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Enhancing Self-Efficacy of Female Engineering Students: A Case Study at ULK Polytechnic Institute, Rwanda

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Abstract: *The study aimed to contribute to the existing body of knowledge on self-efficacy enhancement strategies while providing practical insights. Employing a structured qualitative survey, the research explored the experiences, perceptions, and challenges encountered by female engineering students at ULK Polytechnic Institute in their academic journey, with a particular focus on self-efficacy beliefs. The sample comprised 22 first-year students chosen for their willingness to engage in interventions aimed at improving self-efficacy, ensuring a varied representation of academic performance and backgrounds. Through comprehensive data collection and analysis, the study showed a range of self-efficacy perceptions among participants, highlighting the influence of individual experiences and support networks on confidence levels. Importantly, interactions with faculty, peers, and mentors emerged as pivotal factors influencing students' confidence in their engineering abilities. Recommendations included the implementation of mentorship programs, raising inclusive learning environments, and organizing workshops to strengthen confidence and resilience among female engineering students. The study further emphasized the significant contribution of practical learning experiences to enhancing self-efficacy levels in engineering education.*

Keywords: *Academic achievement, Female engineering students, Self-efficacy, Student motivation, ULK Polytechnic Institute.*

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1. Introduction

In the modern education, adopting self-efficacy among engineering students, particularly females, has emerged as a critical focus area for academic institutions globally (Lourens, 2014). Self-efficacy, as conceptualized by Albert Bandura, refers to an individual's belief in their ability to succeed in specific situations or accomplish a task. Recognizing the importance of self-efficacy in academic achievement and professional development, this study investigated into the enhancement of self-efficacy among female engineering students at ULK Polytechnic Institute. Through a case study approach, this research aimed to explore the influences persuading self-efficacy levels among female engineering students and propose effective strategies for enhancement.

The field of engineering has historically been male dominated, with women significantly underrepresented in various engineering disciplines (Baird, 2018; Verdín, Godwin, Kirn, Benson, & Potvin, 2018; Jung & Kim, 2020). Despite efforts to promote gender diversity in STEM (Science, Technology, Engineering, and Mathematics), disparities persist, particularly in engineering education (Niyibizi & Mutarutinya, 2023; Bibakumana & Niyibizi, 2024). Research indicated that female engineering students often experience lower levels of self-efficacy compared to their male counterparts, which impacted their academic performance, persistence, and career aspirations (Verdín et al., 2018). Understanding the underlying factors contributing to this disparity was crucial for encouragement an inclusive and supportive learning environment that empowers female engineering students to succeed.

The underrepresentation of women in engineering and the lower levels of self-efficacy among female engineering students pose significant challenges to the field of engineering education and workforce multiplicity (Jung & Kim, 2020). Despite numerous initiatives aimed at promoting gender equity and inclusion in STEM fields, the persistent gender gap in engineering enrollment and retention rates underscores the need for targeted interventions (Jean, Payne, & Thompson, 2015; Cowgill, Halper, Rios, & Crane, 2021; Kuchynka, Eaton, & Rivera, 2022; Bibakumana & Niyibizi, 2024). The problem of this study concentrated around the identification of barriers delaying the development of self-efficacy among female engineering students at ULK Polytechnic Institute and the exploration of potential solutions to address these challenges effectively.

The motivation behind this research stems from the imperative to create a more equitable and inclusive learning environment that empowers female engineering students to realize their full potential. By enhancing the self-efficacy levels of these students, academic institutions stand-in a culture of confidence, resilience, and academic excellence within the engineering community. Moreover, promoting gender diversity in engineering education not only enriches the learning experience but also contributes to innovation and problem-solving in the field (Niyibizi & Mutarutinya, 2024). This study pursued to contribute to the existing body of knowledge on self-efficacy enhancement strategies while offering practical insights and recommendations personalized to the unique context of ULK Polytechnic Institute and its female engineering student population. Ultimately, the goal was to inspire positive change and empower female engineers to thrive in academia and beyond.

2. Related literature

The study underscored the importance of addressing the gender gap in STEM entrepreneurship through targeted education and mentorship initiatives. By focusing on women engineering and computer science students, the program not only provided classroom instruction but also offered experiential learning and peer support, recognizing the multifaceted challenges faced by women in pursuing entrepreneurial endeavors. Through qualitative analysis of student peer mentors' experiences, the research revealed significant enhancements in entrepreneurial self-efficacy (ESE) and entrepreneurial intent (EI), accompanied by heightened awareness of diversity and gender issues (Niyibizi, et al., 2024). Moreover, the findings indicated a fundamental shift in problem-solving approaches and perspectives on life among the mentors. While the mentors expressed a keen interest in entrepreneurship, the study emphasized that their aspirations might not manifest immediately after graduation, highlighting the complex interplay of personal and professional development in the entrepreneurial journey of women in STEM fields (Elliott, Mavriplis, & Anis, 2020).

Creativity within engineering has been described as crucial to the field, and as an aspect that is appealing to women engineers. Undergraduate women engineering students local to the Philadelphia area volunteered to take a survey of CSE and beliefs about creativity. Quantitative data analysis showed that an increase in GCM likely results in an increase in CSE for students with higher-than-average GPA. A change in CSE had no effect on FCM. Interviews were conducted with 15 survey respondents with different levels of CSE who met criteria for success in the engineering major (2.5 GPA or above and successful completion of calculus II). Synthesis of the quantitative and qualitative data revealed that interview participants had similar lived experiences that lead them to a level of success in the engineering major, but different lived experiences that distinguished them with respect to CSE level. Participants with all levels of CSE highlighted their own creativity with respect to the performing and visual arts, before reflecting on innovation as creative. Most participants with low CSE described their lack of creativity in the arts. They also discussed being “intimidated” by negative classroom experiences more than their peers with higher levels of CSE. Those with low CSE were also exposed to more engineering centered experiences in high school, and most had a parent who worked in the profession. It is expected that this research will provide a more comprehensive understanding of CSE, perceptions of engineering as a creative field, and the educational reform needed that connects creativity to engineering in an atmosphere that welcomes diversity (Delahanty & Silverman, 2021).

In a comprehensive study, a cohort of Swedish first-year engineering students (N=88) underwent scrutiny regarding their motivation, self-efficacy, and perceptions regarding the nature of mathematics, alongside an exploration into how these factors interplayed with their task performance in mathematics. The findings revealed a significant correlation between students who prioritized precise reasoning in their conceptualization of mathematics and their superior performance across a series of mathematical tasks compared to those who emphasized mathematical applications. Moreover, heightened levels of self-efficacy, as well as intrinsic and utility values attributed to mathematics, were associated with enhanced task performance. Despite pronounced levels of self-efficacy and motivational values, the overall task performance of students remained notably moderate, signaling potential gaps between perceived capabilities and actual achievements in mathematical tasks (Tossavainen, Rensaa, & Johansson, 2021).

The study investigated the issue within the broader context of understanding what motivates women to pursue engineering education. Specifically, the study aimed to determine whether respondents showed different levels of achievement on self-efficacy measures.

3. Methodology

3.1. Research approach

The research approach for enhancing self-efficacy among female engineering students at ULK Polytechnic Institute entails a qualitative design. A structured qualitative survey employed to explore the experiences, perceptions, and challenges faced by female engineering students in their academic journey, particularly regarding self-efficacy beliefs. Additionally, a case study approach was utilized to provide a deep understanding of the specific context at ULK Polytechnic Institute, allowing for the exploration of unique institutional dynamics and interventions that impacted self-efficacy among female engineering students.

3.2. Participants

Participants were chosen based on their willingness to engage in the intervention aimed at improving self-efficacy. The sample included 22 students with first year (level one) of academic performance and backgrounds to ensure a comprehensive understanding of the efficacy of the intervention across different profiles. Through this diverse participant pool, the study aimed to capture insights into the challenges and successes encountered by female engineering students in their pursuit of academic and professional excellence, thereby informing effective strategies for enhancing self-efficacy within this demographic.

3.3. Data collection and analysis

Qualitative research method, particularly survey was employed to collect and analyze data. Structured survey was conducted with female engineering students at ULK Polytechnic Institute to explore their experiences, challenges, and perceptions regarding self-efficacy in engineering education. It focused on probing participants' beliefs about their capabilities to perform engineering tasks, their confidence levels, and the factors influencing their self-efficacy beliefs. Through thematic analysis, recurring patterns, themes, and insights emerged from the survey, shedding light on the specific strategies, interventions, and support mechanisms that effectively enhanced self-efficacy among female engineering students. Additionally, the qualitative approach facilitated a deeper understanding of the experiences and perspectives of participants, allowing for a comprehensive exploration of the topic within the context of ULK Polytechnic Institute.

3.4. Validity and reliability

In the context of the qualitative survey conducted to explore the effectiveness of strategies aimed at enhancing self-efficacy among female engineering students at ULK Polytechnic Institute, ensuring validity and reliability were paramount. Validity was crucial to confirm that the study accurately measured what it was intended to assess, ensuring that the findings truly reflected the experiences and perceptions of the participants regarding self-efficacy enhancement. This involved using appropriate research instruments and methodologies aligned with the study's objective. In order to assess validity, the researcher sent the survey to an expert for removal of items unrelated to the research topic. The updated survey was then sent to participants. Reliability, on the other hand, expressed to the consistency and replicability of the study's results. To enhance reliability, rigorous data collection and analysis methods were employed, and steps were taken to minimize bias and subjectivity. To assess reliability, the researcher sent a survey to study participants who weren't involved in the research to make sure the instrument measured all that it was intended to. Establishing the validity and reliability of the qualitative survey were integral to the credibility and trustworthiness of the study's findings, providing a robust foundation for drawing meaningful conclusions and implications for improving self-efficacy among female engineering students.

3.5. Ethical consideration

Ethical considerations played a pivotal role in ensuring the well-being and rights of participants. Respecting the principles of informed consent, confidentiality, and voluntary participation were paramount to uphold the ethical standards of the study. Researcher provided clear and comprehensive information about the purpose, procedures, and potential risks and benefits of the study to participants. Additionally, safeguards were implemented to protect the anonymity and privacy of participants, especially when discussing personal experiences and perceptions.

4. Results and Discussion

All twenty-two of the participating students were female and enrolled in the first year of an engineering degree, named (S01-22). Their responses were analyzed thematically across different themes to identify common patterns and unique insights. The themes explored included their motivations for choosing engineering, the challenges they faced in their studies, their perceptions of gender roles in engineering, and their career aspirations. This thematic analysis aimed to provide a comprehensive understanding

of the students' experiences and perspectives, shedding light on the factors that influence female students in engineering programs.

4.1 Theme 1: Perceptions of Self-Efficacy

The perceptions of self-efficacy among the interviewed students varied widely. While some expressed high confidence in their ability to succeed in their engineering studies, others reported lower levels of confidence, particularly in challenging subjects or when facing unfamiliar tasks. This discrepancy suggested that individual experiences and past successes play a significant role in shaping students' perceptions of their self-efficacy in engineering. As one respondent reported:

> *I am certain that I have the skills and determination to excel in my engineering studies (S18).*

The study revealed a considerable variation in the self-efficacy perceptions among the interviewed engineering students. Those with high self-efficacy typically reported strong confidence in their ability to excel in their engineering studies. These students often linked their confidence to prior successes and positive experiences in related subjects, suggesting that a history of accomplishments significantly boosts one's belief in their own capabilities. They felt well-prepared to tackle complex problems and were more likely to engage actively in their studies, approaching challenges as opportunities to demonstrate and enhance their skills. This positive outlook is crucial for maintaining motivation and persistence in a demanding field like engineering.

Conversely, students who reported lower self-efficacy often cited struggles with particularly challenging subjects or the anxiety of dealing with unfamiliar tasks. This group tended to focus on past difficulties and perceived failures, which negatively impacted their confidence levels. The disparity in self-efficacy among students highlights the importance of providing support mechanisms, such as mentorship, tutoring, and positive feedback, to help all students build confidence in their abilities. It also underscores the need for educational strategies that consider individual differences in past experiences and self-perception, aiming to create an inclusive learning environment that fosters resilience and self-belief among all engineering students.

4.2 Theme 2: Source of Self-Efficacy

Interactions with faculty members, peers, and mentors emerged as crucial factors influencing students' confidence in their engineering abilities. Positive feedback, encouragement, and mentorship from these sources were cited as enhancing self-efficacy, whereas negative experiences or lack of support could undermine confidence levels. Peer collaboration and group study sessions were also highlighted as valuable in building confidence and sharing knowledge. One respondent highlighted that:

> *Interactions with professors, colleagues, and mentors profoundly shape a student's belief in their engineering aptitude (S07).*

The findings underscore the pivotal role of social interactions within the academic ecosystem in shaping students' self-perceptions and confidence in their engineering prowess. The significance of faculty members, peers, and mentors cannot be overstated, as they serve as both guides and motivators in students' academic journeys. Encouraging feedback and mentorship from these figures act as catalysts for bolstering self-efficacy, empowering students to tackle challenges with greater assurance. Conversely, the absence of constructive support or encountering negative experiences can erode students' confidence, impeding their progress and stifling their potential. This highlights the need for a nurturing and supportive environment within educational institutions, where students feel valued, supported, and empowered to thrive.

Moreover, the collaborative nature of peer interactions emerges as a cornerstone in the development of engineering students' confidence and competence. Through group study sessions and collaborative projects, students not only deepen their understanding of complex concepts but also cultivate a sense of camaraderie and shared learning. These interactions provide opportunities for knowledge exchange, skill refinement, and mutual encouragement, fostering a sense of collective achievement. By engaging in collaborative endeavors, students not only enhance their confidence in their own abilities but also contribute to the cultivation of a supportive and collaborative learning culture within the engineering community, laying the groundwork for future success and innovation.

4.3 Theme 3: Challenges to Self-Efficacy

Several challenges and obstacles were identified by the interviewed students that impact their confidence in their engineering abilities. These challenges included academic pressure, fear of failure, imposter syndrome, and a lack of representation and recognition, particularly for female engineering students. Additionally, difficulties in balancing academic workload with personal commitments and extracurricular activities were commonly reported as challenges. One respondent said that:

> *The weight of expectations presses down: academic pressure, fear of failure, and the constant suggestion of cheat condition (S13).*

The results of the interviews highlight a range of challenges faced by students in the engineering field, which significantly affect their confidence levels. Academic pressure emerges as a major concern, with students grappling with high expectations and demanding coursework. This pressure is often exacerbated by the fear of failure, which was paralyzing in a field where precision and accuracy are paramount. Moreover, imposter condition, a phenomenon where individuals doubt their accomplishments and fear being exposed as frauds despite evidence of their competence, was found to be prevalent among the students.

Furthermore, the lack of representation and recognition, especially for female engineering students, emerged as a key issue impacting confidence. Female students often face gender stereotypes and biases that can undermine their belief in their abilities and their sense of belonging in the field. Balancing academic workload with personal commitments and extracurricular activities was also highlighted as a significant challenge, suggesting that the demands of the engineering curriculum can sometimes be overwhelming, leading to a sense of inadequacy and reduced confidence among students.

4.4 Theme 4: Support Systems and Resources

The effectiveness of existing support services and resources provided by ULK Polytechnic Institute in enhancing self-efficacy varied among the interviewed students. While some students praised the availability of tutoring services, academic advisors, and career counseling, others expressed dissatisfaction with the accessibility and effectiveness of these resources, particularly in addressing gender-specific issues and concerns. One respondent reported:

> *I enthusiastically commend the institution for its commitment to student success. The availability of tutoring services, academic advisors, and career counseling has been a game-changer for me (S02).*

The results indicate a mixed perception among students regarding the support services and resources offered by ULK Polytechnic Institute in enhancing self-efficacy. While a subset of students appreciated the availability of tutoring services, academic advisors, and career counseling, others expressed dissatisfaction with the accessibility and effectiveness of these resources. Specifically, some students felt that these services were lacking in addressing gender-specific issues and concerns, highlighting a potential gap in the support system provided by the institute. This disparity in experiences suggests that while ULK Polytechnic Institute offers a range of support services, there is room for improvement in adapting these resources to meet the diverse needs of all students, including addressing gender-specific challenges that may impact self-efficacy.

Additionally, the varying perspectives on the effectiveness of support services at ULK Polytechnic Institute underscore the importance of a holistic approach to student support. While some students may find certain resources beneficial, others may not feel adequately supported. This highlights the need for the institute to continually assess and improve its support services, ensuring they are accessible, effective, and responsive to the diverse needs of its student body. By addressing these concerns and implementing targeted interventions, ULK Polytechnic Institute can enhance its support system, ultimately fostering a more inclusive and supportive environment conducive to improving student self-efficacy.

4.5 Theme 5: Perceptions of Gender Dynamics

Many female engineering students perceived gender-related barriers or biases within the engineering field that may impact their self-efficacy. Instances of implicit bias, stereotype threat, and unequal opportunities for leadership and recognition were reported, contributing to feelings of self-doubt and imposter syndrome among female students. The need for greater awareness and proactive measures to address gender disparities was emphasized by several interviewees. One respondent outlined:

> *It's time to recognize the urgency of addressing gender disparities and take proactive steps toward real change (S20).*

The results indicate a concerning trend among female engineering students, highlighting their perception of gender-related barriers and biases within the field. These findings underscore the existence of implicit bias, stereotype threat, and disparities in leadership and recognition, all of which can significantly impact the self-efficacy of female students. The reported experiences contribute to feelings of self-doubt and imposter syndrome, which could potentially hinder their academic and professional advancement in engineering. It is evident from the interviews that there is a pressing need for greater awareness and proactive measures to address these gender disparities and create a more inclusive environment within the engineering discipline.

Moreover, the results suggest that the experiences of female engineering students are indicative of broader systemic issues within the field. The reported instances of

bias and unequal opportunities are reflective of deeper-rooted challenges that need to be addressed at institutional and societal levels. The emphasis on the need for greater awareness and proactive measures underscores the urgency of implementing strategies to promote gender equity in engineering. This requires not only addressing overt discrimination but also actively working to counter implicit bias and create a more inclusive culture that supports the advancement of all individuals, regardless of gender.

4.6 Theme 6: Strategies for Enhancing Self-Efficacy

To better support female engineering students in enhancing their self-efficacy, several strategies were proposed by the interviewed students. These included implementing mentorship programs, creating inclusive learning environments, organizing workshops and seminars on confidence-building and resilience, and promoting female role models and success stories in engineering. Additionally, providing opportunities for hands-on experience and practical application of skills was identified as beneficial in boosting confidence levels. One respondent voiced that:

> *Mentorship, inclusive environments, and hands-on opportunities are key to cultivating confidence and success in engineering (S06).*

The findings from the interviews with female engineering students underscore the critical need for proactive measures to bolster their self-efficacy within academic and professional contexts. The suggested strategies, such as mentorship programs and inclusive learning environments, align with existing research highlighting the importance of supportive networks and environments in fostering confidence and resilience among underrepresented groups in STEM fields. By implementing mentorship programs, institutions can facilitate meaningful connections between students and experienced professionals who can offer guidance, support, and encouragement tailored to the unique challenges faced by female engineering students. Furthermore, workshops and seminars focusing on confidence-building and resilience can equip students with practical strategies and resources to navigate obstacles and setbacks effectively, thus empowering them to persist and thrive in their academic and professional pursuits.

Moreover, the emphasis on promoting female role models and success stories in engineering serves as a powerful means of challenging stereotypes and inspiring confidence among aspiring engineers. By highlighting the achievements and contributions of women in the field, institutions can counteract the pervasive gender biases that may undermine the self-efficacy of female engineering students. Additionally, providing opportunities for hands-on experience and practical application of skills not only enhances technical proficiency but also cultivates a sense of competence and mastery, thereby reinforcing students' confidence in their abilities. Through a multifaceted approach encompassing mentorship, inclusive learning environments, confidence-building initiatives, and exposure to diverse role models and experiences, institutions can effectively support female engineering students in developing the self-efficacy needed to excel in their academic and professional endeavors.

4.7 Theme 7: Long-Term Goals and Aspirations

As students progress through their engineering studies and enter the workforce, their self-efficacy is expected to evolve in response to new challenges and experiences. Many students expressed optimism about their future prospects and aspirations within the engineering field, highlighting the importance of continued support and professional development opportunities to maintain and enhance their confidence levels. However, concerns about gender bias and workplace discrimination remain prevalent, underscoring the need for ongoing efforts to promote inclusivity and equity in the engineering profession. As one respondent highlighted:

> *As an aspiring engineer, my optimism for the future is boundless. I believe in the transformative power of engineering to solve complex problems and improve lives. Continued support and access to professional development opportunities are the cornerstones of our success (S20).*

The findings from the interviews with female engineering students underscore the critical need for proactive measures to bolster their self-efficacy within academic and professional contexts. The suggested strategies, such as mentorship programs and inclusive learning environments, align with existing research highlighting the importance of supportive networks and environments in fostering confidence and resilience among underrepresented groups in STEM fields. By implementing mentorship programs, institutions can facilitate meaningful connections between students and experienced professionals who can offer guidance, support, and encouragement tailored to the unique challenges faced by female engineering students. Furthermore, workshops and seminars focusing on confidence-building and resilience can equip students with practical strategies and resources to navigate obstacles and setbacks effectively, thus empowering them to persist and thrive in their academic and professional pursuits.

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institutions can counteract the pervasive gender biases that may undermine the self-efficacy of female engineering students. Additionally, providing opportunities for hands-on experience and practical application of skills not only enhances technical proficiency but also cultivates a sense of competence and mastery, thereby reinforcing students' confidence in their abilities. Through a multifaceted approach encompassing mentorship, inclusive learning environments, confidence-building initiatives, and exposure to diverse role models and experiences, institutions can effectively support female engineering students in developing the self-efficacy needed to excel in their academic and professional endeavors.

The present results are in line with Verdín et al. (2018), who found that female engineering students often experience self-efficacy challenges, which impacted their academic performance, persistence, and career aspirations. This alignment suggests that the self-perceptions and confidence levels of female engineering students continue to play a crucial role in their academic journey. They highlighted the importance of fostering a supportive environment that enhances self-efficacy to improve educational outcomes and long-term career success for these students. Our findings underscore the ongoing relevance of these factors, indicating that targeted interventions to boost self-efficacy could be beneficial in engineering education.

Additionally, the present results are consistent with those of Delahanty and Silverman (2021), who discovered that students with low Computer Science Self-Efficacy (CSE) often had more high school experiences focused on engineering and that many had a parent in the field. This connection suggests that early exposure to engineering, combined with familial influence, can shape students' self-efficacy and interest in the discipline. Delahanty and Silverman also provided a thorough explanation of CSE and emphasized the need for educational reform that integrates engineering and creativity in a welcoming environment. Our findings support their call for a reimagined educational approach that nurtures creativity alongside technical skills to enhance student engagement and success.

Moreover, the present results are in line with Tossavainen, Rensaa, and Johansson (2021), who found that the performance of students in mathematical tasks remained notably moderate. This trend signals potential gaps between students' perceived capabilities and their actual achievements. The moderate performance observed by Tossavainen et al. suggests that students may overestimate their mathematical abilities, which can impact their performance in engineering courses that heavily rely on math skills. Our findings highlight the need for more accurate self-assessment tools and supportive measures to help students bridge the gap between their perceptions and actual performance.

These consistent findings across multiple studies indicated a complex interplay between self-efficacy, early educational experiences, familial influences, and actual performance in engineering education. Addressing these factors holistically can create a more supportive and effective learning environment for engineering students. Educational institutions should consider implementing comprehensive support systems that address self-efficacy issues, provide early and diverse engineering experiences, and facilitate accurate self-assessment to improve student outcomes.

Therefore, the present results reinforce the importance of self-efficacy, early exposure to engineering, and accurate self-assessment in shaping the academic performance and persistence of engineering students. By drawing on the insights from Verdín et al. (2018), Delahanty and Silverman (2021), and Tossavainen et al. (2021), educational reform efforts can be better informed to create an inclusive and supportive environment that enhances both the confidence and capabilities of engineering students. This holistic approach can help bridge the gap between perceived and actual achievements, ultimately leading to more successful and fulfilled engineering graduates.

5. Conclusion and recommendations

5.1 Conclusion

In conclusion, the study indicated a various range of self-efficacy perceptions among first-year female engineering students at ULK Polytechnic Institute, indicating the influence of individual experiences and support systems on confidence levels. Interactions with faculty, peers, and mentors play pivotal roles in shaping students' confidence in their engineering abilities.

5.2 Recommendations

This study recommends the following: implementing mentorship programs, encouragement inclusive learning environments, and organizing workshops to strengthen confidence and resilience among female engineering students. Additionally, providing practical learning experiences significantly contributes to enhancing self-efficacy levels among students pursuing engineering degrees.

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