2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38401

# Evaluating the Impact of Experiment-Centric Pedagogy on Civil Engineering Undergraduates' Motivation

**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, heavy metal contamination, and use of experiment-centric pedagogy in STEM fields.

**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.

**Dr. Steve Efe, Morgan State University**

Dr. Steve Efe is an Assistant Professor and the Assistant Director of the Center for Advanced Transportation and Infrastructure Engineering Research. He obtained his Doctor of Engineering in Civil Engineering with a major in Structural Engineering and min

**Dr. Mehdi Shokouhian, Morgan State University**

Dr. Shokouhian is an Assistant Professor at the Department of Civil Engineering, Morgan State University. His research focuses on performance-based design of structures made of high performance steel and concrete using theoretical, numerical and experimen

**Oyinkansola Aladeokin**
**Adebayo Iyanuoluwa Olude, Morgan State University**
**Neda Bazyar Shourabi, Pennsylvania State University, Berks Campus**
**Ms. Sotonye Ikiriko, Morgan State University**

Ms. Sotonye Ikiriko is currently a Doctoral student and Research Associate in the Department of Civil Engineering, Morgan State University (MSU) in Baltimore Maryland. Prior to joining the department in January of 2019, Ms. Sotonye Ikiriko was a Graduate

**Dr. Krishna Bista, Morgan State University**

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

**Dr. Uttam Gaulee**
**Frank Efe**
**Dr. Md Mahmudur Rahman, Morgan State University**

Dr. Mahmudur Rahman received his PhD in Computer Science in 2008 from Concordia University, Montreal, Canada with an emphasis on Medical informatics and Image Retrieval. Prior to joining as an Assistant Professor at Morgan State University in 2014, Dr. Rahman extensively conducted research at the

National Institutes of Health (NIH), USA for almost six years as a Research Scientist. He significantly contributed to research and development of the image processing, classification, and retrieval methods extensively used in the NLM's Open-i Search Engine for biomedical literature. Dr. Rahman has good expertise in the fields of Computer Vision, Image Processing, Information Retrieval, Machine Learning, and Data Mining and their application to retrieval of biomedical images from large collections. Since joining Morgan, Dr. Rahman also has been actively involved in basic educational and instructional research by infusing several interactive and active learning techniques in classroom to teach introductory programming courses with a goal to improve the retention rate in the CS department. Dr. Rahman has published a book, two book chapters and around seventy articles in peer-reviewed journals and conference proceedings, such as IEEE Transaction on Information Technology in Biomedicine, Computerized Medical Imaging and Graphics, etc. and presented his works in numerous conferences and workshops, such as ICPR, CBMS, CLEF, CIVR, HISB, SPIE, BIBE, IEEE FIE, etc. His current research is focusing on Crowdsourcing and Deep learning techniques and their application in medical fields, especially for retrieval and diagnostic purposes.

Pursuing continuous financial support is an integral part of Dr. Rahman's research agenda Over the years, Dr. Rahman ¬received (as both PI and Co-PI) several competitive grants for both Imaging Informatics and Applied Machine Learning based research and also Instructional (CS Education) research, such as NSF HBCU-UP and NSF HBCU IUSE grants, and also several internal grants form MSU, such as ASCEND, I-Gap, etc.

**Hannah Abedoh, Morgan State University**
**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.

# Evaluating the Impact of Experiment-Centric Pedagogy on Civil Engineering Undergraduates' Motivation


## Abstract

Motivation is a strong factor in effective learning, and it has an impact on learning outcomes. Students' motivation can impact their ability to grasp abstract concepts that are taught in civil engineering. When learners are motivated to study, they tend to persevere and put in more effort to perform better in class tasks, assignments, hands-on experiments, and standardized tests. This study is designed to answer the following questions: (i) What is the difference between the motivation of civil engineering undergraduates pre- and postimplementation of experiment-centric pedagogy? (ii) What is the difference between civil engineering undergraduates' motivation pre- and postimplementation of experiment-centric pedagogy based on gender? The motivation of participants was measured using five (5) subscales. Undergraduates' responses were collected using 7-point Likert scales, and statistical analyses were performed using Statistical Package for Social Scientists (SPSS 25.0) at a statistical significance level of 0.05. The self-identified gender binary revealed that 28.8% were females and 71.2% were males. At the pretest, 50.9% of the participants had a high level of motivation, which increased to 55.9% at the posttest. At the posttest, it was found that more females had high motivation than males (58.8% vs 54.8%), which was not significantly different ($p>0.05$). The study therefore concludes that ECP has the capacity to improve undergraduate motivation and increase engagement among learners.


## Introduction

In recent years, technological advancements have significantly impacted how we learn, with many K-12 education programs incorporating a hands-on, constructivist approach to teaching and learning [1]–[3]. However, as students transition to undergraduate programs, there is often a lack of continuity in the teaching methods used, leading to challenges in understanding and applying the lessons taught, aside from continuing in the discipline. Therefore, there is a need to seek out a teaching methodology that can stimulate the motivation of learners and further learners' zeal in the chosen field.

Experiment-centric pedagogy (ECP) is a hands-on learner-centered teaching technique that employs inexpensive, portable instruments to demonstrate STEM concepts. Experiment-centric pedagogy (ECP) offers a more engaging approach to learning in STEM fields by providing learners with hands-on tools and activities that can enhance understanding, familiarization, and retention and lead to measurable outcomes [4]–[6]. In the literature, it was affirmed that the learners enrolled in undergraduate programs in the last decade had been socio-educationally groomed with highly engaging, simple-complex technological tools, as well as several push-button devices, to gain knowledge before their undergraduate classes [4]. Although several pieces of evidence emphasize that colleges and universities are making efforts to ensure a smooth transition from high school into STEM fields by employing activities outside the regular curriculum and summer school strategies, there is little evidence that after transitioning into diverse undergraduate programs, several concepts in different STEM fields are taught similarly [7]. Such discontinuity in learning methods tends to discourage several students and poses challenges in understanding and applying the lessons taught, leading to students changing disciplines [8].

Motivation is a critical factor in achieving successful learning outcomes, as it plays a significant role in retention and knowledge acquisition. STEM educators, particularly engineering faculty at colleges and universities, require a review of methodology as well as utilization of up-to-date knowledge and tools to effectively boost motivation among their students [8]. While there is a significant body of research on motivation in K12 STEM education, there needs to be more literature on motivation in engineering courses, especially civil engineering at colleges and universities [9], [10]. Motivation in learners is a complex and dynamic phenomenon influenced by several factors. The quality of curriculum and instruction, effective classroom management, and a conducive learning environment are some of the factors that can significantly impact students' extrinsic motivation. These external factors play a crucial role in increasing students' drive to learn and achieve academic success. It is therefore imperative for educators to prioritize these factors and create an environment that fosters intrinsic motivation, which stems from within the learners themselves [11]. The impact of perceived competence on intrinsic motivation is significant. Perceived competence refers to the individual's need for opportunities and support in performing an activity, as well as their ability to showcase their knowledge, skills, abilities, or talents [12]. Research suggests that these factors can have a varying impact on an individual's learning characteristics, either positive or less positive [10].

Motivation is a crucial element of active participation, desired goals, and achievements or setbacks in any activity, particularly those related to learning or work [7], [13]. The literature reveals how pedagogical techniques and instructors' conduct influence learners' motivation, which serves as an external factor that can enhance intrinsic motivation [14], [15]. The motivated strategies for learning questionnaire is a widely recognized tool in the literature for investigating the impact of various pedagogies on learners' motivation [16]–[18]. This questionnaire has provided valuable insights into the factors influencing learners' motivation and how different teaching strategies can impact learners’ motivation levels. In civil engineering, which entails a strong combination of mathematical concepts with theories in physics and chemistry, including complex and abstract ideas, motivation is essential to enable students to internalize the concepts and apply their knowledge. Findings in the literature revealed that self-efficacy and learners' achievement goals significantly impact STEM college students' motivation, according to a study conducted in Canada [8]. Another study established that reinforcing learners' self-belief and peer collaboration increased motivation among students studying mathematics [19]. Therefore, this study explores how experiment-centric pedagogy, a hands-on learning approach, influenced undergraduates' motivation in civil engineering at one of the historically black universities and colleges, building on preliminary research. Two research questions guided the study:

(i) Is there a significant difference between the motivation of civil engineering undergraduates pre- and postimplementation of experiment-centric pedagogy?

(ii) Does gender mediate civil engineering undergraduates' motivation pre- and postimplementation of experiment-centric pedagogy?

## Motivation and Self-Determination Theory

Deci and Ryan in 2012 published the first self-determination theory (SDT), a framework with scientific support that is useful for understanding people's motivations and personalities in social circumstances [12], [20]. This theory posits that there are two types of motivation: intrinsic and extrinsic [21]. It was from their work that it was identified that there are internal drivers that stir humans to do what they do and act in certain ways, which was classified as intrinsic motivation. When the drive comes from what is outside the man, in his environment, or around him, it is termed extrinsic motivation. The SDT paradigm holds great significance in understanding practices and systems that support or hinder the fulfillment of needs and the resulting optimal functioning, both at a general and behavior-specific level [20]. In addition to the primary classification of motivation, the study of motivation has been further expanded to encompass four broad categories that range from a deep-seated, inherent desire, passion, and satisfaction in an activity (intrinsic) to a lack of attachment or disconnection to the learner's expectations regarding the activity (amotivation). Identified and external regulations lie between these two extremes and can be summarized as an internal drive based on the perceived usefulness, value, or goal of an activity and an engagement based on external pressures, perceived rewards, or public acknowledgment of an activity, respectively. Understanding the various extrinsic motives is crucial because they demonstrate a student's level of self-determination when completing a learning assignment and the caliber of the effort they are making [20]. Figure 1 reveals the contextual interpretation of the types of motivation in light of self-determination theory (SDT).

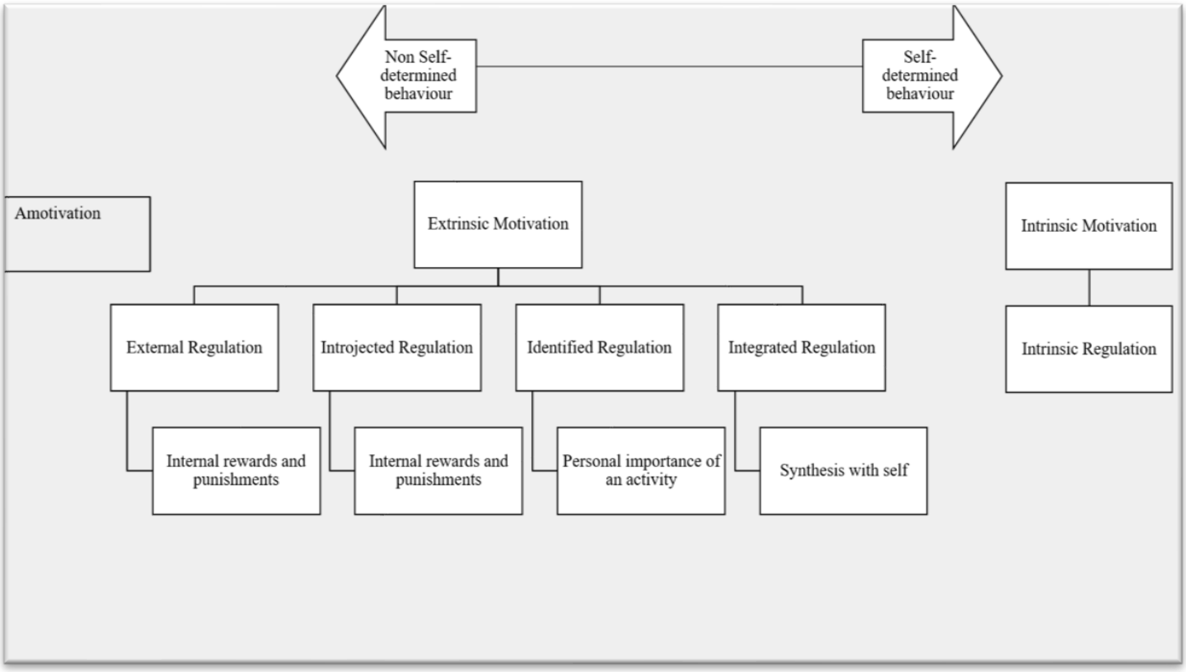


Figure 1: Self Determination Theory Model [22]

Considering the different types of motivation and factors, it is important to note that not all types of motivation lead to effective learning. Effective learning is strongly correlated with internalized motivation, as evidenced by learners' engagement and desirable learning outcomes  10], [12], [20]. SDT, as a need-based theory, argues that individuals develop internalized or autonomous motivation when their basic needs for autonomy, competence, and relatedness are met [20]. Learning that is internalized enables students to recognize the importance of lessons, accept objectives, and customize their learning journey. Intrinsic motivation correlates with positive engagement and better learning outcomes[23], [24]. Instructors play a vital role in developing intrinsic motivation by creating a conducive learning environment, building positive relationships with learners, and providing constructive feedback to build competence [14]. Hands-on learning is an effective way for instructors to motivate learners in STEM fields, particularly in civil engineering, by providing an active learning experience [25].

Summarily, self-determination theory emphasizes providing learners with autonomy, competence, and relatedness support to foster intrinsic motivation. Experiment-centric pedagogy offers opportunities for learners to engage in hands-on activities, make choices, and collaborate with peers, which may enhance their sense of autonomy, competence, and relatedness and in turn increase their intrinsic motivation.

## Methodology

### Study area and sample size

This study was conducted on a group of civil engineering undergraduates at a historically black college and university in the United States during the spring and fall semesters of 2022. The research group's preliminary findings described the module design for any course taught with an experiment-centric approach [6]. The research is multistage, and the current implementation stage and report are limited to a single dose. The design is restricted to a single experiment or module alongside other existing experiments in the learners' course. Figure 2 is the representation of the research process.

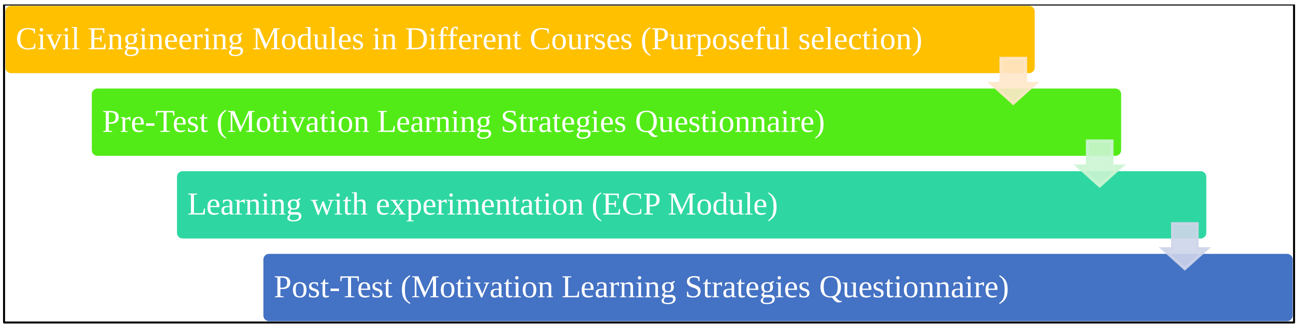


Figure 2: The implementation and data collection procedure in the study

Table 1 displays the courses taught and their corresponding experimental modules. Additionally, it includes the total number of students who completed the pre- and posttest surveys. A detailed explanation of each of the experiments designed to demonstrate different concepts related to civil engineering has been published in the preliminary report of [6].

Table 1: Courses taught using ECP pedagogy

| Term | Course | Experiment | Number of students |
|---|---|---|---|
| Spring (2022) | Structural Analysis and Lab | Bending Stress & Strain | 8 |
| Spring (2022) | Environmental Engineering | Total Dissolved Solids | 12 |
| Spring (2022) | Mechanics of Materials and Lab | Bending Stress & Strain Beam | 6 |
| Fall (2022) | Statics | Deflection/Modulus of Elasticity of Specimen | 7 |
| Fall (2022) | Environmental Engineering | pH | 9 |
| Fall (2022) | Transportation Engineering | Traffic Count | 17 |
| Total Participants | | | 59 |

In this study, the Motivated Strategies for Learning Questionnaire was used to collect information on students' self-reported gender, ethnicity, and levels of academic motivation [17]. The study utilized five subscales from the Motivated Strategies for Learning Questionnaire (MSLQ) to assess undergraduate students' motivation to learn civil engineering concepts. The subscales were intrinsic goal orientation (IGO), extrinsic goal orientation (EGO), task value (TV), expectancy component (EC), and test anxiety (TA). The MSLQ has a 7-point Likert scale ranging from 1 (Not true of me) to 7 (Very true of me) and covers the three theoretical components of motivation, namely, value beliefs, expectancy, and affect [18]. The five subscales in this study are composed of a 3-item intrinsic goal orientation (IGO), a 3-item extrinsic goal orientation (EGO), a 3-item task value (TV), a 3-item expectancy component (EC), and a 2-item test anxiety (TA). These scales have undergone validation and exhibit acceptable internal reliability coefficients [17], [18], [26]. The intercorrelation between the motivation subscales has been documented in the literature [27]. In this study, student responses were collected electronically and then recoded and transformed. The total maximum score for all subscales was 98, while the minimum score was 14. To categorize the level of motivation, the study utilized a percentage range categorization technique adopted from Tus [28]. The participants' total scores were classified into four levels of motivation: low, moderate, high, and very high. Scores less than or equal to 39 (below 50%) were considered low motivation, scores between 40% and 69% (40-69) were considered moderate motivation, scores between 70% and 88% (71-88) were considered high motivation, and scores between 89% and 98% (89-98) were considered very high motivation. The study conducted both descriptive (frequency, percentages, mean, and standard deviation) and inferential statistics (Wilcoxon z test, Mann–Whitney U test) to analyze the data. Due to the data's nonnormal distribution and the study's 95% confidence level, nonparametric methods were employed. The analysis was carried out using Statistical Package for the Social Sciences (SPSS IBM 25.0), including data cleaning.

**Findings and discussion**

According to Table 2, the distribution of self-identified gender among the 59 participants in this study showed that there were more males than females, with a ratio of 2.5:1. Most participants were Black or African American, accounting for 79.7% of the sample. In contrast, 3.4% of participants identified as Hispanic/Latino, and another 3.4% identified as White/Caucasian.

Table 2: Sociodemographic Characteristics

| Variables | Frequency, N=59 | Percentage, % |
|---|---|---|
| Sexual identity | | |
| Male | 42 | 71.2 |
| Female | 17 | 28.8 |
| Nonbinary or transgender | 0 | 0.0 |
| Prefer not to say | 0 | 0.0 |
| Ethnicity | | |
| American Indian or Alaskan Native | 1 | 1.7 |
| Asian or Pacific Islander | 4 | 6.8 |
| Black or African American | 47 | 79.7 |
| Hispanic or Latino | 2 | 3.4 |
| White/Caucasian | 2 | 3.4 |
| Prefer not to say | 3 | 5.1 |

The results presented in Table 3 clearly revealed that there was a decrease in the Test Anxiety of learners' postimplementation of ECP. Test anxiety is a common issue among students, and it may have implications for their academic performance and overall learning outcomes. A lowered score in posttest anxiety was observed in the items "I have an uneasy, upset feeling when I take an exam" and "I have an uneasy, upset feeling when I take an exam." In addition, it was observed that there was an increase in the expectancy component items, which is a subscale of motivation in the study. The result showed an increase in the item, "I'm confident I can do an excellent job on the assignments and tests in this course," as well as, "I believe I will receive an excellent grade in this class." This is a common issue among students, and it may have implications for their academic performance and overall learning outcomes. In studying factors that contribute to students' learning outcomes, evidence has been found that intrinsic goal orientation was significant to learning engineering among first-year undergraduates [29]. Although the finding persists that students who start out in engineering tend to drop out before the end of the course, highly motivated students tend to stay through to the end [29].

The observation that there was less variation in the standard deviation (SD) values of mean scores at posttest than at pretest could be an indication that learners' scores at posttest were more clustered around the mean than at pretest. The intervention (ECP) could be seen to have helped improve the level of motivation and reduce the variability in motivation among the participants. This is a positive finding suggesting that the ECP may have benefitted the participants' motivation.

Table 4 shows the mean scores with standard deviation of the five subscales (IGO, EGO, TV, EC, TA) measured before and after the intervention, as well as the percentage change, Wilcoxon Z score, and p value for each subscale. The Wilcoxon Z score and p value indicate whether there is a statistically significant difference between the pretest and posttest scores. A negative direction (-4.1%) was found in test anxiety, which indicated an overall impact of ECP on learners' motivation. A slight increase in task value (approximately 1%) was found among the leaners. There was no significant difference in the motivation constructs that were investigated ($p>0.05$). The Wilcoxon z score of 8.90 revealed a large effect size; however, it was not significant. Additionally, the reduction in posttest scores in IGO and EGO could be interpreted as learners' personality as it addresses how learners perceived the experiment.

Table 3: Mean scores of participants in motivation subscales

| Subscales[1] | Pre-Test | Post-Test | ΔMean |
|---|---|---|---|
| Intrinsic Goal Orientation (IGO) | Mean ± SD | Mean ± SD | |
| In a class like this, I prefer course material that truly challenges me so I can learn new things. | 5.4±1.3 | 5.4±1.2 | 0.0 |
| In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn. | 5.5±1.3 | 5.3±1.4 | -0.2 |
| The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible. | 5.6±1.3 | 5.5±1.2 | -0.1 |
| Extrinsic Goal Orientation (EGO) | | | |
| Getting a good grade in this class is the most satisfying thing for me right now. | 5.9±1.5 | 5.6±1.5 | -0.3 |
| The most important thing for me right is now improving my overall grade point average. | 5.8±1.5 | 5.5±1.6 | -0.3 |
| I want to do well in this class because it is important to show my ability to my family, friends, employer, or others. | 5.6±1.44 | 5.5±1.32 | -0.1 |
| Task Value (TV) | | | |
| It is important for me to learn the course material in this class. | 5.9±1.4 | 5.9±1.1 | 0.0 |
| I am very interested in the content area of this course. | 5.3±1.6 | 5.3±1.4 | 0.0 |
| I like the subject matter of this course. | 5.2±1.58 | 5.2±1.33 | 0.0 |
| Expectancy Component (EC) | | | |
| I believe I will receive an excellent grade in this class. | 5.3±1.5 | 5.4±1.3 | 0.1 |
| I'm confident I can do an excellent job on the assignments and tests in this course. | 5.4±1.4 | 5.5±1.2 | 0.1 |
| I expect to do well in this class. | 5.6±1.4 | 5.5±1.4 | -0.1 |
| Test Anxiety (TA) | | | |
| I have an uneasy, upset feeling when I take an exam. | 5.0±1.8 | 4.9±1.8 | -0.1 |
| I feel my heart beating fast when I take an exam. | 4.6±1.5 | 4.3±1.9 | -0.3 |

1 Likert Scale 1-7

Table 4: Overall Mean and Standard Deviation of Participant Responses and Wilcoxon Test

| Subscales | Pre-Test Mean±SD | Post-Test Mean±SD | % Change | Wilcoxon Z score | *p* value |
|---|---|---|---|---|---|
| Intrinsic Goal Orientation (IGO) | 5.5±1.1 | 5.5±1.1 | -1.6% | 1.1 | 0.27 |
| Extrinsic Goal Orientation (EGO) | 5.8±1.3 | 5.6±1.2 | -3.6% | 1.6 | 0.11 |
| Task Value (TV) | 5.4±1.4 | 5.5±1.1 | 0.6% | 0.0 | 0.94 |
| Expectancy Component (EC) | 5.5±1.3 | 5.5±1.2 | 0.0% | 0.0 | 0.97 |
| Test Anxiety (TA) | 4.8±1.7 | 4.6±1.6 | -4.2% | 8.9 | 0.37 |

Figure 3 displays the summary of the motivation categorization of participants. The results showed that at the pretest, the average proportion of the participants (50.85%) had a high level of motivation, indicating a promising starting point for the study. This proportion increased to 55.93% at the posttest, showing an improvement in motivation levels after the implementation of the hands-on pedagogy. Another notable finding was that initially, 3.39% of participants had low motivation, which was reduced to 0.0% in the posttest, indicating that the pedagogical approach had a positive impact on learners who were struggling with motivation. Additionally, at the pretest, 18.64% of the participants had a very high level of motivation, which was reduced to 8.47% at the posttest, indicating that the hands-on approach may have helped balance the motivation levels across participants. These findings suggest that hands-on pedagogy is an effective approach to improving motivation levels among learners and could be a valuable addition to classroom instruction.

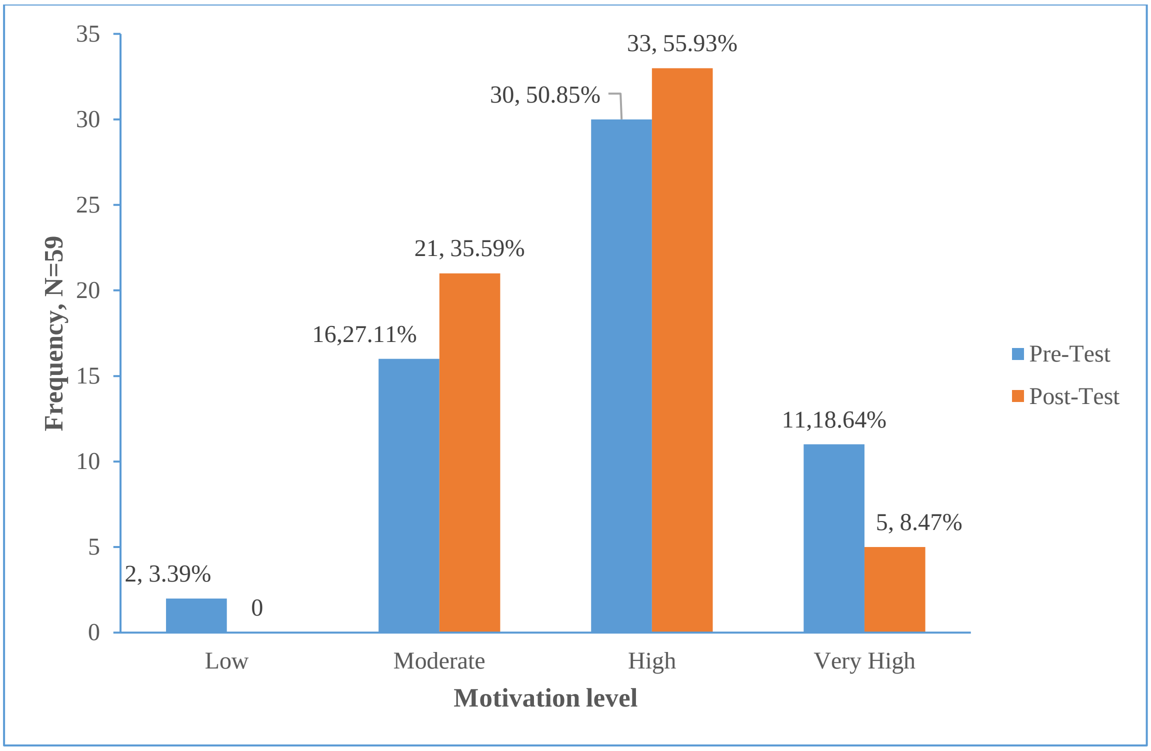

Figure 3: Summary of Level of Motivation of Participants pre- and posttest

The Motivation of Participants by Gender

Table 5 indicates a positive change in the mean scores of intrinsic goal orientation, task value, expectancy component and test anxiety among female participants. In contrast, males only demonstrated an increase in test anxiety mean scores. The findings also suggested that females scored higher in extrinsic goal orientation than males, indicating that they were more likely to be influenced by external factors. This is consistent with previous studies such as D'Lima *et al*. [30] and Boggiano and Barrett [31], who reported similar findings. Furthermore, the study found that at pretest, males had higher expectancy component scores than females, but at posttest, the females had higher mean scores on this subscale, suggesting that the ECP is more effective in influencing females than males.

Table 6 presents a comparison of the mean scores of overall motivations between self-identified genders (male and female), and it was found that there was no significant difference between pre- and posttest mean scores of motivations across the gender spectrum ($p>0.05$). These results support the notion that the hands-on pedagogy approach is effective in improving the motivation of both male and female learners equally.

Table 5: Mean Score of Motivation Subscales by Gender

| Subscales | Female (Mean±SD) | | Male (Mean±SD) | |
|---|---|---|---|---|
| | Pre-Test | Post-Test | Pre-Test | Post-Test |
| Intrinsic Goal Orientation (IGO) | 5.5±1.3 | 5.6±0.9 | 5.56±1.1 | 5.4±1.1 |
| Extrinsic Goal Orientation (EGO) | 5.8±1.3 | 5.8±1.1 | 5.7±1.4 | 5.5±1.3 |
| Task Value (TV) | 5.5±1.4 | 5.6±1.2 | 5.4±1.4 | 5.4±1.1 |
| Expectancy Component (EC) | 5.4±1.1 | 5.7±1.0 | 5.5±1.4 | 5.4±1.3 |
| Test Anxiety (TA) | 5.2±1.9 | 5.0±1.9 | 4.6±1.4 | 4.4±1.6 |

Table 6: Mean Score Comparison of Motivation among the Self-identified Genders

| | Pre-Test Mean±SD | Post-Test Mean±SD | % Change | Wilcoxon Z score | *p* value |
|---|---|---|---|---|---|
| Female | 5.5±0.9 | 5.6±0.7 | 2.2% | 0.3 | 0.77 |
| Male | 5.4±0.9 | 5.3±0.7 | -2.6% | 1.7 | 0.09 |
| Mann–Whitney U Test | 331.5 | 280.5 | | | |
| *p* value | 0.67 | 0.20 | | | |

Figure 4 displays the comparison of the levels of motivation between male and female civil engineering students. The results showed an overall increase in the percentage of highly motivated participants, with a higher increase observed among the female participants.

Specifically, the proportion of females who were very highly motivated increased from 11.76% to 17.65%, while the proportion of highly motivated males increased from 45.24% to 54.76%. Interestingly, a higher proportion of females were very highly motivated than males (17.65% vs. 4.76%), which further supports the finding that hands-on pedagogy has a stronger impact on female participants. Additionally, the proportion of participants who were highly motivated was higher among females than males (58.82% vs. 54.76%). Overall, these findings suggest that hands-on pedagogy was effective in improving the motivation levels of both male and female civil engineering students.

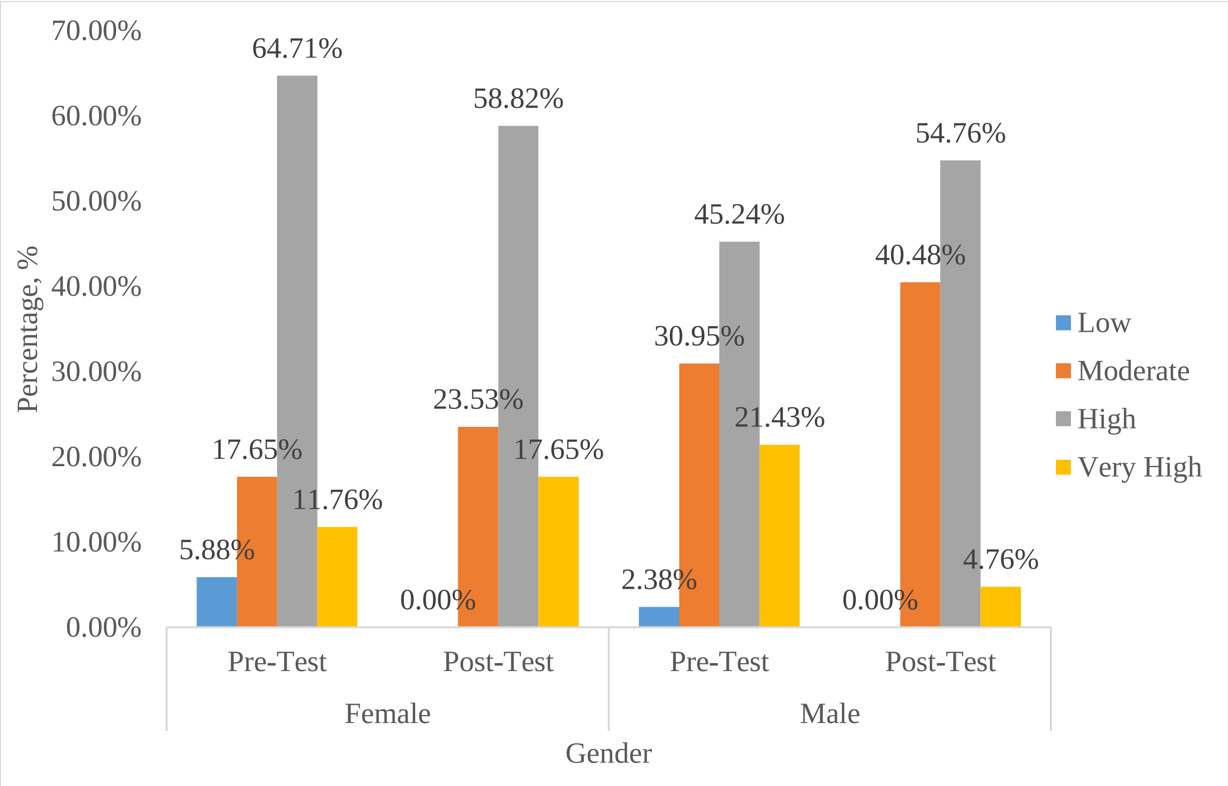


Figure 4: Summary of Motivation Levels by Self-identified Gender

## Conclusion

The study findings suggest that the experiment-centric pedagogy was effective in stimulating motivation among undergraduate civil engineering students. The self-determination theory framework used in the study highlighted the importance of autonomy, relatedness, and competency in driving motivation. The use of hands-on learning and a combination of technology, mechanical tools, and scientific principles helped to improve students' motivation and lower test anxiety. The results also revealed that the ECP helped to balance motivation between the male and female students. These findings highlight the potential of hands-on learning approaches to improve motivation and enhance learning outcomes in civil engineering education.

Further research in other engineering fields and STEM disciplines can help to expand our understanding of the impact of different teaching pedagogies on student motivation and success. Considering the promising findings of this study, future research could explore ways to increase the dosage of experiment-centric pedagogy (ECP) per course to further enhance the motivation levels of undergraduate civil engineering students. Furthermore, future studies could explore how the integration of ECP with other teaching pedagogies and technologies can contribute to students' motivation and 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] L. Ah-Nam and K. Osman, "Developing 21st Century Skills through a Constructivist-Constructionist Learning Environment. K-12 STEM Education," *Inst. Promot. Teach. Sci. Technol.*, vol. 3, no. 2, pp. 205–216, 2017.

[2] S. Guzey and G. Roehrig, "Teaching Science with Technology: Case Studies of Science Teachers' Development of Technological Pedagogical Content Knowledge (TPCK)," *Contemp. Issues Technol. Teach. Educ.*, vol. 9, no. 1, pp. 25–45, 2009.

[3] D. S. Niederhauser and D. L. Lindstrom, "Addressing the Nets for Students Through Constructivist Technology Use in K–12 Classrooms," *J. Educ. Comput. Res.*, vol. 34, no. 1, pp. 91–128, Jan. 2006, doi: 10.2190/E0X3-9CH0-EE2B-PLXG.

[4] K. Connor *et al.*, "Matched Assessment Data Set for Experiment-Centric Pedagogy Implementation in 13 HBCU ECE Programs," in *2017 ASEE Annual Conference & Exposition Proceedings*, Columbus, Ohio: ASEE Conferences, Jun. 2017, p. 28652. doi: 10.18260/1-2--28652.

[5] 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.

[6] 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.
[7] J. Vennix, P. den Brok, and R. Taconis, “Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM?,” *Int. J. Sci. Educ.*, vol. 40, no. 11, pp. 1263–1283, Jul. 2018, doi: 10.1080/09500693.2018.1473659.
[8] R. Simon, M. Aulls, H. Dedic, K. Hubbard, and N. Hall, “Exploring Student Persistence in STEM Programs: A Motivational Model,” *Can. J. Educ.*, vol. 38, no. 1, pp. 1–27, 2015.
[9] R. Bybee, *The case for STEM education: Challenges and opportunities*. National Science Teacher Association, 2013.
[10] J. D. Stolk, M. D. Gross, and Y. V. Zastavker, “Motivation, pedagogy, and gender: examining the multifaceted and dynamic situational responses of women and men in college STEM courses,” *Int. J. STEM Educ.*, vol. 8, no. 1, p. 35, Dec. 2021, doi: 10.1186/s40594-021-00283-2.
[11] O. A. Sogunro, “Motivating Factors for Adult Learners in Higher Education,” *Int. J. High. Educ.*, vol. 4, no. 1, p. p22, Nov. 2014, doi: 10.5430/ijhe.v4n1p22.
[12] E. L. Deci and R. M. Ryan, “Self-Determination Theory,” in *Handbook of Theories of Social Psychology: Volume 1*, 1 Oliver’s Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2012, pp. 416–437. doi: 10.4135/9781446249215.n21.
[13] M. Alizadeh, “The Impact of Motivation on English Language Learning,” *Int. J. Res. Engl. Educ.*, vol. 1, no. 1, pp. 11–15, 2016.
[14] D. Johnson, “The Role of Teachers in Motivating Students To Learn,” *J. Grad. Stud. Educ.*, vol. 9, no. 1, pp. 46–49, 2007.
[15] S. Saeed and D. Zyngier, “How Motivation Influences Student Engagement: A Qualitative Case Study,” *J. Educ. Learn.*, vol. 1, no. 2, p. p252, Nov. 2012, doi: 10.5539/jel.v1n2p252.
[16] P. Nenniger, “On the role of motivation in self-directed learning: The ‘two-shells-model of motivated self-directed learning’ as a structural explanatory concept,” *Eur. J. Psychol. Educ.*, vol. 14, no. 1, pp. 71–86, Mar. 1999, doi: 10.1007/BF03173112.
[17] P. R. Pintrich, D. A. F. Smith, T. Garcia, and W. J. Mckeachie, “Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq),” *Educ. Psychol. Meas.*, vol. 53, no. 3, pp. 801–813, Sep. 1993, doi: 10.1177/0013164493053003024.
[18] M. Credé and L. A. Phillips, “A meta-analytic review of the Motivated Strategies for Learning Questionnaire,” *Learn. Individ. Differ.*, vol. 21, no. 4, pp. 337–346, Aug. 2011, doi: 10.1016/j.lindif.2011.03.002.
[19] E. Seda and K. Zahitjan, “The Factors Affecting Learners’ Motivation in English Language Education,” *J. Foreign Lang. Educ. Technol.*, no. 1, pp. 18–38, 2016.
[20] R. M. Ryan and E. L. Deci, “Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being,” *Am. Psychol.*, vol. 55, pp. 68–78, 2000.
[21] E. L. Deci and R. M. Ryan, “The general causality orientations scale: Self-determination in personality,” *J. Res. Personal.*, vol. 19, no. 2, pp. 109–134, Jun. 1985, doi: 10.1016/0092-6566(85)90023-6.
[22] I. van Beek, T. W. Taris, and W. B. Schaufeli, “Workaholic and work engaged employees: Dead ringers or worlds apart?,” *J. Occup. Health Psychol.*, vol. 16, no. 4, pp. 468–482, 2011, doi: 10.1037/a0024392.

[23] M. Theobald, *Increasing student motivation: Strategies for middle and high school teachers*. Corwin Press, 2005.
[24] Q. Zhang, "Assessing the Effects of Instructor Enthusiasm on Classroom Engagement, Learning Goal Orientation, and Academic Self-Efficacy," *Commun. Teach.*, vol. 28, no. 1, pp. 44–56, Jan. 2014, doi: 10.1080/17404622.2013.839047.
[25] A. Ahmad, M. K. Nordin, D. F. Ali, and A. Nabil, "Conducting hands-on task in vocational education: teaching method in automotive courses," *J. Tech. Educ. Train.*, vol. 7, no. 1, 2015.
[26] T. G. Duncan and W. J. McKeachie, "The Making of the Motivated Strategies for Learning Questionnaire," *Educ. Psychol.*, vol. 40, no. 2, pp. 117–128, Apr. 2005, doi: 10.1207/s15326985ep4002_6.
[27] J. Stolk and J. Harari, "Student motivations as predictors of high-level cognitions in project-based classrooms," *Act. Learn. High. Educ.*, vol. 15, no. 3, pp. 231–247, Nov. 2014, doi: 10.1177/1469787414554873.
[28] J. Tus, "Academic stress, academic motivation, and its relationship on the academic performance of the senior high school students," *Asian J. Multidiscip. Stud.*, vol. 8, no. 11, pp. 29–37, 2020.
[29] S. Y. Chyung, A. J. Moll, and S. A. Berg, "The Role of Intrinsic Goal Orientation, Self-Efficacy, and E-Learning Practice in Engineering Education," *J. Eff. Teach.*, vol. 10, no. 1, pp. 22–37, 2010.
[30] G. M. D'Lima, A. Winsler, and A. Kitsantas, "Ethnic and Gender Differences in First-Year College Students' Goal Orientation, Self-Efficacy, and Extrinsic and Intrinsic Motivation," *J. Educ. Res.*, vol. 107, no. 5, pp. 341–356, Sep. 2014, doi: 10.1080/00220671.2013.823366.
[31] A. K. Boggiano and M. Barrett, "Gender differences in depression in college students," *Sex Roles*, vol. 25, no. 11–12, pp. 595–605, Dec. 1991, doi: 10.1007/BF00289566.