# The Importance of Hand-on Physics Preparation for a Pre-Engineering Program at Historical Black University College in Maryland: Second-year student as a case study

**Mr. Samuel Oluwagbenga Inuyomi, Morgan State University**

Samuel Oluwagbenga Inuyomi is a distinguished researcher affiliated with Obafemi Awolowo University in Nigeria and Morgan State University, Maryland, where he has made significant contributions to STEM, environmental science, and public health. He had served on several boards of directors and currently on the Eboard of the Graduate Student Association (GSE) and One Trybe, an international organization at Morgan State University.

**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 director of the sustainable infrastructure development, smart innovation and resilient engineering lab and the director of undergraduate programs in the department of civil engineering at Morgan State University.

**The Importance of Hand-on Physics Preparation for a Pre-Engineering Program at Historical Black University College in Maryland: Second-year student as a case study**

**Abstract**

The integration of hands-on physics preparation in pre-engineering programs is essential for strengthening students' foundational knowledge, engagement, and career readiness, particularly at Historically Black Colleges and Universities (HBCUs). This study investigates the impact of experiential learning approaches, including laboratory experiments, collaborative projects, and simulations, on the academic performance and professional preparedness of second-year pre-engineering students at HBCU in Maryland. Using a mixed-methods research design, quantitative and qualitative data were collected to assess students' engagement, conceptual understanding, and confidence in applying physics principles to engineering challenges. Findings indicate that hands-on physics activities significantly enhance students' comprehension of theoretical concepts, improve problem-solving skills, and foster greater motivation toward STEM careers. Statistical analyses reveal strong correlations between engagement and conceptual understanding ($r = 0.92$), as well as engagement and career preparedness ($r = 0.73$), demonstrating that active participation in hands-on learning is a key driver of both academic success and confidence in professional applications. While a moderate correlation ($r = 0.43$) was found between conceptual understanding and career preparedness, the results suggest that practical application of knowledge is crucial in bridging the gap between academic learning and workforce readiness. Additionally, a marginally significant difference ($p = 0.053$) between engagement and career preparedness highlights the role of external factors such as industry exposure in shaping students' career confidence. By reinforcing the gap between theoretical instruction and real-world engineering applications, this research underscores the critical role of hands-on physics education in shaping a skilled and diverse engineering workforce. The findings advocate enhanced experiential learning opportunities in STEM curricula, ensuring equitable access to high-quality education and professional success for students at HBCUs.

## 1.0 Introduction

The principles of physics serve as fundamental roots for the Engineering career pursuit. Therefore, concepts like mechanics, electromagnetism, thermodynamics, and wave theory form a major foundation of engineering design, analysis, and innovation. In pre-engineering programs, especially those at Historically Black Colleges and Universities (HBCUs), effective physics preparedness is vital for professional readiness, academic success, and the highly technical field of engineering. Research by [1], described some hindrances in students' ability to apply theoretical knowledge to complex real-world engineering problems due to inadequate hands-on physics preparation. This issue can be observed mainly among second-year engineering students, where a bridge in fundamental physics education can hinder academic performance and progression and cause a reduction in career aspirations.

The importance of hands-on physics preparation cannot be overemphasized, it emerged as an experiential approach to bridge gaps, and fostering deeper learning. This method enhances understanding and engages students in laboratory experiments, collaborative projects, and simulations. It also assists in problem-solving, and critical thinking skills [2]; [3]. Pertaining to engineering education, these procedures are essential for developing the technical and analytical capabilities needed to address modern challenges. In Kolb's experiential, learning theory, it was seen that active engagement encourages retention and skill development, which STEM fields consider to be valuable.

However, HBCUs play a vital position in spreading the STEM workforce by delivering systemic barriers to participation. Based on the National Science Foundation [4], HBCUs produce 27% of African American graduates with STEM degrees despite comprising only 3% of U.S. colleges and universities. Bridging the achievement gap and preparing students to stand out in competitive engineering fields need strong foundational physics education at various institutions. Exposure to hands-on STEM activities in an early stage has indicated some improvement in persistence and self-efficacy among underrepresented students [5].

This study examines the importance of hands-on physics preparation in a pre-engineering program at an HBCU in Maryland, focusing on second-year undergraduate students. By using a mixed-methods approach that integrates quantitative and qualitative analyses, it gave proper investigation of how hands-on preparation enhances students' academic performance, engagement, and career readiness. The research aims to provide perceptions into curriculum development and pedagogical strategies that address fundamental gaps and provide support for the HBCU's wider mission to cultivate a diverse and skilled engineering workforce.

## 2.0 Literature Review

Recent research has highlighted the critical role that hands-on learning plays in enhancing STEM education at Historically Black Colleges and Universities (HBCUs). Hands-on approaches, including laboratory experiments, project-based learning, and simulation activities, have been shown to significantly improve student engagement, retention, and academic success [6]. The integration of experiential learning aligns with Kolb’s learning model [2], emphasizing the importance of active participation in knowledge acquisition.

Studies have found that HBCUs, despite their smaller size and fewer resources, produce a disproportionately high number of Black STEM graduates, largely due to their emphasis on supportive learning environments and innovative teaching strategies [4]. Additionally, recent work by [7] underscores the importance of culturally responsive pedagogy in STEM education at HBCUs, demonstrating that hands-on engagement fosters not only technical skills but also confidence and career readiness among underrepresented students.

As HBCUs continue to play a pivotal role in diversifying the STEM workforce, expanding access to laboratory resources and incorporating industry-relevant hands-on learning experiences remain essential strategies for improving student outcomes and career preparedness.

### 2.1 Bridging Theory and Practice Through Hands-On Learning

A pedagogical approach (Hands-on learning), highlighting active student encounters with practical activities, has widely been recognized as a transformative and effective tool in physics education. By bridging theoretical concepts with substantial experiences, students can achieve some depth of understanding of abstract ideas while developing problem-solving and critical thinking skills. Experiential learning methods such as laboratory experiments, project-based tasks, and simulations, effectively complement theoretical instruction in STEM disciplines [2]; [3].

### 2.2 Integrating Curriculum Innovation, Pedagogy, and Equity

Innovative and supportive curricula that stress hands-on physics preparation can improve engagement and learning outcomes for different student populations. Interdisciplinary collaborations, inquiry-based projects, and simulation-based tools prepare students for real-world problem-solving while encouraging flexible skills like data analysis and teamwork [8]. Moreover, to address barriers faced by disregarded groups and ensure equitable access to resources and opportunities, there is a need to create inclusive classroom environments. [9].

### 2.3 Impact on Academic Performance and Career Readiness

Freeman et al. (2014) found that active learning methods extensively reduce failure rates in STEM courses, with marginalized groups benefiting the most. Significant research highlights the positive impact of hands-on learning on career readiness and academic performance. Based on pre-engineering programs, hands-on physics activities help to enhance skill acquisition and comprehension, preparing and exposing students to complex engineering challenges. Early experiential practical STEM systems have been shown to assist critical thinking, persistence, and problem-solving abilities, as well as the ability to align with employer expectations in technical fields [10].

### 2.4 Addressing Gaps in the Literature

While the benefits of hands-on learning are well-documented, there is limited research on its impact within the unique context of HBCUs, particularly among second-year pre-engineering students. This study addresses this gap by focusing on the intersection of educational innovation, diversity, and equity, examining how hands-on physics preparation supports academic success and career readiness in underserved populations.

### 2.5 Kolb's Experiential Learning Model

This consists of four stages: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. In the study, this model was applied to hands-on physics preparation for pre-engineering students at HBCUs in the following ways:

#### 2.5.1 Concrete Experience

In this experience, students participated in laboratory experiments, collaborative projects, and physics simulations, and the activities included experiments on mechanics, thermodynamics, and electromagnetism, where students physically manipulated equipment and observed real-world applications of physics concepts.

### 2.5.2 Reflective Observation

After completing experiments, students reflected on their observations, discussing results with peers and instructors. They considered discrepancies between theoretical predictions and experimental outcomes, identifying areas where they struggled or needed deeper understanding.

### 2.5.3 Abstract Conceptualization

This shows how students used their reflections to refine their understanding of physics principles. Classroom discussions and problem-solving sessions helped them link hands-on experiences with theoretical frameworks, reinforcing engineering applications.

### 2.5.4 Active Experimentation

This is where students applied learned concepts to new problems, such as designing small engineering prototypes or engaging in collaborative projects that mimicked real-world engineering challenges. This phase ensured they could transfer theoretical physics knowledge into practical engineering applications, improving problem-solving and critical-thinking skills.

## 2.6 Primary Types of Hands-On Learning Activities

These include laboratory experiments, collaborative projects, and simulations. All these were strategically designed to reinforce core physics concepts and their engineering applications.

### 2.6.1 Laboratory Experiments

The laboratory component involved structured physics experiments that aligned with engineering principles. These experiments assist students in applying theoretical concepts to tangible, real-world problems. E.g. Experiment 1: Newton’s Laws and Motion Analysis; Experiment 2: Energy Conservation and Work-Power Calculations; Experiment 3: Circuit Design and Electromagnetism; Experiment 4: Thermodynamics and Heat Transfer; Experiment 5: Wave Propagation and Optics

### 2.6.2 Collaborative Projects

In this, students worked in teams on larger-scale, problem-based projects requiring the application of multiple physics concepts. It involves Project 1: Bridge Design and Load Testing; Project 2: Renewable Energy Systems; Project 3: Robotics and Motion Control

### 2.6.3 Simulations

To complement physical experiments, students engage in physics and engineering simulations using software tools like MATLAB, Python, and PhET interactive simulations. Simulation 1: Projectile Motion and Air Resistance; Simulation 2: Circuit Simulation and Electrical Analysis; Simulation 3: Fluid Dynamics in Engineering Systems; Simulation 4: Structural Stress Testing

## 3.0 Methods

### 3.1 Study Design

This study employs a mixed-methods approach to provide a comprehensive understanding of the intervention's impact. Pre- and post-intervention analyses will compare academic performance, engagement, and career readiness among participants [11]. Quantitative data will measure changes in grades and conceptual understanding, while qualitative data will explore student perceptions and experiences.

### 3.2 Participants

The study targets second-year pre-engineering students at an HBCU in Maryland. Participants are recruited through departmental announcements, with eligibility criteria including enrollment in physics courses. Demographic data, such as age, gender, and prior exposure to hands-on learning, will contextualize the findings.

## 4.0 Data Collection and Analysis

### 4.1.1 Quantitative Methods

### 4.1.1 Survey Design:

A structured questionnaire was designed based on the Physics Motivation Questionnaire (PMQ) by Glynn et al. [12] to ensure validity and reliability. The instrument consisted of 20 items which aim to investigate the role and effectiveness of hands-on physics preparation in enhancing the academic performance, critical thinking skills, and career readiness of second-year engineering students at a Historically Black College or University (HBCU) in Maryland.

The survey employs the use of a 5-point Likert scale tailored to the topic of hands-on physics preparation for pre-engineering students.

- **Demographics:** Age, gender, prior physics background.
- **Engagement:** Participation in hands-on physics activities (e.g., labs, experiments).
- **Self-Efficacy:** Confidence in applying physics concepts to engineering tasks.
- **Academic Performance:** Self-reported grades in physics-related coursework.
- **Career Readiness:** Perceptions of preparedness for engineering challenges.

#### 4.1.2 Sample:

A total of 25 second-year engineering students were selected using stratified random sampling to ensure demographic and academic diversity.

#### 4.1.3 Data Analysis:

Surveys were administered online and in-person.

**Statistical Techniques**:

- Descriptive statistics (mean, standard deviation) to summarize survey responses.
- Correlation analysis to assess relationships between hands-on preparation and academic outcomes.
- Regression analysis to identify predictors of success in engineering coursework.

### 4.2 Qualitative Methods

#### 4.2.1 Interviews and Focus Groups:

Semi-structured interviews were conducted with 25 students, lasting 30–45 minutes each.

### 4.3 Ethical Considerations

This study adhered to ethical research standards, including informed consent and data confidentiality. Institutional Review Board (IRB) approval was obtained, and participants were assured of their voluntary participation and the ability to withdraw at any time without penalty.

## 5.0 Results and Discussion

The results show the responses to the questionnaire used for this study. The Likert scale responses provide insights into students' perceptions of the impact of hands-on activities on their learning and preparation for engineering careers.

## 5.1 Data Preparation

1. Data Validation:

The dataset was reviewed for completeness and accuracy. All questions received 25 responses, ensuring consistent participation, and the responses were classified into five categories: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree.

2. Numerical Assignment:

Likert responses were converted into numerical values for quantitative analysis:

- Strongly Agree = 5
- Agree = 4
- Neutral = 3
- Disagree = 2
- Strongly Disagree = 1

## 5.2 Quantitative Analysis

Descriptive Statistics:

Frequency counts and percentages were calculated for each response category per question and the weighted scores were computed to determine overall trends. Also, the mean and standard deviation values were calculated to identify the central tendency and variability of responses.

For a better structural overview of the data, questions were grouped into various themes including future preparedness motivation, learning effectiveness, and engagement making analyzing patterns and relationships easier. The Statements and theme questions are represented in Table 1 and Table 2.

**Table 1 – Statement from Questionnaire**

| | Statements |
|---|---|
| 1 | I regularly participate in laboratory sessions as part of my physics coursework. |
| 2 | The hands-on physics activities are well-integrated with the theoretical content. |
| 3 | The availability of laboratory equipment supports effective learning. |
| 4 | The hands-on activities help me understand abstract physics concepts better. |
| 5 | I feel engaged and interested during hands-on physics sessions. |
| 6 | Hands-on physics preparation has improved my understanding of engineering concepts. |
| 7 | My performance in physics-related courses has improved due to hands-on activities. |
| 8 | I feel confident applying physics principles in solving engineering problems. |
| 9 | Hands-on physics preparation has made me more motivated to pursue my engineering studies. |
| 10 | I have observed an improvement in my critical thinking skills due to physics labs. |
| 11 | Hands-on physics preparation has increased my confidence in handling real-world engineering challenges. |
| 12 | The hands-on approach has enhanced my teamwork and collaborative skills. |
| 13 | I believe the skills learned from physics labs will benefit my future career. |
| 14 | The problem-solving tasks in physics labs mirror challenges in engineering practice. |
| 15 | My career goals in engineering have been influenced positively by the physics curriculum. |
| 16 | I would recommend including more hands-on components in the physics curriculum. |
| 17 | Access to advanced physics laboratory facilities should be improved. |
| 18 | Faculty should incorporate real-world engineering scenarios in hands-on physics activities. |
| 19 | Feedback from students should be used to enhance hands-on physics experiences. |
| 20 | Collaborative projects involving physics and engineering should be encouraged. |

**Table 2** – **Theme Questions**

| **Themes** |
|---|
| **Engagement -** *reflecting students' participation and interest during hands-on activities* |
| I regularly participate in laboratory sessions as part of my physics coursework. |
| The hands-on physics activities are well-integrated with the theoretical content. |
| Feedback from students should be used to enhance hands-on physics experiences |
| **Understanding Concepts (Learning Effectiveness and Motivation) -** *relating to the impact of hands-on physics on understanding and skill-building; highlighting the role of hands-on preparation in driving students' interest and commitment to their studies* |
| The hands-on physics activities are well-integrated with the theoretical content. |
| The availability of laboratory equipment supports effective learning. |
| The hands-on activities help me understand abstract physics concepts better. |
| My performance in physics-related courses has improved due to hands-on activities. |
| Access to advanced physics laboratory facilities should be improved. |
| Faculty should incorporate real-world engineering scenarios in hands-on physics activities. |
| Hands-on physics preparation has improved my understanding of engineering concepts. |
| Hands-on physics preparation has made me more motivated to pursue my engineering studies. |
| I feel confident applying physics principles in solving engineering problems. |
| Collaborative projects involving physics and engineering should be encouraged |
| **Future Preparedness -** address how the hands-on approach prepares students for careers and real-world challenges |
| Hands-on physics preparation has increased my confidence in handling real-world engineering challenges. |
| The hands-on approach has enhanced my teamwork and collaborative skills. |
| I believe the skills learned from physics labs will benefit my future career. |
| The problem-solving tasks in physics labs mirror challenges in engineering practice. |
| My career goals in engineering have been influenced positively by the physics curriculum. |
| I would recommend including more hands-on components in the physics curriculum. |

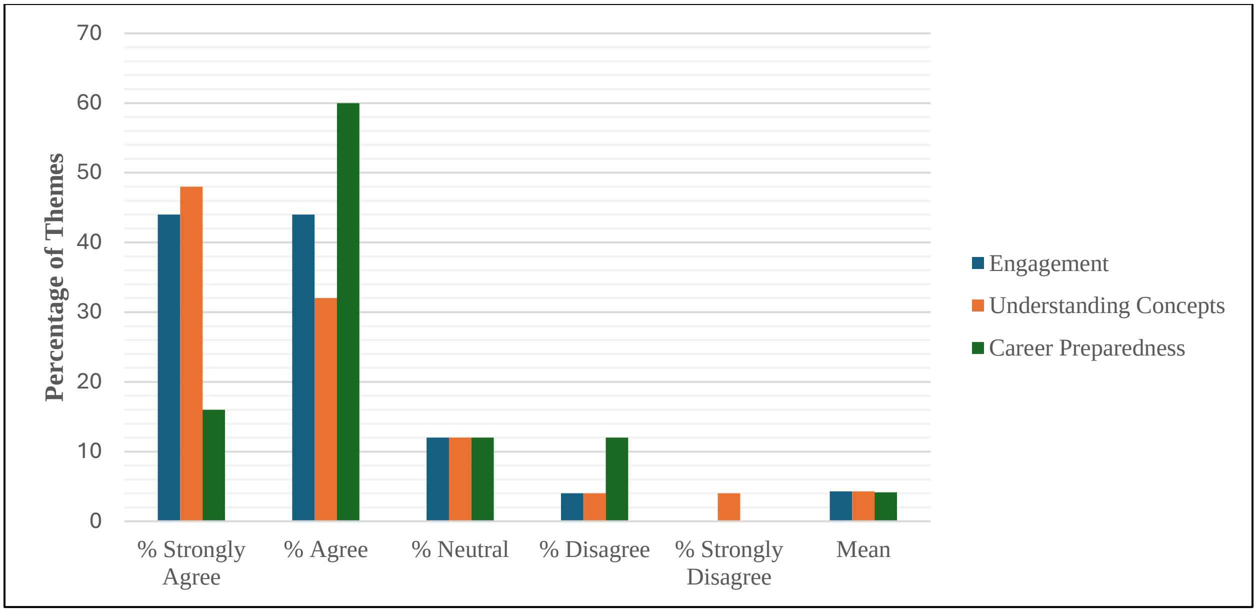


**Figure 1: Showing the Percentage of Themes**

**Table 3: Summary Statistics of Responses on Themes**

| **Question** | **Mean** | **Standard Deviation** | **% Strongly Agree** | **% Agree** | **% Neutral** | **% Disagree** | **% Strongly Disagree** |
|---|---|---|---|---|---|---|---|
| **Engagement** | 4.28 | 0.73 | 44 | 44 | 12 | 4 | 0 |
| **Understanding Concepts** | 4.32 | 0.69 | 48 | 32 | 12 | 4 | 4 |
| **Career Preparedness** | 4.16 | 0.75 | 16 | 60 | 12 | 12 | 0 |

**Table 4 – Correlation Coefficient Measure**

| | Question | Engagement | Understanding Concepts | Career Preparedness |
|---|---|---|---|---|
| **Question** | 1.0000 | | | |
| **Engagement** | -0.9363 | 1.0000 | | |
| **Understanding Concepts** | -0.8773 | 0.9200 | 1.0000 | |
| **Career Preparedness** | -0.5462 | 0.7274 | 0.4314 | 1.0000 |

**Engagement**

Table 3 shows high levels of agreement were observed in responses to questions about engagement during hands-on sessions (44% Strongly Agree, 44% Agree), This has a mean score of 4.28, and a standard deviation of 0.73, indicating strong overall engagement.

**Understanding Concepts (Learning Effectiveness & Motivation)**

Questions on understanding abstract physics concepts through hands-on activities showed strong agreement (48% Strongly Agree, 32% Agree). This has a mean score of 4.32, and a standard deviation of 0.69, reflecting positive perceptions of learning effectiveness.

**Preparation for Engineering Careers**

Strong agreement was evident in students' belief that skills learned in labs benefit future careers (16% Strongly Agree, 60% Agree). This has a mean score of 4.16, and a standard deviation of 0.75.

**Correlation analysis**

Table 4 presents correlation coefficients that measure the strength and direction of relationships between Engagement, Understanding Concepts, and Career Preparedness in hands-on physics activities.

**Engagement and Understanding Concepts**

A very strong positive correlation (0.9200**)** means that as students engage more in hands-on activities, their understanding of physics concepts improves significantly. This confirms that active learning is highly effective in reinforcing theoretical knowledge.

**Engagement and Career Preparedness**

A strong positive correlation (0.7274) shows that students who actively participate in hands-on learning also feel more prepared for engineering careers. However, this correlation is lower than engagement-understanding (0.9200), suggesting that while hands-on learning builds conceptual understanding, other factors (e.g., internships, industry exposure) may also influence career confidence.

**Understanding Concepts and Career Preparedness**

A moderate positive correlation (0.4314) indicates that students who better understand physics concepts tend to feel more prepared for their careers. However, this relationship is weaker compared to engagement-understanding (0.9200), suggesting that simply understanding physics is not enough rather application through hands-on experience is key to career readiness.

**T-test**

The p-value between the means of engagement and future preparedness is 0.0533. This shows the significant difference in the agreement of response.

The p-value of 0.0533 comes from a T-test comparing the means of engagement and career preparedness. In statistical hypothesis testing, a p-value below 0.05 typically indicates a statistically significant difference between two groups. The obtained p-value is very close to 0.05, meaning that there is a marginally significant difference in how students rate their engagement versus their career preparedness.

Therefore, this suggests that while engagement and career preparedness are strongly related (as shown by the correlation), there is a slight variation in how students perceive them, potentially due to differences in personal experiences or external factors influencing career confidence.

## 6.0 Conclusion

This study underscores the transformative impact of hands-on physics preparation in enhancing academic performance, engagement, and career readiness for second-year pre-engineering students at HBCU. Through the integration of experiential learning methods, students can bridge the gap between theoretical physics concepts and practical engineering applications, fostering critical skills like problem-solving, collaboration, and adaptability. The results reveal that hands-on activities not only improve conceptual understanding and academic outcomes but also boost confidence and motivation, equipping students to tackle real-world engineering challenges.

The findings emphasize the importance of designing innovative, inclusive, and resource-rich curricula tailored to the unique needs of underrepresented students in STEM. By expanding access to advanced laboratory facilities, incorporating real-world scenarios, and fostering active student engagement, institutions can better prepare their students for the demands of competitive engineering fields. This approach aligns with the broader mission of HBCUs to diversify the STEM workforce and support the success of historically marginalized populations.

By incorporating these findings into the first-year engineering curriculum, HBCUs can better prepare students for the rigorous demands of STEM fields. This proactive approach can ensure that students develop strong foundational skills, confidence in problem-solving, and an early understanding of engineering applications, ultimately increasing retention and success in engineering programs. Also, this study advocates for continued investment in experiential learning strategies and pedagogical innovations to bridge gaps in STEM education, ensuring that all students, regardless of background, are empowered to excel in their academic and professional journeys.

## References

[1] R. M. Felder and R. Brent, "Random thoughts: learning by doing," *Chemical engineering education,* vol. 37, no. 4, pp. 282-283, 2003.

[2] D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*. Pearson Education, 2015.

[3] M. Prince, "Does Active Learning Work? A Review of the Research," *Journal of Engineering Education,* vol. 93, no. 3, pp. 223-231, 2004, doi: https://doi.org/10.1002/j.2168-9830.2004.tb00809.x.

[4] N. S. Foundation, *NSF 23-563: Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)*. Directorate for STEM Education, Division of Equity for Excellence in STEM, 2023.

[5] E. Litzler, C. C. Samuelson, and J. A. Lorah, "Breaking it Down: Engineering Student STEM Confidence at the Intersection of Race/Ethnicity and Gender," *Research in Higher Education,* vol. 55, no. 8, pp. 810-832, 2014/12/01 2014, doi: 10.1007/s11162-014-9333-z.

[6] A. T. Arroyo and M. Gasman, "An HBCU-Based Educational Approach for Black College Student Success: Toward a Framework with Implications for All Institutions," *American Journal of Education,* vol. 121, no. 1, pp. 57-85, 2014, doi: 10.1086/678112.

[7] A. Byars-Winston, J. Rogers, J. Branchaw, C. Pribbenow, R. Hanke, and C. Pfund, "New Measures Assessing Predictors of Academic Persistence for Historically Underrepresented Racial/Ethnic Undergraduates in Science," *CBE—Life Sciences Education,* vol. 15, no. 3, p. ar32, 2016, doi: 10.1187/cbe.16-01-0030.

[8] E. A. Becker *et al.*, "The Effects of Practice-Based Training on Graduate Teaching Assistants' Classroom Practices," *CBE—Life Sciences Education,* vol. 16, no. 4, p. ar58, 2017, doi: 10.1187/cbe.16-05-0162.

[9] S. L. L. Heather Thiry, Anne-Barrie Hunter, "What Experiences Help Students Become Scientists?: A Comparative Study of Research and Other Sources of Personal and Professional Gains for STEM Undergraduates," *The Journal of Higher Education,* vol. 82, no. 4, pp. 357-388, 2011, doi: 10.1353/jhe.2011.0023. The Ohio State University Press.

[10] R. J. B. Matthew T. Hora, and Amanda K. Oleson, "Beyond the skills gap: How the lack of systemic supports for teaching and learning undermines employer, student, and societal interests," vol. 9, p. 9, 2016. [Online]. Available: https://files.eric.ed.gov/fulltext/ED580842.pdf.

[11] J. W. C. a. V. L. P. Clark, *Designing and Conducting MIXED METHODS RESEARCH*. Sage, 2018, p. 522.

[12] S. M. G. P. B. N. A. G. Taasoobshirazi, "Science Motivation Questionnaire II: Validation With Science Majors and Nonscience Majors," *JOURNAL OF RESEARCH IN SCIENCE TEACHING,* vol. 48, no. 10, pp. 1159–1176, 2011, doi: 10.1002/tea.20442. Wiley Periodicals, Inc.