The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #41461

Board 33: Enhancing Self-Efficacy Among Transportation Engineering Undergraduates Using Hands-On Pedagogy.

Mr. Adebayo Iyanuoluwa Olude, 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 passion to communicate research findings and gleaned from experts in the field as he advances his career, Olaitan has attended several in-persons and virtual conferences and workshop, and at some of them, made presentation on findings on air pollution, waste water reuse, and heavy metal contamination.

Dr. Oludare Adegbola Owolabi P.E., Morgan State University

Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the assistant director of the Center for Advanced Transportation and Infrastructure Engineering Research (CATIER) at Morgan State Universit

Enhancing Self-Efficacy Among Transportation Engineering Undergraduates using Hands-On Pedagogy

Abstract

Self-efficacy, a belief in one's potential to achieve a desired outcome, stands as a significant factor towards learners' achievement in learning. Engineering education, which is often distinguished by its rigorous theoretical emphasis and empirical analysis, demands an innovative and comprehensive approach toward student development that includes not only technical knowledge but also instills confidence and problem-solving ability. This study investigates the factors moderating transportation engineering undergraduates' self-efficacy and the impact of an evidence-based, experiment-focused, hands-on pedagogy. The study adopts a descriptive and quantitative method using the Motivated Strategy for Learning Questionnaires (MSLQ) in a pre-post-test design. The responses of the survey were obtained from 68 learners who fully participated in the transportation engineering modules where experiment-centric pedagogy was implemented. The data were cleaned and analyzed using Statistical Package for Social Sciences (SPSS). Inferential analysis was conducted at a confidence level of 95%. The mean self-efficacy score at the baseline was 9.21±5.98 which was found to significantly increase at post-test to 17.06±3.39. The Cohen d effect size was found to be greater than 0.8 which revealed that the changes were not due to chance. At baseline, the most strongly significantly correlated factor to mean self-efficacy score was the current academic level of the undergraduates ($p<0.001$) which was later found to be insignificantly and uncorrelated at the post-test. In conclusion, hands-on activities helped learners to learn engineering skills and gain real-life experience during learning which led to more confidence in their engineering skills. This study showed that hands-on pedagogy can boost engineering learners' self-efficacy which is noted to influence performance and retention.

Introduction

Self-efficacy is one of the most important predictors of success and persistence for learners enrolled in challenging undergraduate engineering programs. Self-efficacy, defined as one's belief in one's ability to perform in given conditions, is an important factor in engineering student success and persistence. Undergraduates in transportation engineering face exceptionally difficult technical courses comprising sophisticated mathematics, complex physics, and applied civil engineering mechanics, which can weaken confidence and self-belief. According to studies, learners who lack confidence in their skills to understand key ideas, use analytical tools effectively, and apply information to real-world systems are more likely to struggle academically or drop out of programs before graduation [1]. As a result, developing instructional approaches that promote self-efficacy is crucial for transportation engineering student retention and workforce development.

Self-efficacy has been found to influence learning, motivation, achievement, and self-regulation [2], [3]. Furthermore, in educational settings, self-efficacy is poised to influence learners' activity choices, effort expended, persistence, interest, and achievement [4], [5]. Learners with strong self-efficacy participate more readily, work harder, persist longer, show greater interest in learning, and succeed at higher levels than learners with low self-efficacy [3], [6]. Self-efficacy is defined as one's belief in one's own ability to carry out actions and achieve goals [6]. When faced with adversity, learners with higher engineering self-efficacy demonstrate stronger drive, self-confidence, and resilience than those with lower self-efficacy [1]. Self-efficacy has been linked to the help-seeking attitude of learners in the school achievement fields [7], [8]. A student who seeks assistance demonstrates knowledge of a difficulty that he or she cannot solve on his or her own and remedies that difficulty by requesting assistance from peers or instructors as necessary. A vast amount of research demonstrates that learners who seek assistance are capable of monitoring and assessing what they learn [9].

Hands-on learning pedagogies that directly engage learners in engineering methods, problems, and tools have grown in popularity in engineering curriculum aimed at developing critical thinking, technical, and collaborative skills [10]. Hands-on learning includes a wide range of experiential approaches such as open-ended design projects, modeling, simulation assignments, laboratory procedures, field activities, and capstone projects [11]. A primary purpose of hands-on activities is to provide learners with actual experiences that allow them to apply engineering skills to reinforce knowledge and directly observe the outcomes of their efforts, which leads to deeper learning.

In this study, a hands-on approach called, the Experiment-Centric Pedagogy (ECP) was implemented. This pedagogy has been found to actively engage learners by utilizing affordable, safe, and portable electronics in various educational settings (classrooms or laboratories). ECP combines problem-solving exercises and constructive learning methods with a hands-on, portable multifunction tool that can be used in place of larger and complex laboratory apparatus.

This paper addresses the need to include hands-on pedagogy which is posited to enhance transportation engineering undergraduates' self-efficacy significantly. Over a two-year period, a transportation engineering program that incorporated hands-on learning with projects, coursework, and lab procedures, resulted in significant gains in learners' self-reported efficacy. The survey data, collected over a period, using validated engineering self-efficacy rating scales among women revealed significant improvements in all efficacy categories, including technical skills, confidence, problem-solving ability, teamwork, and communication [1]. The findings emphasize the benefits of hands-on pedagogy in increasing student self-belief and such findings show the potential that hands-on learning strategies may improve retention in transportation engineering degree programs. Additional structured procedures that promote student reflection and peer learning through hands-on activities may have a greater impact. Also, there is a dearth of evidence on the implementation of such experiential and experimental approach among transportation engineering learners' as well as among historically black colleges and universities. Therefore, this study seeks out the elements that influence transportation engineering undergraduates' self-efficacy in one of the nations' historically black colleges and universities and the impact of an evidence-based, experiment-focused hands-on pedagogy.

Theoretical Framework

Social Cognitive Theory

Bandura's [6] social cognitive theory, emphasizes the importance of self-efficacy beliefs in human motivation and achievement. Bandura defines self-efficacy as an individual's belief in their ability to perform tasks, overcome problems, and achieve goals. In an educational context, academic self-efficacy refers to learners' conviction that they can absorb content, use information meaningfully, and meet academic demands [12].

Social cognitive theory posits that self-efficacy directly influences the learning processes and outcomes. This influence can be seen in their effort, tenacity, resilience, and use of self-regulation skills when confronted with problems [4]. High academic self-efficacy leads to increased engagement, intrinsic motivation, and superior academic accomplishment in learners across various topics when compared to low academic self-efficacy. Individuals with stronger academic self-efficacy are also more likely to face difficult activities, put out effort to satisfy expectations, and build robust self-regulation skills [13].

According to Bandura's social cognitive theory, self-efficacy beliefs play a critical role in human motivation, effort, and eventual achievement. Mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states are all ways for learners to create their self-efficacy beliefs [14]. Mastery experiences of successfully solving issues are regarded the most effective source for establishing self-efficacy among the four sources because they help learners develop cognitive foundations for evaluating the level of effort required for success. Learners with high self-efficacy are more likely to continue in pursuing intrinsic objectives and to tackle difficult tasks.

Engineering learners' self-efficacy, according to research, is a predictor of their outcome expectancies, interests, and goals [15]. Self-efficacy is a result of effective learning experiences, not simply a path to success. According to a study [16], high-achieving college learners had a greater self-efficacy score than low-achieving learners. According to the theory, four factors influence self-efficacy beliefs: past performance, peer models, social persuasion, and physiological arousal. The goal of this research is to investigate the factors moderating transportation engineering undergraduates' self-efficacy and the impact of an evidence-based, experiment-focused, hands-on pedagogy. According to social cognitive theory, this strategy enhances student confidence, motivation, and academic outcomes. Mastery experiences resulting from active skill development and overcoming obstacles provide the most significant self-efficacy improvements.

The theory is classified into three factors: Personal, behavior and environmental as seen in figure 1.

1. Personal Factors - This includes an individual's beliefs, self-efficacy, knowledge, expectations, objectives, and intentions. Personal factors influence how learners perceive the activities they engage in. Self-efficacy is an important human trait that promotes motivation and perseverance.

2. Environmental Factors - External social and physical variables that influence behavior are referred to as environmental factors. Social environments include family, friends, culture, and the media. The physical environment includes space, technology, and resources. The environment can reward, penalize, model, or permit specific behaviors. Learners can connect with the experiment within classroom settings and laboratories.

3. Behavioral Factors - These are the actions that learners make in response to internal cognitive processes and external environmental inputs. Behavioral capability is defined as having the knowledge and skills to perform a behavior. Learners actively engage in the experiment and successfully perform the activity, enhancing their mastery and fostering a greater belief in their competence and ability.

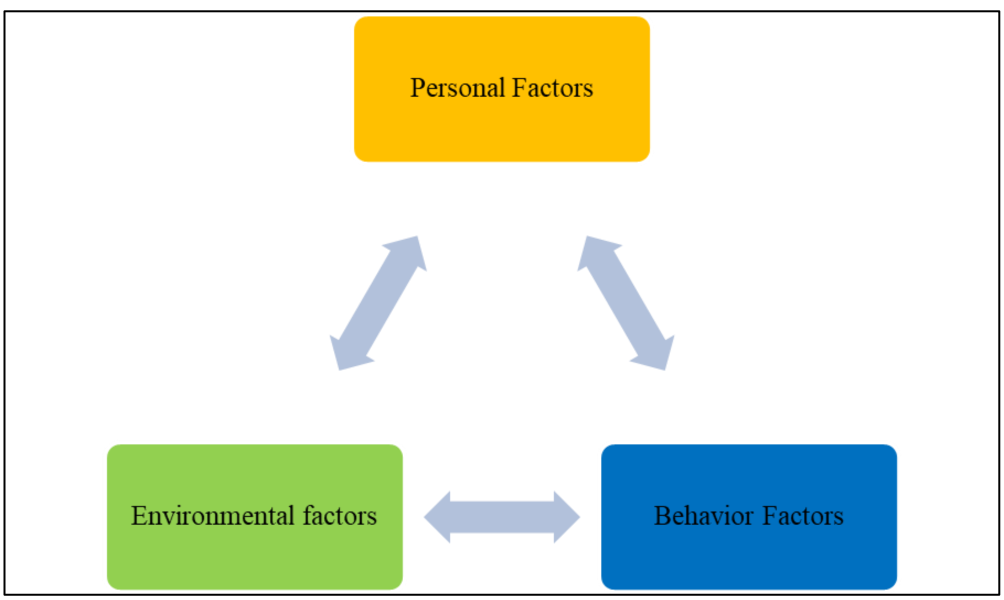

Figure 1: Social Cognitive Theory [17]

According to social cognition theory, personal, environmental, and behavioral factors interact and impact each other bi-directionally, with self-efficacy influencing behaviors and performance outcomes influencing self-efficacy.

Methodology

This study was conducted at one of America's historically Black universities and colleges. This quantitative study adopted a pre-posttest single group design. ECP implementation was carried out in the Transportation Engineering department. Between 2020 and 2023, two experiments in the Transportation field were carried out across the semester. The two experiments are the sound experiment and the soil moisture experiment. The implementation took place in two courses which were Introduction to Transportation Systems (TRSS 301) and Highway Engineering (TRSS 415). These experiment helps learners to develop mastery and improve their efficacy through active participation, problem-solving, and the practical application of theoretical knowledge. By actively participating in the experiment, learners are directly involved in the learning process, allowing them to ask questions and collaborate with their peers. This hands-on experience bridges the gap between theory and practice, allowing learners to see the relevance of what they have learned and how to apply it in practical settings.

The TRSS 301 is an introductory course that covers transportation system principles and procedures like planning, engineering, management, and logistics, as well as important issues like physical, economic, social, and environmental concerns. Among the subjects covered are passenger and freight transportation networks, intermodal connectivity, and traffic control operations. This transportation course covers nine modules in total. TRSS 415, a course consisting mostly junior and senior students, had five modules: Principles of Highway Drainage, Soil Properties, Earthwork Calculations, Highway Alignments, and Intersection Design. This course covers the fundamental principles, methodologies, and approaches of highway design. Table 1 provides an overview of the courses where experiment-centric pedagogy (ECP) was implemented, as well as the number of students in each class.

Table 1: Implementation of Transportation Engineering Courses

Semester (Year)	Course Code	Course Title	Frequency, N	Percentage, %
Fall (2020)	TRSS 415	Highway Engineering	13	19.1
Fall (2021)	TRSS 301	Introduction to Transportation Systems	22	28.1
Fall (2022)	TRSS 415	Highway Engineering	10	14.7
Spring (2023)	TRSS 301	Introduction to Transportation Systems	23	33.8
		Total Students	**68**	**100.0**

Figure 2 summarized the well-developed module structure where ECP is implemented and divided into four sections, and which was elaborated by [19]. The module structure serves as a framework for developing successful and engaging learning experiences. This describes a four-step procedure for developing an educational module. The instructor introduces the experiment and determines the learners' prior knowledge of the experiment using a set of questions known as the signature assignment, which is often administered before and after the experiment is implemented. The experiment's outcomes are then discussed and illustrated. Learners are also actively participating in the activity. Finally, the instructor asks the same sets of questions to assess how well students comprehend the experiment.

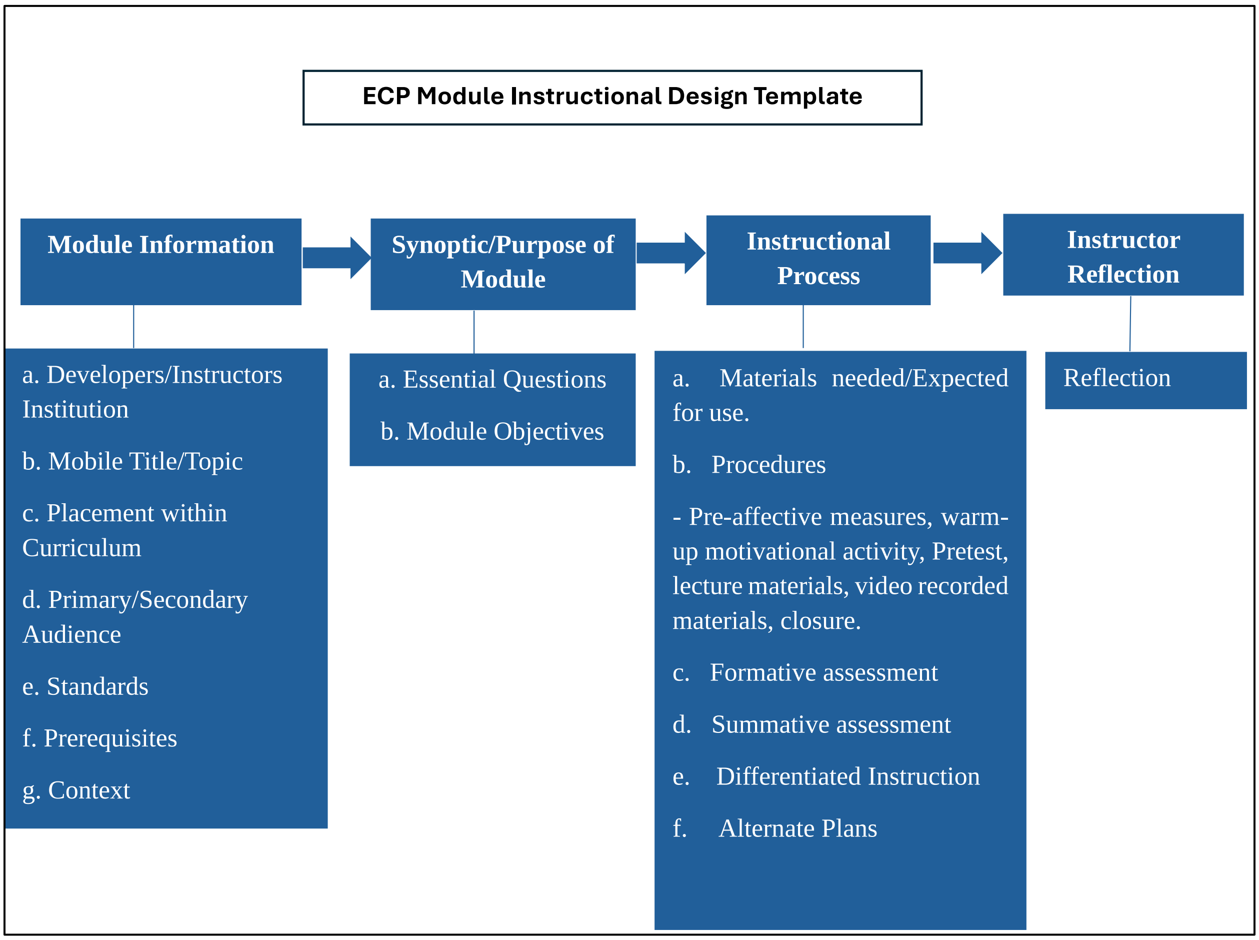

Figure 2: ECP Design Template [19]

Experiment Conducted:

Sound Experiment

This experiment was conducted in TRSS 301. Learners used an analog device and mobile apps throughout the lab session. Prior to the start of the experiment, instructors exposed the learners to basic sound concepts such as frequency, amplitude, decibels, wavelength, etc., so that they could understand the experiment. Learners were expected to measure 60 data points of different decibel levels of various sounds, including internal sounds such as a radio, mixer, and vacuum. Lawnmower, lawn blower. and drilling noises are examples of external sounds. Local streets, highways, and parking lots all have traffic sounds. The recording period was for 60 seconds (1 minute) and the app automatically displays the minimum, maximum, and average values, as well as frequency and peak frequency. Learners worked in groups during the activity. The experiment's objective is to teach learners about sound and hearing by using a decibel meter to compare noise levels in various situations and locales. Learners gain a better understanding of noise and how to plan and develop transportation infrastructure that will reduce noise pollution because of this activity. Learners were instructed to assess the outcomes of their data by comparing several variables such as time of day, frequency, and different decibel values in their report at the end of the experiment. Figure 3 shows the hands-on device used.

Figure 3: (a) Apple (iPhone) Apps (b) Android Apps (C) Analog Sound Sensor and ADALM 1000

Soil Moisture Experiment

This included the use of soil samples, a soil moisture sensor, an Arduino Uno, and a data streamer installed on Microsoft Excel. Learners were able to conduct the experiment using this hands-on device. The instructor explained the investigations' background concepts to them. The samples were prepared at various moisture levels and given to the learners to use in the experiment. Using a data streamer, they were able to read moisture content readings in real-time. Prior to testing, Arduino code had been integrated to allow for simple conversion from electrical to digital phase. In other tests, the Arduino has produced consistent results for various data gathering and streaming tasks [21]. At the end of the experiment, the learners were able to analyze, understand, and draw conclusions based on scientific evidence. As part of the outcome, this will allow learners to monitor soil moisture levels, ensuring the stability and lifespan of the road system. The experiment was conducted in TRSS 415 which provides insight into soil compaction properties under various moisture conditions, which is critical for developing road and pavement systems. The learners for this course did not participate in TRSS 301 where the sound experiment was conducted. Figure 4 shows the soil moisture experiment set-up.

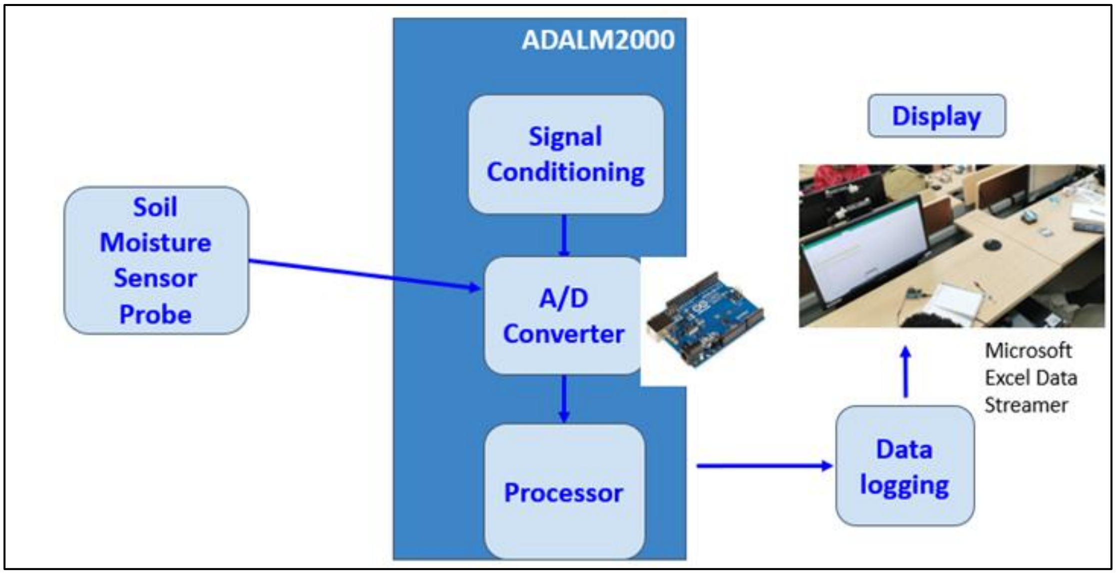

Figure 4: Soil Moisture Experiment Set-up

Throughout these experiments, learners encountered various challenges, including issues like incorrectly connecting jumper wires to the Arduino and misinterpreting values on the decibel apps. Despite these challenges, learners remained actively engaged in participating in the hands-on experiments.

Data Collection

This study adopted the validated Motivated Strategies Learning Questionnaires (MSLQ) [18] was used. The questionnaires were given to 68 learners who participated both before and after the experiment. The survey questions were presented on the day of the experiment. The MSLQ was administered to learners to evaluate the efficacy of ECP implementation in Transportation discipline. This questionnaire measures core motivation and learning variables such as intrinsic goal orientation (IGO), extrinsic goal orientation (EGO), task value (TV), expectancy component (EC), peer learning and cooperation (PLC), metacognition (MC), and test anxiety (TA) using a 7-point Likert-type scale. For this present study, and in determining the self-efficacy of learners, the EC construct was used. This subscale includes a 3-item7-point Likert scale: *I believe I will receive an excellent grade in this class, I'm confident I can do an excellent job on the assignment and tests in this course, I expect to do well in this class.* The learners' responses were collected, cleaned, and analyzed using the Statistical Package for the Social Sciences (SPSS).

Data Analysis

Descriptive statistics was conducted using box-and-whiskers plots, frequency, and simple percentages, mean and standard deviation. The normality test showed that the data was normally distributed and hence, a parametric inferential statistical analysis was adopted. To determine the significance of the constructs for pre and post-test data, an inferential analysis using SPSS was performed and the confidence level set at 95.0%. Also, analysis was conducted on correlation of self-efficacy of learners by considering factors such as gender, grade point average (GPA) and class level. Ratings of the Expectancy Component among self-efficacy learners were analyzed for the objective of this study. The rating of the self-efficacy scores was done by utilizing the university academic performance rating. The minimum self-efficacy scores that can be obtained was 3 and the maximum was 21. The categorization was done using 3-12 as the low level of self-efficacy, 13-17 as the moderate level of self-efficacy and >17 was categorized as high level of self-efficacy. This categorization was conducted to capture distinct variations in self-efficacy levels, easier ways to understand and compare across different levels. Also, analyzing the effect of hands-on pedagogy on the self-efficacy of learners, a paired sample t-test and effect was conducted. The effect size of a paired sample t-test was calculated by dividing the mean difference by the standard deviation of the difference as shown below:

$$\text{Cohen's d} = \frac{Mean_D}{SD_D}$$

Where D, is the difference of the paired samples.

Results

The number of learners who participated in this study was 68. Table 2 showed that among the racial groups, 89.7% of the learners were mostly Black or African American, indicating that the study was indeed carried out at a Historically Black College and University (HBCU).

Table 2: Learners' Racial Distribution

Race	**Frequency (N=68)**	**Percentage (%)**
American Indian	1	1.47
Asian or pacific Islander	1	1.47
Black or African American	61	89.7
Hispanic or Latino	3	4.41
White or Caucasian	1	1.47
Prefer not to say	1	1.47

Figure 5a displays the distribution of learners across four academic levels: freshman, sophomore, junior, and senior, which make up 16%, 24%, 26%, and 33.8% of the total, respectively. Figure 1b displays the gender distribution of learners in the transportation engineering class, revealing a higher proportion of males (73%) compared to females. Figure 5c displays the distribution of students' GPAs. Specifically, 34% of students have a GPA between 3.1 and 3.5, 29% have a GPA between 2.6 and 3.0, 18% have a GPA between 2.1 and 2.5, and 3% of students have a GPA below 2.0.

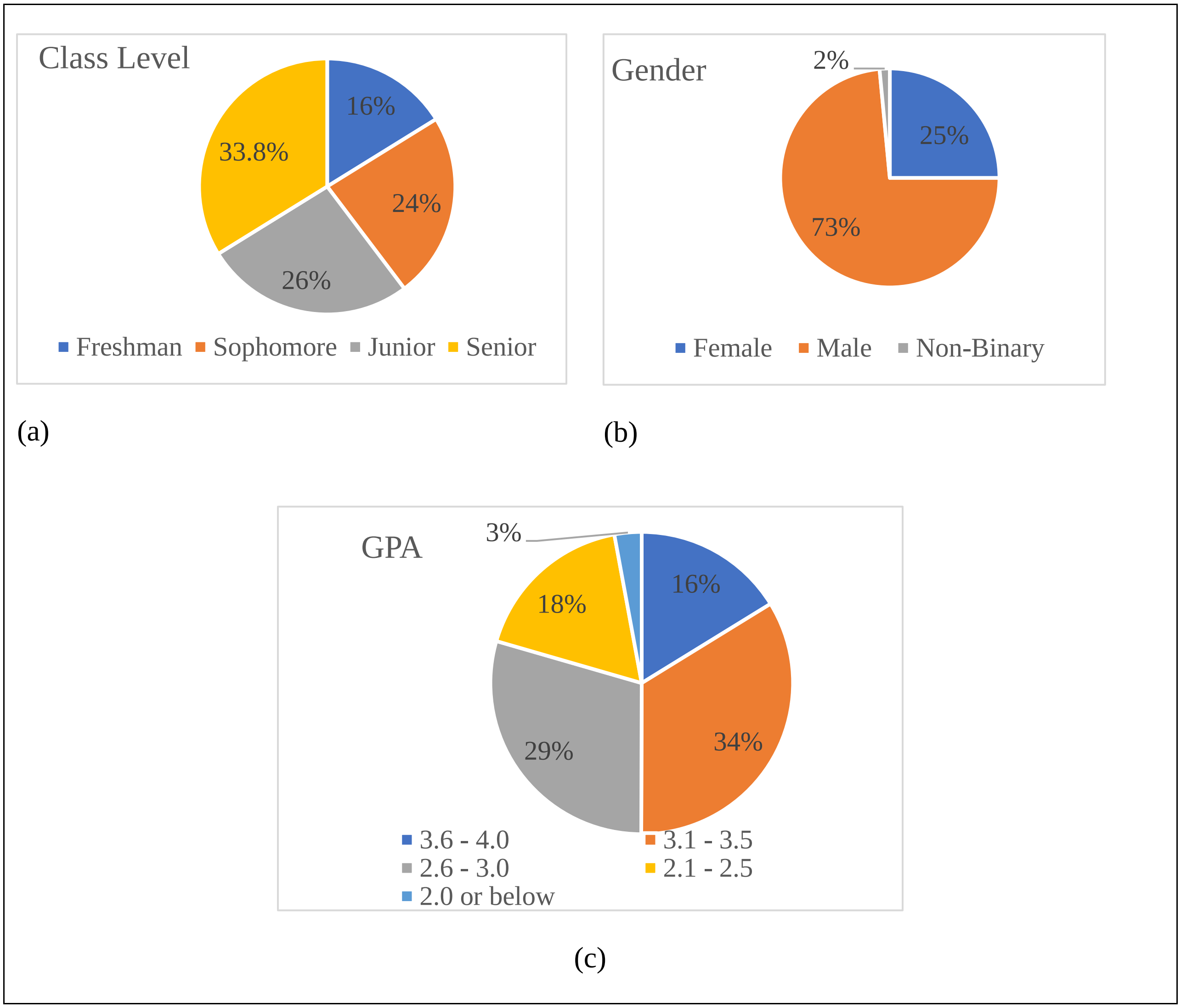

Figure 5: Profile of Learners

Distribution Self-Efficacy Item Scores Among Learners

The figure below shows the scales assigned for each question in the EC. EC1 shows 35.3% of learners believe they will receive an excellent grade in this class before the experiment while 33.8% of learners will receive an excellent grade in this class after the commencement of the experiment. In EC 2, 39.7% of learners are confident that they can do an excellent job on the assignment and tests before and after the experiment. However, in EC 3, 48.5% of Learners before the experiment expect to do well in this class while 39.7% of learners expect to do well in this class after the implementation of the experiment.

"I believe I will receive an excellent grade in this class": This phrase expresses a strong belief and assurance in attaining a high grade, implying that the person is positive about their performance and anticipates excelling academically.

"I'm confident I can do an excellent job on the assignment and tests in this course": In this statement, the learner demonstrates a strong belief in their competence to excel in completing assignments and exams during the duration of the course. This level of confidence indicates a strong belief in one's own abilities, expertise, and readiness to fulfill the demands and anticipations of the course.

"I expect to do well in this class": This phrase affirms a confident and optimistic belief in achieving success in the class. Having an expectation of performing well indicates a mental attitude focused on attaining favorable results and sustaining a superior level of performance throughout the duration of the course.

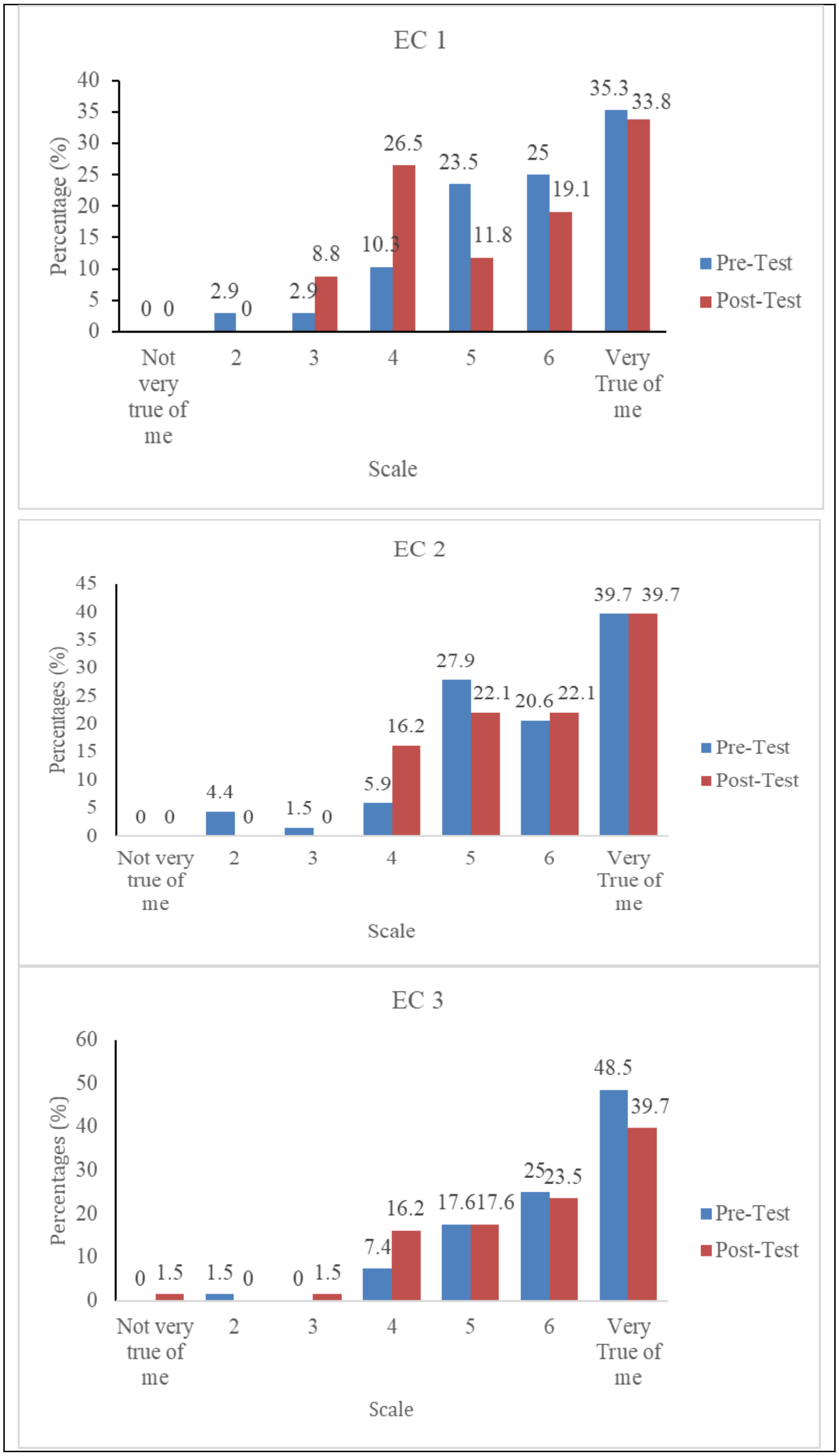

Figure 6: Self Efficacy of Learners were EC1- I believe I will receive an excellent grade in this class; EC2 - I'm confident I can do an excellent job on the assignment and tests in this course; EC3- I expect to do well in this class.

Distribution of Overall Self-Efficacy scores among Learners

The box and whisker plot presented in figure 7 shows the mean, interquartile ranges and the median score of the learners in this current study. Clearly, there was an 83.3% increase in the mean score of the learner indicating the improvement in their average level of overall self-efficacy. Noteworthy, the lowest score as shown in the box and whisker plot was about 10 out of a total of 21 at post-test and when compared with the least score at pre-test (3) also revealed that there was over 100% increase in each respondent's self-efficacy of the learners from the baseline.

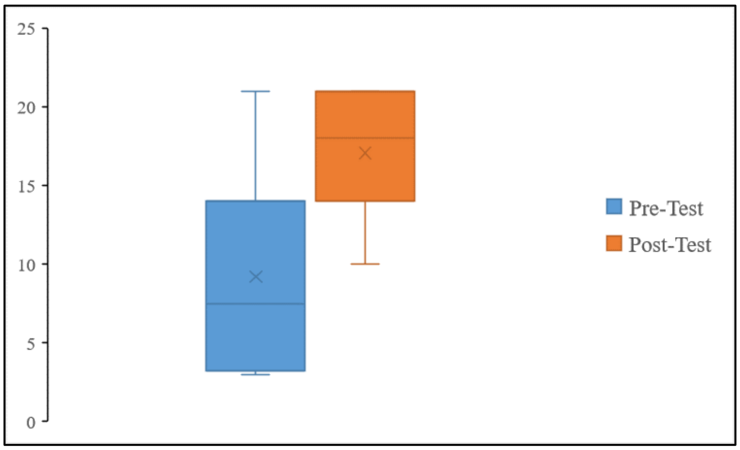

Figure 7: Box and Whisker Plots of Overall Self-Efficacy Scores Among the Learners

Level of Self-efficacy of Learners

The distribution of the levels of the self-efficacy of learners in the course is presented in Figure 8. At the baseline, there were 67.6% of learners who had a low self-efficacy which reduced at post-test to 14.7%. The result further revealed that about 17.6% of learners with a good level of self-efficacy increased to 33.8%. In addition, there was an increase from 14.7% to 51.5% of learners with high self-efficacy post-implementation of the experiment centric pedagogy.

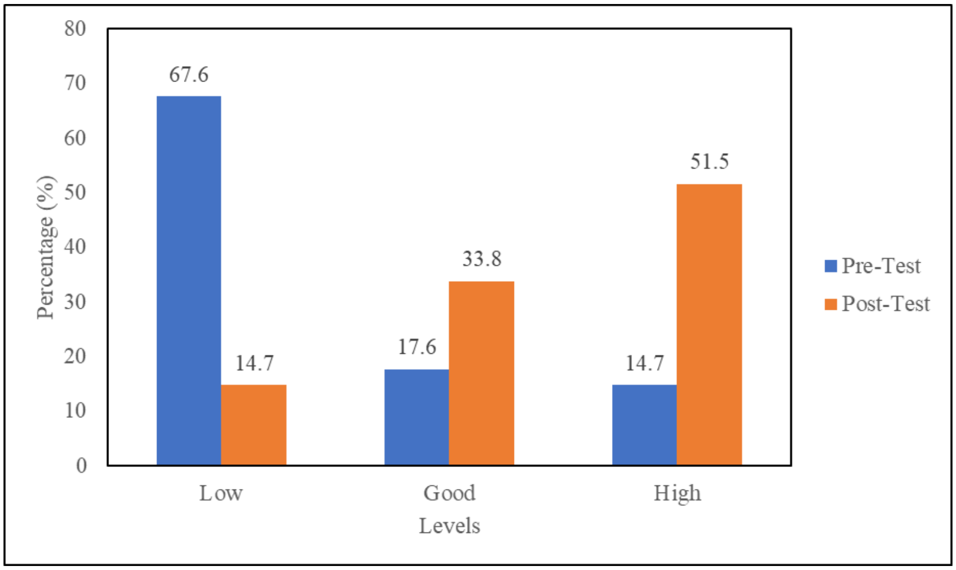

Figure 8: Summary of Self-Efficacy Levels Among Learners

Table 3 reveals the statistics of gender and the self-efficacy scores using the frequency, mean and standard deviation. This showed that prior to the commencement of the experiment, the expectancy component mean score of females (5.8) was lower than the male (10.4). However, after the implementation of the experiment there was a significant expectancy component mean score among the genders; male (16.56) and female (18.7). Also, a significant difference is shown between the expectancy component before the experiment (ECPre) and the gender. This further explains that the female gender believed more in their ability after the implementation of the experiment.

Table 3: Gender Statistics of Self-Efficacy Among Learners

	Gender	N	Mean	Std. Deviation
ECPost	Female	17	18.70	2.73
	Male	50	16.56	3.46
ECPre	Female	17	5.82	4.98
	Male	50	10.42	5.93

Table 4 shows the correlation result of self-efficacy among learners across factors of GPA, gender, and their class level before and after the implementation of the experiment.

Table 4: Correlation Between Self-Efficacy Among Learners

		Current GPA	Gender	Class level	ECPre	ECPost
Current GPA	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	68				
Gender	Pearson Correlation	.251*	1			
	Sig. (2-tailed)	.039				
	N	68	68			
Class level	Pearson Correlation	.280*	.311**	1		
	Sig. (2-tailed)	.021	.010			
	N	68	68	68		
ECPre	Pearson Correlation	-.005	.294*	.496**	1	
	Sig. (2-tailed)	.969	.015	.000		
	N	68	68	68	68	
ECPost	Pearson Correlation	-.122	-.296*	-.073	-.264*	1
	Sig. (2-tailed)	.322	.014	.554	.030	
	N	68	68	68	68	68

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Before implementation, a significant correlation between the expectancy component and the class level was detected. Additionally, when comparing other factors such as GPA and class level, no correlation was observed. Nonetheless, the purpose of this comparison was to ascertain whether learners' GPA influenced their self-efficacy levels before and after the experiment at different class levels. The table shows that there are statistically significant correlations between some of the variables, such as Class level and Gender (=0.311), ECPre and Class level (=0.496), and ECPost and ECPre (-0.264), indicating positive and negative relationships between the variables.

Self-Efficacy Paired Sample t-test and the Effect Size

A paired sample t-test analysis was run on 68 learners' expectancy component scores before and after they were taught using the experiment-centric pedagogy to see if the utilization of low-cost, safe, and hands-on devices can boost their self-efficacy. Learners' mean self-efficacy scores before the implementation of the pedagogy was 9.21±5.99 and after the implementation was 17.06±3.40. A statistically significant increase of 7.85±7.62, t(67) = 8.49, $p < .0005$ was found. Cohen's result showed the d value of 1.03 (with CI of 0.73 and 1.32), revealing a large effect size with a practical significance as seen in Table 5 and Table 6. However, the confidence interval before and after expectancy component reveals it is not significant. The value of Hedge's correction shows a positive correlation.

Table 5: Paired Sample T-Test

	Mean score ± Std Deviation	Mean Difference	Standard Deviation	t-test	df	Sig
ECPost	17.06±3.40	7.85	7.62	8.49	67	<0.001
ECPre	9.21±5.99					

Table 6: Expectancy Component Effect Size (Paired Samples Effect Sizes)

			Standardizer	Point Estimate	95% Confidence Interval	
					Lower	Upper
Pair 1	ECPost - ECPre	Cohen's d	7.62413	1.030	.733	1.322
		Hedges' correction	7.71082	1.018	.725	1.307

Discussion

The study sheds light on the traits of the student body, which was selected from a historically Black university. Table 1 indicates that 85% of the participants identified as Black or African American. This is in line with historically Black colleges and universities' (HBCUs) goal of giving access to underrepresented groups, even though it restricts the findings' applicability to the larger engineering community [20].

The central tenet of Bandura's self-efficacy theory is that by exhibiting personal capability, mastery experiences increase efficacy beliefs. The significant rise in self-efficacy scores from the pre-test (M=9.21) to the post-test (M=17.06) indicates that the practical experiments yielded valuable experiences of mastery. According to qualitative research, students' engineering self-efficacy is increased through active learning when they can apply concepts in meaningful ways [21]. But without a control group, it is impossible to pinpoint changes solely to educational intervention. The effects of experiment-centric pedagogy could be better understood by using control groups.

Given that more advanced students would have accumulated more mastery experiences, the positive correlation between pretest self-efficacy and class level is consistent with Bandura's theory [6]. The higher increase in efficacy among females is consistent with earlier studies that suggest practical methods could help reduce gender disparities in engineering [21]. The small sample size, however, calls for caution when extrapolating these subgroup results. Greater sample sizes would yield more solid proof of the effects on a diverse learner’s body.

According to [22], there is a high practical significance and potential for real-world impact due to the very large effect size (d=1.03). However, depending solely on self-report measures has its limitations due to its potential for bias. The conclusion that effects are meaningful would be strengthened by the inclusion of objective competence measures. Long-term monitoring is also required to ascertain whether effects endure over time [21]. All things considered, this preliminary study offers a promising foundation for future research on self-efficacy and experiment-centric pedagogy.

Conclusion

This study demonstrates that introducing hands-on learning activities into the undergraduate transportation engineering curriculum can considerably increase students' engineering self-efficacy. The experimental study design used a validated Motivated Strategy Learning Questionnaire survey tool to assess differences among the learners between 2020 and 2023 semesters. Learners showed significant improvements in self-efficacy ratings post the hands-on activity.

The findings support Bandura's social cognitive theory, which holds that mastery experiences gained via experiential learning increase self-belief in one's abilities. Active participation in engineering practices tends to equip transportation engineering students with confidence-building skills and vicarious learning possibilities. Obtaining data, using hands-on tools, and working on complicated tasks provided students with tangible evidence of their growing skill. This increased their confidence in their capacity to understand concepts, use knowledge meaningfully, and solve problems.

Hands-on pedagogy emerges as an effective strategy for increasing difficult students' motivation, resilience, and chances of completing challenging transportation engineering programs. Educational improvements that promote self-efficacy can increase retention. Institutions should offer professional development possibilities as well as incentives for professors to include self-efficacy interventions within technical education programs. Future study can improve hands-on learning implementations to enhance engineering self-concept outputs.

Acknowledgements

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] R. M. Marra, K. A. Rodgers, D. Shen, and B. Bogue, "Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy," *J of Engineering Edu*, vol. 98, no. 1, pp. 27–38, Jan. 2009, doi: 10.1002/j.2168-9830.2009.tb01003.x.

[2] K. R. Wentzel and A. Wigfield, Eds., *Handbook of motivation at school*. in Educational psychology handbook series. New York ; London: Routledge, 2009.

[3] R. M. Ryan, Ed., *The Oxford handbook of human motivation*. in Oxford library of psychology. New York: Oxford University Press, 2012.

[4] D. H. Schunk and M. K. DiBenedetto, "Motivation and social cognitive theory," *Contemporary Educational Psychology*, vol. 60, p. 101832, Jan. 2020, doi: 10.1016/j.cedpsych.2019.101832.

[5] E. L. Usher and F. Pajares, "Sources of Self-Efficacy in School: Critical Review of the Literature and Future Directions," *Review of Educational Research*, vol. 78, no. 4, pp. 751–796, Dec. 2008, doi: 10.3102/0034654308321456.

[6] A. Bandura, “Self-efficacy: Toward a Unifying Theory of Behavioral Change”.

[7] S. A. Karabenick, “Perceived Achievement Goal Structure and College Student Help Seeking,” *Journal of Educational Psychology*, vol. 96, no. 3, pp. 569–581, Sep. 2004, doi: 10.1037/0022-0663.96.3.569.

[8] G. Marchand and E. Skinner, “Motivational Dynamics of Children’s Academic Help-Seeking and Concealment,” *Journal of Educational Psychology*, vol. 99, pp. 65–82, Feb. 2007, doi: 10.1037/0022-0663.99.1.65.

[9] “Social Influences on the Development of Children’s Adaptive Help Seeking: The Role of Parents, Teachers, and Peers - ScienceDirect.” Accessed: Jan. 15, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0273229799905026?casa_token=uIo_DRImDykAAAAA:nNH0IaVsnxRHrvDwjfNaVE4ISgitOB_QjxVeIMKwxH8W4veD0HongMMQLGpHfQMZS1phZXTNPw

[10] M. J. Prince and R. M. Felder, “Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases,” *Journal of Engineering Education*, vol. 95, no. 2, pp. 123–138, Apr. 2006, doi: 10.1002/j.2168-9830.2006.tb00884.x.

[11] J. Macias-Guarasa, J. M. Montero, R. San-Segundo, A. Araujo, and O. Nieto-Taladriz, “A Project-Based Learning Approach to Design Electronic Systems Curricula,” *IEEE Trans. Educ.*, vol. 49, no. 3, pp. 389–397, Aug. 2006, doi: 10.1109/TE.2006.879784.

[12] B. J. Zimmerman, “Self-Efficacy: An Essential Motive to Learn,” *Contemporary Educational Psychology*, vol. 25, no. 1, pp. 82–91, Jan. 2000, doi: 10.1006/ceps.1999.1016.

[13] D. H. Schunk, “Self-Efficacy and Academic Motivation,” *Educational Psychologist*, vol. 26, no. 3–4, pp. 207–231, Jun. 1991, doi: 10.1080/00461520.1991.9653133.

[14] “Self-Efficacy: The Exercise of Control - ProQuest.” Accessed: Jan. 15, 2024. [Online]. Available: https://www.proquest.com/docview/220140280?pq-origsite=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals

[15] R. W. Lent, H.-B. Sheu, D. Singley, J. A. Schmidt, L. C. Schmidt, and C. S. Gloster, “Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students,” *Journal of Vocational Behavior*, vol. 73, no. 2, pp. 328–335, Oct. 2008, doi: 10.1016/j.jvb.2008.07.005.

[16] A. F. Al-Alwan, “Self-Regulated Learning in High and Low Achieving Students at Al-Hussein Bin Talal University (AHU) in Jordan,” *International Journal of Applied Educational Studies*, vol. 1, no. 1, pp. 1–13, Apr. 2008.

[17] “Social Cognitive Theory – Educational Learning Theories.” Accessed: Jan. 12, 2024. [Online]. Available:

https://openoregon.pressbooks.pub/educationallearningtheories3rd/chapter/chapter-3-social-cognitive-theory-2/

[18] 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.

[19] 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.

[20] M. Gasman and T.-H. Nguyen, “Myths Dispelled: A Historical Account of Diversity and Inclusion at HBCUs,” *New Directions for Higher Education*, vol. 2015, no. 170, pp. 5–15, 2015, doi: 10.1002/he.20128.

[21] M. A. Hutchison, D. K. Follman, M. Sumpter, and G. M. Bodner, “Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students,” *Journal of Engineering Education*, vol. 95, no. 1, pp. 39–47, 2006, doi: 10.1002/j.2168-9830.2006.tb00876.x.

[22] F. Crowther, M. Ferguson, and L. Hann, *Developing Teacher Leaders: How Teacher Leadership Enhances School Success*. Corwin Press, 2009.