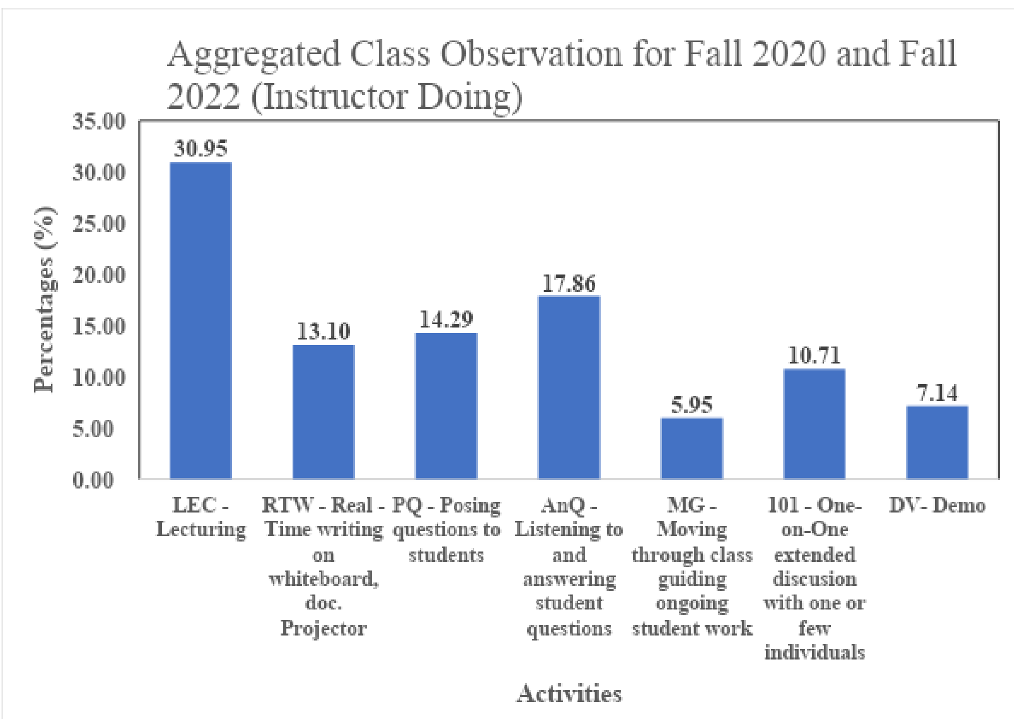
(a)


Class Observation (Instructor Doing)
Fall 2022
Fall 2020
Percentages (%)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
28
44
11
28
6
16
13
12
11
19
13
LEC - Lecturing
RTW - Real - Time writing on whiteboard, doc. Projector
PQ - Posing questions to students
AnQ - Listening to and answering student questions
MG - Moving through class guiding ongoing student work
101 - One-on-One extended discusion with one or few individuals
DV- Demo
Activities

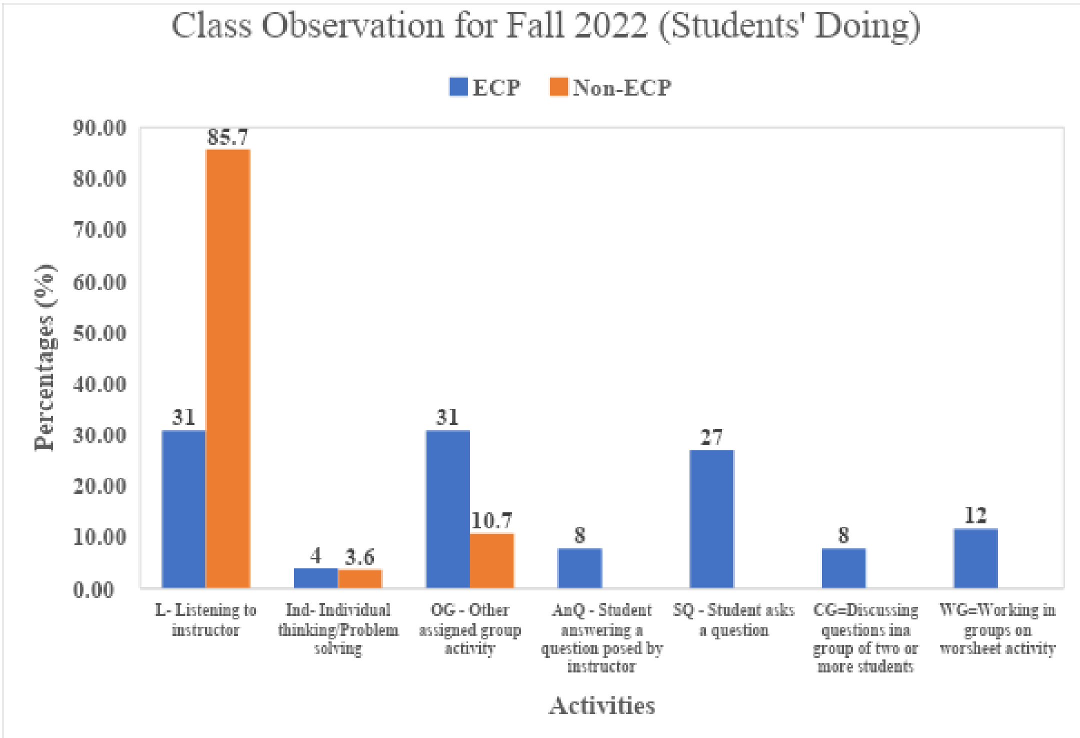
(b)


Aggregated Class Observation for Fall 2020 and Fall 2022 (Students' Doing)
Percentages (%)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
34.43
1.64
13.11
16.39
26.23
3.28
4.92
L- Listening to instructor
Ind- Individual thinking/Problem solving
OG - Other assigned group activity
AnQ - Student answering a question posed by instructor
SQ - Student asks a question
CG=Discussing questions ina group of two or more students
WG=Working in groups on worsheet activity
Activities

(c)


Aggregated Class Observation for Fall 2020 and Fall 2022 (Instructor Doing)
Percentages (%)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
30.95
13.10
14.29
17.86
5.95
10.71
7.14
LEC - Lecturing
RTW - Real - Time writing on whiteboard, doc. Projector
PQ - Posing questions to students
AnQ - Listening to and answering student questions
MG - Moving through class guiding ongoing student work
101 - One-on-One extended discusion with one or few individuals
DV- Demo
Activities

(d)

(e) 

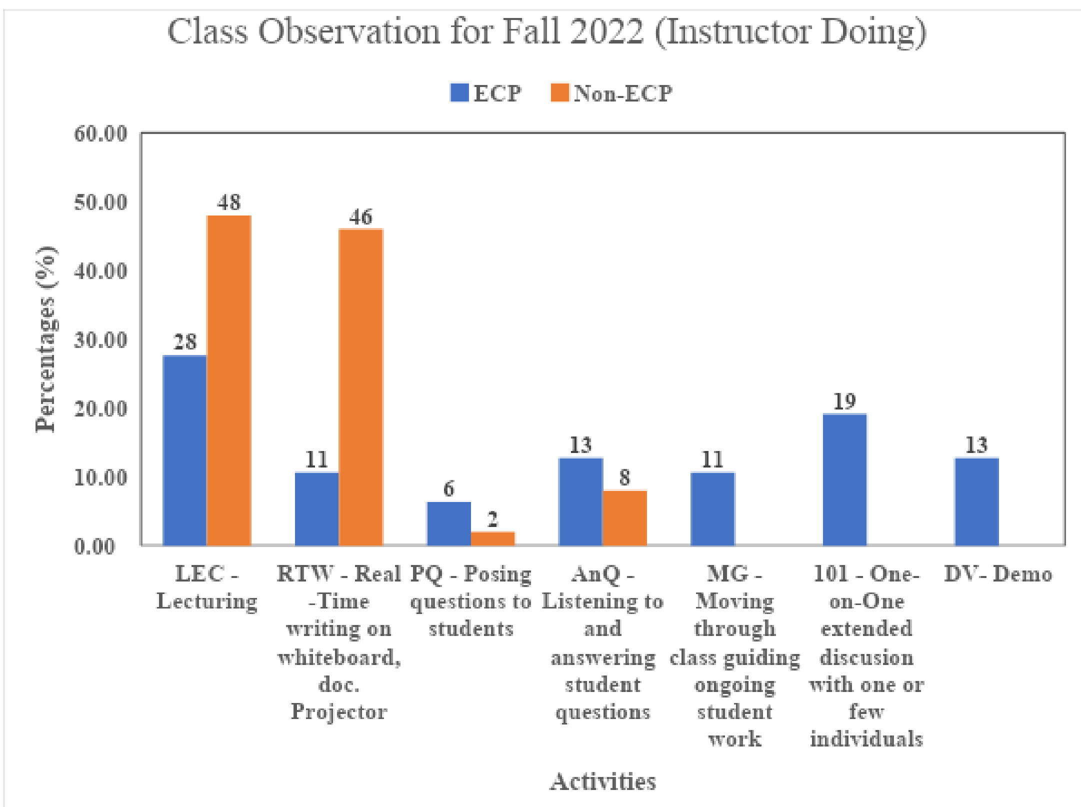
(f) 

Figure 6: Comparison of class observation feedback

In the Fall of 2022, signature assignments were developed to measure student success outcomes from adopting the pedagogy. Figure 7 shows the results of the measure of student success in Fall 2022. The students' minimum score increased from 30 to 60, and the maximum score increased from 90 to 100. The mean difference between the pre-test and post-test was 22.85%, while the maximum percentage change was 60%. The Wilcoxon Z-statistics revealed a significant increase in students' success due to the implementation of ECP in teaching transportation-related concepts at a historically black university (Z=-3.207, $p<0.05$).

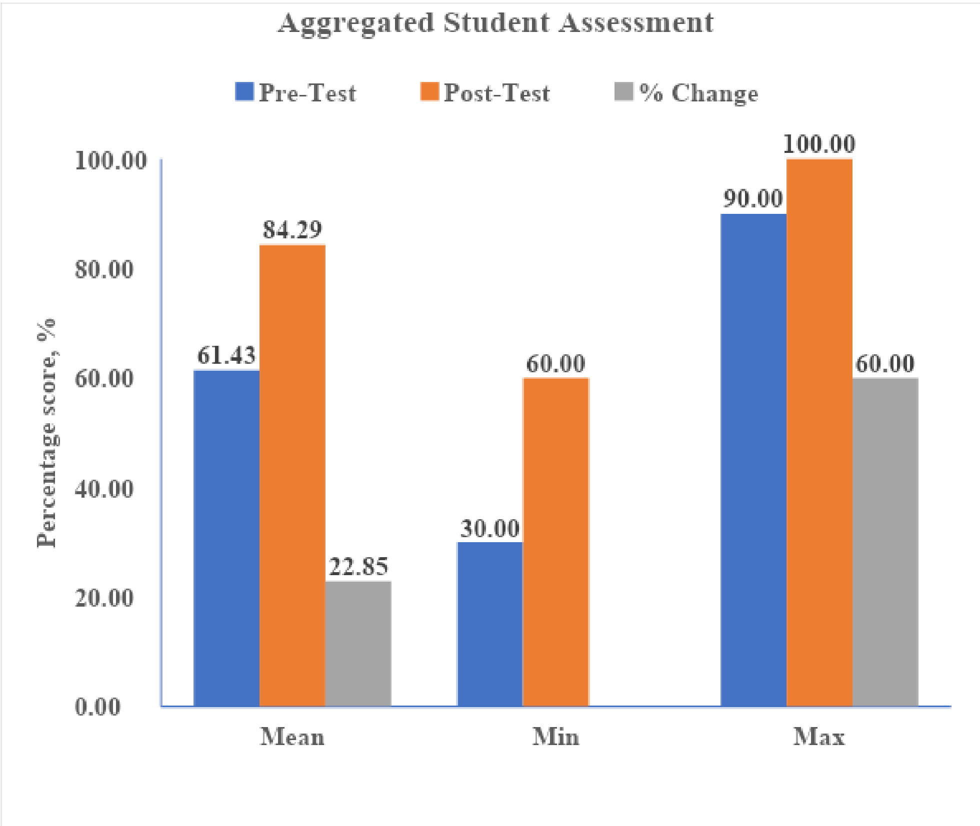


Figure 7: Fall 2022 Students' Signature Assignment Results (N=14, Z=-3.207, $p = 0.001$)

Conclusion

Students understanding of transportation concepts increases while adopting the 5E Model. Hands-on pedagogy encourages active engagement during laboratory sessions in the classroom. In the sound and moisture experiments, ECP was utilized. When ECP is introduced and compared to the traditional approach in Fall 2022, the Classroom Observation Protocol for Undergraduate STEM demonstrates significant engagement. In the peer/collaboration construct, the MSLQ findings of 44 students demonstrate a significant difference. When ECP was introduced in the Fall of 2022, the results of the signature assignment revealed a considerable increase in students' knowledge of transportation-related concepts. The recent findings highlight the importance of ECP. Increased student engagement and understanding of transportation concepts using hands-on devices have proved this. As a result of achieving the stated learning objectives for transportation concepts, ECP has positively impacted transportation engineering students' understanding of transportation concepts. ECP has demonstrated that students better understand the modules' expected learning outcomes.

Acknowledgment

This study is part of the work that was supported by the National Science Foundation Grant # 1915615, titled "Adapting an Experiment-centric Teaching Approach to Increase Student Achievement in Multiple STEM Disciplines". It should be noted that the opinions, results and conclusion or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

[1] S. Zhu, F. Xie, and D. Levinson, "Enhancing Transportation Education through Online Simulation Using an Agent-Based Demand and Assignment Model," *J. Prof. Issues Eng. Educ. Pract.*, vol. 137, no. 1, pp. 38–45, Jan. 2011, doi: 10.1061/(ASCE)EI.1943-5541.0000038.

[2] A. H. Yasir and .Prof. Bushra Saadoon Mohammed Alnoori, "Teacher Perceptions of Critical Thinking among Students and Its Influence on Higher Education," *IJRST*, vol. 10, no. 4, 2020, doi: 10.37648/ijrst.v10i04.002.

[3] N. Razia and A. Majid Khan, "Activity-Based Teaching versus Traditional Method of Teaching in Mathematics at Elementary Level," *Bulletin of Education and Research*, vol. 41, no. 2, pp. 145–149, 2019.

[4] D. F. Halpern and M. D. Hakel, "Applying the Science of Learning to the University and Beyond: Teaching for Long-Term Retention and Transfer," *Change: The Magazine of Higher Learning*, vol. 35, no. 4, pp. 36–41, Jul. 2003, doi: 10.1080/00091380309604109.

[5] A. Ahmad, M. K. Nordin, D. F. Ali, and A. Nabil, "Conducting hands-on task in vocational education: teaching method in automotive courses," *Journal of Technical Education and Training*, vol. 7, no. 1, 2015.

[6] C. O. Ekwueme, E. E. Ekon, and D. C. Ezenwa-Nebife, "The Impact of Hands-On-Approach on Student Academic Performance in Basic Science and Mathematics," *HES*, vol. 5, no. 6, p. 47, Nov. 2015, doi: 10.5539/hes.v5n6p47.

[7] O. Owolabi *et al.*, "Best Practices for the Implementation of Home-based, Hands-on Lab Activities to Effectively Engage STEM Students During a Pandemic," in *2021 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual Conference: ASEE Conferences, Jul. 2021, p. 36744. doi: 10.18260/1-2--36744.

[8] H.-T. Wu, P.-C. Hsu, C.-Y. Lee, H.-J. Wang, and C.-K. Sun, "The impact of supplementary hands-on practice on learning in introductory computer science course for freshmen," *Computers & Education*, vol. 70, pp. 1–8, Jan. 2014, doi: 10.1016/j.compedu.2013.08.002.

[9] S. Ikiriko, A. Wemida, S. Efe, M. Shokouhian, O. Owolabi, and J. “Kemi” Ladeji-Osias, “Home-based Cantilever Beam Experiment for Civil Engineering Undergraduate Students,” in *Best in 5 Minutes: Demonstrating Interactive Teaching Activities*, Virtual On line: American Society for Engineering Education, 2021, pp. 1–24.

[10] H. Chowdhury, F. Alam, and I. Mustary, “Development of an innovative technique for teaching and learning of laboratory experiments for engineering courses,” *Energy Procedia*, vol. 160, pp. 806–811, Feb. 2019, doi: 10.1016/j.egypro.2019.02.154.

[11] C. E. Brawner, C. Mobley, R. Brent, M. K. Orr, M. Rucks, and C. Waters, “Overview of Policies and Programs to Retain Black Students in Engineering,” presented at the 2019 CoNECD - The Collaborative Network for Engineering and Computing Diversity, 2019. [Online]. Available: https://peer.asee.org/31780

[12] K. Thomas, M. L. Greene, B. C. Coley, D. Maitra, J. M. Brisbane, and J. S. London, “For Us, By Us: Recommendations for Institutional Efforts to Enhance the Black Student Experience in Engineering,” presented at the 2022 CoNECD (Collaborative Network for Engineering & Computing Diversity), 2022. [Online]. Available: https://peer.asee.org/39118

[13] J. “Kemi” Ladeji-Osias *et al.*, “Initial Impact of an Experiment-centric Teaching Approach in Several STEM Disciplines,” in *2020 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual On line: ASEE Conferences, Jun. 2020, p. 34829. doi: 10.18260/1-2--34829.

[14] J. Van Aalst and C. K. K. Chan, “Empowering Students as Knowledge Builders,” in *Transformative Approaches to New Technologies and Student Diversity in Futures Oriented Classrooms*, L. Rowan and C. Bigum, Eds., Dordrecht: Springer Netherlands, 2012, pp. 85–103. doi: 10.1007/978-94-007-2642-0_6.

[15] C. Joswick and M. Hulings, “A Systematic Review of BSCS 5E Instructional Model Evidence,” *Int J of Sci and Math Educ*, Mar. 2023, doi: 10.1007/s10763-023-10357-y.

[16] A. C. Sugiarti, S. Suyatno, and I. G. M. Sanjaya, “The development of learning material using learning cycle 5E model based stem to improve students’ learning outcomes in Thermochemistry,” *J. Phys.: Conf. Ser.*, vol. 1006, p. 012039, Apr. 2018, doi: 10.1088/1742-6596/1006/1/012039.

[17] C. Yata, T. Ohtani, and M. Isobe, “Conceptual framework of STEM based on Japanese subject principles,” *IJ STEM Ed*, vol. 7, no. 1, p. 12, Dec. 2020, doi: 10.1186/s40594-020-00205-8.

[18] L. B. Duran and E. Duran, “The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching,” *Science Education Review*, vol. 3, no. 2, pp. 49–58, 2004.

[19] A. Yadav and N. Sakle, “Development of low-cost data logger system for capturing transmission parameters of two-wheeler using Arduino,” *Materials Today: Proceedings*, vol. 72, pp. 1697–1703, 2023, doi: 10.1016/j.matpr.2022.09.471.

[20] T. Garcia and P. R. Pintrich, “Assessing Students’ Motivation and Learning Strategies in the Classroom Context: The Motivated Strategies for Learning Questionnaire,” in *Alternatives in Assessment of Achievements, Learning Processes and Prior Knowledge*, M. Birenbaum and F. J. R. C. Dochy, Eds., Dordrecht: Springer Netherlands, 1996, pp. 319–339. doi: 10.1007/978-94-011-0657-3_12.

[21] J. A. Litman and C. D. Spielberger, “Measuring Epistemic Curiosity and Its Diversive and Specific Components,” *Journal of Personality Assessment*, vol. 80, no. 1, pp. 75–86, Feb. 2003, doi: 10.1207/S15327752JPA8001_16.

[22] M. K. Smith, F. H. M. Jones, S. L. Gilbert, and C. E. Wieman, “The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices,” *LSE*, vol. 12, no. 4, pp. 618–627, Dec. 2013, doi: 10.1187/cbe.13-08-0154.

[23] J. B. Velasco, A. Knedeisen, D. Xue, T. L. Vickrey, M. Abebe, and M. Stains, “Characterizing Instructional Practices in the Laboratory: The Laboratory Observation Protocol for Undergraduate STEM,” *J. Chem. Educ.*, vol. 93, no. 7, pp. 1191–1203, Jul. 2016, doi: 10.1021/acs.jchemed.6b00062.