Motivations, Challenges, and Future Aspirations of Women in Engineering at an HBCU

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Abstract

This work in progress investigates the motivations, challenges, and future aspirations of self-identified women in engineering at one of the nation's oldest Historically Black Colleges and Universities (HBCUs) - institutions that serve as vital pipelines for advancing diversity, equity, and inclusion in the STEM workforce. The study aims to inform institutional strategies that create more inclusive, supportive environments for women in engineering. Employing a mixed-methods approach, the study integrates qualitative interviews with one female faculty member and survey data from 14 undergraduate and graduate women in engineering. Interviews, guided by semi-structured questions, explored themes of mentorship, leadership, diversity, and work-life balance. Thematic analysis was used to identify key patterns. Initial findings reveal that a passion for STEM and problem-solving drives these women, with mentorship and family support acting as key motivators. Major challenges include balancing academic and personal life, limited access to leadership opportunities, and a lack of community support. Nonetheless, most participants expressed confidence in their career paths, particularly those with strong mentorship and institutional backing. By bridging qualitative and quantitative insights, this ongoing research contributes to a deeper understanding of the lived experiences of women in engineering at HBCUs. The study highlights the importance of mentorship, inclusive academic practices, and institutional support - critical themes for enhancing equity and leadership development in engineering. This work will be presented as a traditional lecture at the conference.

Keywords: Women in Engineering, HBCU, Mentorship, Diversity, Inclusion, Mixed Methods, STEM Education, Equity in STEM

Introduction

Engineering is often regarded as a cornerstone of innovation and economic progress, yet it remains a field with fewer women, particularly women of color. Historically Black Colleges and Universities (HBCUs) play a pivotal role in addressing this disparity, serving as incubators of

diversity, equity, and inclusion in STEM disciplines. These institutions have historically provided access to quality education and leadership opportunities for marginalized communities, empowering underrepresented groups to break barriers and drive progress [1], [2]. For women in engineering at HBCUs, this mission holds profound personal and professional implications. These women navigate a dual identity - pioneering as trailblazers in engineering while contending with systemic challenges tied to gender and cultural identity in predominantly male-dominated spaces. This study investigates the motivations, challenges, and future aspirations of self-identified women in engineering at one of the nation's oldest HBCUs. By examining their lived experiences, this research seeks to uncover the factors driving their pursuit of engineering, the hurdles they face, and the ambitions that fuel their perseverance. Using a mixed-method approach, the study integrates qualitative insights from in-depth interviews with faculty and students and quantitative data were collected through surveys. This comprehensive approach ensures a nuanced understanding of themes such as mentorship, work-life balance, representation, leadership aspirations, and the broader significance of diversity in engineering [3], [4]. Despite significant contributions from existing literature, research gaps remain in understanding how the intersection of race, gender, and institutional context uniquely shapes the experiences of women in engineering at HBCUs. Previous studies often focus on broader issues of gender disparity in STEM or highlight the role of HBCUs in fostering diversity, but few studies [5], [6] dig deeply into the specific challenges and aspirations of women in engineering programs within these institutions. Addressing this gap is essential to tailoring interventions and policies that reflect the unique needs and strengths of this demographic.

The findings of this work have implications that extend beyond academic inquiry. Insights gained from this research can inform institutional policies at HBCUs by highlighting the importance of mentorship, community support, and targeted interventions to enhance retention and success among women in engineering. These findings could bring about broader diversity and inclusion efforts within engineering education, contributing to a more innovative and representative workforce. By centering the voices and experiences of women in engineering at HBCUs, this research emphasizes the essential role these institutions play in shaping an equitable future in STEM.

Literature review

Women remain significantly underrepresented in engineering globally, with enrollment and graduation rates lagging behind those of men. According to the American Society for Engineering Education (ASEE), women accounted for approximately 24% of engineering bachelor's degrees awarded in 2020, with even lower representation among African American women [7]. At HBCUs, the supportive environments contribute to incremental progress in addressing this gap, yet challenges persist in bridging the disparity fully.

Motivations for women pursuing engineering are often rooted in a desire to solve real-world problems and drive societal impact. Studies highlight that women are particularly drawn to disciplines such as environmental and biomedical engineering due to their potential to create sustainable solutions [8]. Mentorship and early exposure to STEM activities are critical in fostering these aspirations, particularly within the supportive and culturally affirming contexts of HBCUs. However, the literature also reveals significant gaps in understanding how race, gender, and institutional factors converge to shape these motivations, specifically for women in HBCUs [9]. Gender biases and stereotypes pose persistent barriers for women in engineering, often undermining their technical credibility and leadership potential. African American women, in particular, experience compounded biases related to both race and gender, which can result in isolation and limited opportunities for career advancement [10], [11]. Research indicates that these barriers contribute to the underrepresentation of women in leadership roles and critical technical positions, further perpetuating the cycle of exclusion in the field [12]. While HBCUs provide a supportive environment that mitigates some of these challenges, broader systemic issues within engineering education and the workforce remain pervasive.

HBCUs have historically been at the forefront of efforts to promote diversity in STEM fields. According to the National Science Foundation (NSF), these institutions produce a disproportionately high number of Black graduates in STEM disciplines. For instance, HBCUs account for nearly 25% of all African American STEM graduates despite representing only about 3% of U.S. higher education institutions [13]. Such contributions underscore the vital role HBCUs play in fostering diversity, particularly for African American women in engineering. Studies suggest that the culturally responsive teaching methods and robust mentorship programs at HBCUs significantly enhance students' academic confidence and career preparedness [14], [15]. Despite these advancements, gaps persist in the broader representation of women in engineering. Research

often emphasizes the contributions of HBCUs to STEM diversity broadly but lacks specificity in addressing the unique challenges faced by women within these programs. There is limited understanding of how institutional factors, such as mentorship structures and community support, specifically impact the retention and success of women in engineering at HBCUs [16]. This study seeks to fill that gap by exploring the intersectional experiences of African American women in these settings, offering insights into effective strategies for fostering equity and inclusion in engineering education.

Theoretical framework

The experiences of women in engineering at HBCUs cannot be fully understood without examining how personal motivations, institutional support, and systemic barriers intersect to shape their academic and professional journeys. Challenges tied to underrepresentation, cultural identity, mentorship, representation, access to supportive learning environments, and limited pathways to leadership continue to impact how these women engage with their educational and professional spaces. This framework seeks to explore these overlapping influences, offering a deeper understanding of how personal ambition, institutional culture, and broader structural dynamics interact to shape the success and challenges faced by women in engineering at an HBCU.

Social Cognitive Career Theory (SCCT)

Social Cognitive Career Theory, developed by Lent, Brown, and Hackett, provides a foundational model for examining career development, persistence, and success in educational settings [17]. SCCT emphasizes the interaction between personal factors, environmental contexts, and behavioral patterns in shaping career choices. This theory suggests that self-efficacy beliefs, outcome expectations, and personal goals are primary determinants in career decision-making and persistence [17]. In the context of women in engineering at HBCUs, self-efficacy relates to the confidence women have in their ability to succeed in engineering tasks. Outcome expectations refer to the perceived benefits or challenges associated with persisting in the engineering field, such as leadership roles or barriers related to gender bias. Personal goals influence women's aspirations for leadership and professional growth. SCCT is relevant for this study as it allows for the exploration of how mentorship, faculty support, and role models within an HBCU setting shape the academic persistence and leadership ambitions of women in engineering.

Intersectionality Theory

Intersectionality Theory, introduced by Crenshaw, focuses on the ways multiple social identities, such as race and gender, interact to create unique experiences of marginalization [18]. This theory is particularly valuable when studying African American women in engineering because it acknowledges that these women face dual barriers related to both gender bias and racial discrimination. Intersectionality theory allows for a deeper understanding of how systemic challenges manifest differently for women of color compared to other underrepresented groups. At HBCUs, while culturally affirming spaces may reduce some biases, systemic challenges in the broader engineering profession persist. This theory informs the study by emphasizing the importance of acknowledging how race and gender intersect to impact leadership opportunities, career persistence, and support systems for women in engineering.

Critical Race Theory (CRT)

Critical Race Theory, developed by Delgado and Stefancic, emphasizes the systemic nature of racial inequality embedded in social institutions, including higher education and professional fields [19]. CRT posits that racism is endemic and deeply rooted within societal structures, often influencing policies and practices in subtle but pervasive ways. A key principle of CRT is counter-storytelling, where the lived experiences of marginalized individuals challenge dominant narratives and reveal systemic barriers [19]. This study applies CRT by centering the voices of women in engineering at an HBCU through qualitative interviews. Their narratives offer critical insights into challenges such as limited leadership representation, work-life balance struggles, and implicit bias in technical fields.

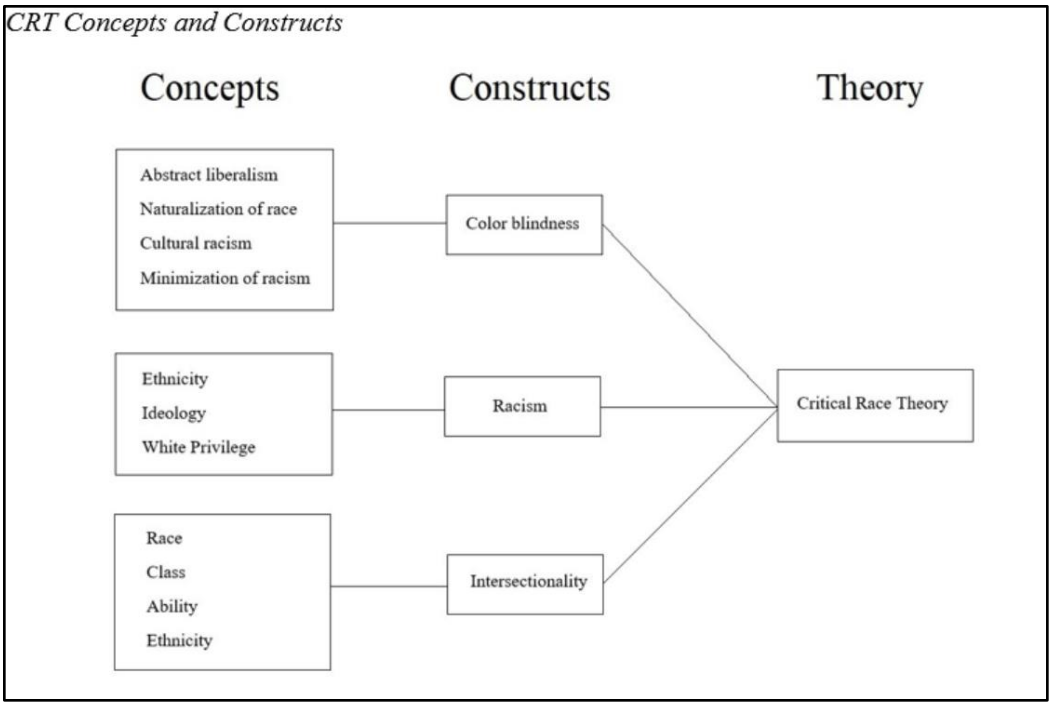

Figure 1: Critical Race Theory Image Note. Adapted from critical Race Theory: Theoretical Models for Teaching and Research by S.E. Movius n.d.

Research Questions

This study aims to investigate the unique experiences of women in engineering at an HBCU to provide actionable insights that enhance institutional practices and support systems. To enable us to achieve this, the following questions would guide our study:

1. What motivates women to pursue and persist in engineering at an HBCU?
2. What challenges do women in engineering face at an HBCU, and how do these challenges influence their academic and professional aspirations?
3. How can HBCUs better support women in engineering to foster their leadership potential and prepare them for future contributions to the field?

Methodology

Research Design

This study used a mixed-methods research design, using both qualitative and quantitative data collection strategies to explore the motivations, challenges, and future aspirations of women in engineering at a Historically Black College and University (HBCU). The mixed-methods approach

was chosen to provide a comprehensive understanding of the participants' experiences, capturing both statistical trends and personal insights. This design is particularly suited for complex social phenomena, such as career motivation and leadership barriers, where both measurable data and narrative insights are necessary for a holistic analysis [20]. A single survey instrument was used to collect data from both students and faculty participants, serving as the foundation for both the qualitative and quantitative components of the study. The survey was structured to gather quantitative data through closed-ended questions while also incorporating qualitative insights via open-ended questions, ensuring the voices of the participants were represented alongside measurable patterns [21].

The quantitative data focused on variables such as motivational drivers, perceived barriers, and career aspirations. Participants rated the importance of mentorship, support systems, and leadership opportunities on a Likert scale, with frequency distributions used to identify trends across the dataset. Meanwhile, the qualitative data, derived from open-ended questions, allowed participants to share personal reflections on their experiences in engineering education, the role of mentorship, and suggestions for institutional improvements. This combined approach offers the benefit of data triangulation, enhancing both the validity and depth of the findings by cross-referencing numerical data with personal narratives.

The survey was designed in alignment with best practices for mixed-methods research, ensuring clarity, inclusivity, and reliability. Using a self-administered format, the survey was distributed to a diverse participant pool, including undergraduate students, graduate students, and faculty, to ensure a broad range of perspectives were captured. This methodological choice provides both breadth (through the statistical representation of trends) and depth (through personal experiences), aligning with the researcher's goal of examining how personal motivations, systemic barriers, and institutional support intersect in shaping the experiences of women in engineering at an HBCU.

Data Collection Methods: Survey distribution: sampling strategy and participant demographics

This study used a structured survey instrument to collect data from both students and faculty members within the engineering department of an HBCU. A purposive sampling strategy was employed, targeting 15 participants, including undergraduate students, graduate students, and faculty, ensuring a diverse representation of experiences and perspectives [21]. The survey was

distributed electronically through institutional channels to maximize accessibility while maintaining participant confidentiality.

The survey was structured into six sections: demographics, motivation, challenges, career aspirations, support systems, and open-ended reflections, balancing quantitative data collection through closed-ended questions with qualitative insights from open-ended responses [20]. Key demographic variables included age group, academic status, engineering discipline, and year in the program, enabling comparative analysis across experience levels. The use of a survey for both faculty and student groups was chosen due to logistical challenges in arranging in-person interviews and the need for methodological consistency. This approach effectively captured both measurable patterns and personal narratives, offering a comprehensive view of the factors shaping women's experiences in engineering at an HBCU [22]

Data Analysis

Thematic analysis for qualitative data

The qualitative data collected from the open-ended survey responses were analyzed using thematic analysis to identify patterns related to motivations, challenges, and career aspirations among women in engineering at an HBCU. Following Braun and Clarke's six-phase framework [23], the process began with familiarization through repeated readings of the data, followed by the generation of initial codes to label key phrases and patterns. Broader themes were then identified, capturing the core experiences shared by participants, after which the themes were reviewed for coherence and alignment with the research objectives. The final stages involved refining and naming the themes for clarity before integrating them into the findings section, supported by participant quotes. This method was chosen for its flexibility and ability to reveal rich, narrative insights that are often overlooked in quantitative data analysis [23].

Statistical analysis for quantitative data

The quantitative data obtained from the closed-ended survey items were analyzed using descriptive statistical methods to summarize key trends in participants' responses. After cleaning the data for completeness, frequency distributions and percentages were calculated to identify patterns related to motivational drivers, challenges, and career aspirations among women in engineering at an

HBCU. Key variables included the frequency of responses related to mentorship, passion for STEM, career advancement, gender bias, work-life balance, and mentorship access.

Likert scale responses were analyzed using mean scores and standard deviations to assess the perceived severity of challenges and the importance of motivational factors. This statistical approach provided insights into both central tendencies and variability, offering a clearer understanding of the patterns influencing participants' educational and professional experiences [20].

Integration of Qualitative and Quantitative Data

The findings from both qualitative and quantitative analyses were integrated during the interpretation phase to provide a more comprehensive understanding of the research questions. The qualitative insights from the thematic analysis were used to explain patterns observed in the quantitative trends, ensuring a richer contextual understanding of the participants' experiences [24].

Ethical Considerations

Participant consent and anonymity

Before data collection, all participants were provided with a detailed informed consent form explaining the study's purpose, procedures, and potential risks. The consent form clearly outlined participants' voluntary involvement and the right to withdraw from the study at any point without consequences. Participants were also informed that their responses would be used exclusively for research purposes and would not affect their academic or professional standing. To ensure anonymity, no personally identifiable information was collected, and all data were reported in aggregate form. Where necessary, any direct quotes used in the qualitative findings were anonymized to prevent traceability to specific individuals.

Data security

Robust measures were taken to ensure the confidentiality and security of all collected data. Survey responses were stored on a password-protected electronic database, with access limited strictly to the primary researcher. All data files were encrypted, and no data were shared with third parties.

Physical copies of consent forms were securely stored in a locked filing cabinet accessible only to the research team. Upon completion of the study, data will be retained for five years as recommended by institutional research policies, after which it will be securely deleted and destroyed. These measures align with best practices in research ethics, emphasizing participant safety and data integrity [25].

Results

The primary motivators for women pursuing engineering include a passion for STEM and a desire to solve real-world problems. Financial incentives, such as high earning potential, were also notable motivators but less common. Family members emerged as the most significant influencers, providing encouragement and support, followed closely by teachers and professors who played a pivotal role in inspiring interest in engineering. These findings align with existing literature that highlights the role of mentorship and early exposure to STEM activities in fostering interest among women in engineering [9] [10]**.** When rating factors that sustain motivation, most respondents highlighted faculty and mentor support as "Very Important," with collaborative opportunities with peers also receiving high importance ratings. However, balancing academic and personal life was identified as the most severe challenge, with the majority rating it as significant or severe. This finding is consistent with prior studies that indicate work-life balance remains a key concern for women in engineering [12]**.** Other challenges, such as limited access to leadership and research opportunities, were generally perceived as less critical, though still notable.

Long-term career aspirations varied, with most respondents aiming for leadership or management roles, while others expressed interest in academia, entrepreneurship, or technical specialization. Confidence levels in achieving these aspirations were high overall, particularly among those who emphasized the importance of strong mentorship and institutional support. The role of institutional mentorship in fostering leadership aspirations aligns with research on the impact of HBCUs in STEM education, where structured mentorship programs have been found to enhance students' professional development [14].

Qualitative Insights

Open-ended responses revealed that mentorship programs, peer networks, and access to financial resources were considered essential support systems for achieving career goals. Participants also

highlighted the need for technical and power skills development, particularly in leadership and communication. Respondents suggested several improvements to better support women in engineering at their HBCU. These included increasing female faculty representation, establishing dedicated communities for women in engineering, and enhancing funding opportunities for research and entrepreneurial activities. Positive experiences often involved hands-on research projects and supportive mentorship, while negative experiences were linked to limited access to resources and difficulties finding supportive communities.

Correlation of Variables

The correlation of variables showed that participants motivated by STEM passion or problem-solving exhibited higher confidence in achieving their career aspirations compared to those primarily motivated by financial incentives. Those who rated faculty and mentor support as "Very Important" were more likely to report positive experiences and clearer career goals. Conversely, severe challenges, particularly in balancing academic and personal life, were associated with lower confidence levels. The availability of scholarships and mentorship programs positively influenced confidence and reduced perceived barriers to success.

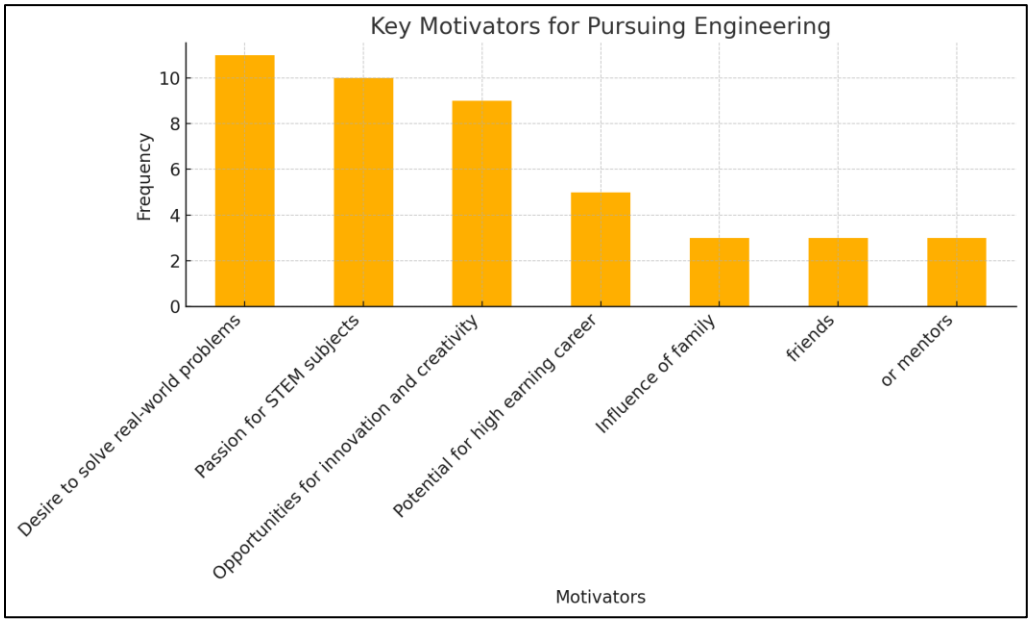

Figure 2: Key Motivators for Pursuing Engineering

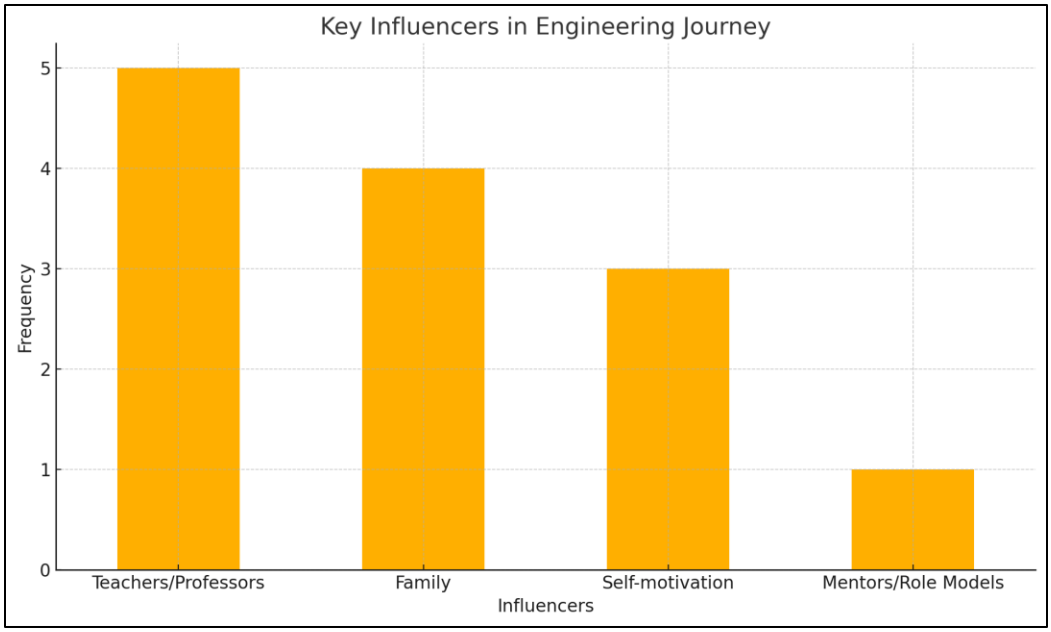

Figure 3: Influencers in Engineering

Discussion

Women in engineering are primarily motivated by a passion for STEM and solving real-world problems, with financial incentives being less influential. This highlights the importance of fostering early exposure to STEM and showcasing its societal impact. The most significant challenge is balancing academic and personal life, followed by limited access to leadership and research opportunities and difficulty finding supportive communities. These barriers highlight the need for improved institutional support. HBCUs can enhance mentorship programs, create peer networks, and increase leadership training opportunities to support women in engineering. Promoting female faculty representation and offering platforms for leadership roles are crucial steps. The findings emphasize the need for inclusive environments in engineering education and industry. Partnerships, policy advocacy, and diversity-focused initiatives are essential for fostering gender equity and increasing women's participation in engineering.

The experiences of women engaged in engineering disciplines at Historically Black Colleges and Universities (HBCUs) exhibit certain limitations. A survey was distributed to a random sample of 15 female undergraduate and graduate engineering students, and one notable limitation pertains to the sample size, which delays the generalizability of the findings to broader populations of women in engineering at various other institutions. Expanding recruiting efforts to include several HBCUs

or a larger, nationally representative demographic could be beneficial for future research, as mixed-methods studies sometimes face trade-offs between diversity [20]. Moreover, the exclusive emphasis on a single institution limits the comprehension of how institutional culture may vary between HBCUs and predominantly white institutions. Performing comparative examinations in a variety of institutional contexts, including those that serve minorities and predominantly white institutions, might uncover both shared and specific issues confronted by these sectors. Leath et al [3] discovers that future research endeavors should prioritize collaborative efforts across multiple institutions to compare structural supports and obstacles encountered by HBCUs, Predominantly White Institutions (PWIs), and minority-serving institutions (MSIs), particularly in relation to mentorship models and diversity policies [3]. Intersectional frameworks ought to be broadened to incorporate underrepresented identities beyond the dimensions of race and gender, including considerations of neurodiversity and immigration status, to effectively address existing gaps in institutional support [19]. In addition, global comparative studies could reveal how cultural norms and educational policies impact women's participation in engineering across the globe, thereby providing valuable insights for U.S. institutions [14]. The influence of technology, particularly in light of post-pandemic transitions to remote learning and virtual mentorship, merits investigation in order to optimize hybrid educational environments for equitable outcomes [10]. Lastly, partnerships with industry should be subjected to study to evaluate how internships, cooperative education programs, and corporate diversity initiatives serve to bridge the gap between academic training and career success [12]. Addressing these identified gaps will further advance initiatives aimed at creating inclusive ecosystems that empower women in the field of engineering.

Conclusion

This study sheds light on the experiences of women pursuing engineering at an HBCU, uncovering both their motivations and the barriers they face. A deep passion for STEM and the desire to tackle real-world challenges emerged as key drivers for these women, with family and educators playing a crucial role in sparking and sustaining their interest in the field. These findings emphasize the importance of early exposure to STEM and the value of strong mentorship in shaping future engineers.

However, the journey is not without hurdles. Balancing academic responsibilities with personal life remains a significant challenge for many, alongside difficulties in accessing leadership

opportunities and finding supportive peer communities. The findings of this study confirm previous research, which has identified work-life balance and mentorship accessibility as primary concerns for women in STEM fields [12][13]. Despite these obstacles, the women in this study displayed remarkable resilience and confidence in pursuing their career aspirations, driven in part by mentorship and institutional support. The findings point to actionable opportunities for HBCUs to better support women in engineering. Expanding mentorship programs, increasing access to leadership roles, and cultivating inclusive peer networks are critical steps to creating an environment where women can thrive. Beyond HBCUs, these insights call for broader efforts to make engineering a more inclusive and supportive field, aligning with national diversity initiatives aimed at improving retention and success rates among underrepresented groups in STEM. By addressing these challenges and amplifying the factors that motivate and sustain women in engineering, we can not only enhance their experiences but also contribute to a more diverse and innovative engineering workforce.

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