Mind the Gap: How Internal Beliefs Shape Gender Disparities in Nigerian Engineering Labs

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Abstract

Gender equity in engineering education remains a global concern, with issues of self-efficacy and engagement often contributing to women's underrepresentation. However, limited evidence exists from African higher education contexts. This study explored gender disparities in engineering students' confidence and engagement with practical work in a Nigerian polytechnic. A cross-sectional survey of 338 students (274 male, 64 female) from four engineering departments was conducted using a validated 30-item scale (α = 0.931). Independent-samples t-tests and effect-size analyses revealed significant gender differences in self-efficacy and engagement. Female students reported lower confidence and reduced engagement with practical tasks. Statistical power (0.71) confirmed sufficient sensitivity to detect a medium effect. No significant gender differences emerged in perceptions of instructor quality, resource adequacy, or the learning environment, indicating that disparities are concentrated in personal efficacy beliefs rather than external conditions. These findings highlight a critical challenge in Nigerian engineering education: female students' lower self-confidence in practical learning. Addressing this gap through targeted interventions can help strengthen female participation and foster more inclusive laboratory environments.

Keywords: *gender equity, engineering education, self-efficacy, practical work, inclusive education, STEM participation*

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1. Introduction

Gender equity in engineering education is one of the most enduring issues in the global engineering community, whose effects extend beyond institutions of learning into workforce diversity and innovation (Yamani and Almazroa, 2024). Even with decades of intervention efforts, very few women are ever represented in the engineering sector worldwide. Recently released meta-analytic data

confirm that gender equality targets can be undone by feminist interventions in STEM education (Yu et al., 2024): the controlled results show a small but significant positive impact of such activities (Hedges g = 0.434). The Nigerian case study is a critical one in terms of formulating how gender functions within the African engineering education. Nigeria is the second-largest economy and most populous country in Africa, so its engineering education system must serve a wide population and address gender equity issues. The realisation of gender inequalities in this setting offers valuable insights into efforts to improve education in similar developing areas, as girls are quite underrepresented in STEM fields in sub-Saharan Africa, with an average participation rate as low as 21 per cent (Ntombela et al., 2025; Ojong and Kareem, 2025).

Self-efficacy theory provides an effective explanation of the relationship between beliefs about capability, motivation, behaviour, and achievement (Bandura, 1997). Through mastery experiences, vicarious experiences, verbal persuasion, and physiological states, Bandura's theory explains how self-efficacy beliefs affect the choice of activities, efforts, perseverance, and eventual accomplishment as they develop. Gender differences in self-efficacy beliefs have been substantial across many areas of life, with female students often showing less confidence than their male counterparts even when they achieve the same level of performance (Chan, 2022). The practical aspect of engineering education is a realm of study that can be considered one of the most crucial in addressing gender inequality. Experiences in laboratories allow the acquisition of theoretical expertise and technical skills, as well as the development of confidence (Hofstein & Lunetta, 2004). Nonetheless, such experiences can also contribute to gender inequality if they are not thoughtfully designed with inclusive practices (Yu et al., 2024).

The research will contribute to the literature by examining gender differences in self-efficacy and the capacity to engage in practical work among engineering students in the Nigerian context. The study bridges a substantial literature gap by providing empirical data on a highly underrepresented culture, thereby making a major contribution to the study of engineering education, where more inclusive experiences can be developed.

The specific objectives of this study are to:

i) Examine gender differences in engineering students' self-efficacy and engagement with practical work.
ii) Identify the areas in which gender disparities are most pronounced.
ii) Assess the practical significance of observed differences through comprehensive effect size analysis.

ii) Provide evidence-based recommendations for creating more inclusive laboratory learning environments in Nigerian engineering education.

2. Literature Review

A comprehensive analysis of global trends in gender inequality in higher education found that despite progress in some areas, significant disparities persist in STEM fields, with the gender gap estimated to take over 100 years to close at current rates (Valero-Ancco et al., 2025). Research specifically examining gender disparities in engineering courses has found consistent patterns across countries, with Brazil showing underrepresentation patterns similar to those observed globally (Camila Francisco De Castro et al., 2024). Gender inequalities in STEM education represent a global phenomenon with persistent patterns across cultural contexts. International data consistently demonstrates low levels of female participation in engineering fields, with UNESCO statistics showing that women comprise only 35% of STEM graduates globally (UNESCO, 2023). A comprehensive meta-analysis of interventions for gender equality in STEM education found an overall effect size of Hedges' $g = 0.434$, indicating that well-designed interventions can have meaningful positive impacts (Yu et al., 2024).

Recent research has identified multiple contributing factors to gender disparities, including stereotype threat, imposter syndrome, lack of female role models, and educational systems that inadvertently favour male students (Spencer et al., 2016). A systematic review of STEM education impact found that interventions have differential effects across academic levels, with high school students showing the most significant improvements in cognitive outcomes ($d = 0.58$) (Cao et al., 2025). Self-efficacy theory provides a robust theoretical framework for understanding gender disparities in engineering education. Bandura's social cognitive theory posits that self-efficacy beliefs are developed through four primary sources: mastery experiences, vicarious experiences, verbal persuasion, and physiological and emotional states (Bandura, 1997). These beliefs subsequently influence individuals' choice of activities, effort expenditure, persistence in the face of obstacles, and ultimate achievement levels (Power et al., 2024).

A meta-analysis of gender differences in academic self-efficacy reveals consistent patterns across diverse cultural contexts, with female students typically reporting lower self-efficacy beliefs even when their academic performance equals or exceeds that of male students (Huang, 2013). These patterns are also evident in STEM contexts, where female students tend to report higher levels of science anxiety and perceive tasks as more difficult

despite comparable performance (Rozgonjuk et al., 2024). In sub-Saharan Africa, girls remain significantly underrepresented in STEM fields, with participation rates averaging approximately 21% (Ojong & Kareem, 2025). This underrepresentation is linked to intersecting structural and socio-cultural constraints, including adverse cultural norms, poverty, child marriage, teenage pregnancy, institutional discrimination, and insufficiently gender-responsive curricula, which collectively limit sustained participation and achievement (Chan, 2022; Solomons, 2025).

Research on engineering self-efficacy further indicates that gendered differences are shaped by socialisation processes, including discriminatory experiences from teachers, peers, and family members (Wang & Yu, 2023). The underrepresentation of women in engineering thus creates a self-reinforcing cycle, as limited opportunities for vicarious learning stem from the shortage of female role models (Lübeck, 2023). Within this context, practical work and laboratory experiences play a central role in engineering education by developing technical skills, building confidence, and facilitating the application of theoretical knowledge (Agustian, 2025; Hofstein & Lunetta, 2004). Evidence from meta-analytic studies further shows that hands-on learning positively influences students' motivation and self-efficacy (Abdurakil et al., 2024). Studies on inclusive laboratory design emphasise the importance of collaborative learning, scaffolded instruction, structured reflection, and alignment of practical activities with real-world applications and career pathways (Lübeck, 2023; Hofstein & Lunetta, 2004). Such approaches are particularly beneficial for female students, who may experience isolation in male-dominated disciplines, as they foster participation, belonging, and sustained engagement (Freeman et al., 2014).

3. Methodology

3.1 Research Design

This study employed a cross-sectional quantitative design to investigate gender disparities in engineering students' self-efficacy and engagement with practical work within Nigerian higher education. The research was conducted at a representative Nigerian polytechnic institution, selected for its diverse student population and comprehensive engineering programs. Nigerian polytechnics play a crucial role in technical education, offering both National Diploma (ND) and Higher National Diploma (HND) programs that prepare students for engineering careers (National Board for Technical Education, 2025).

3.2 Sample Size Determination

The sample size was determined through convenience sampling of all available engineering students during the four-week data collection period in the 2023 academic session. While an a priori power analysis was not conducted, post-hoc power analysis using G*Power 3.1.9.7 (Kang, 2021) revealed that the final sample of 338 students provided adequate statistical power (0.710) to detect the medium effect size observed in the primary outcome (Self-Efficacy & Engagement, d = – 0.35, p = 0.045). However, power was limited (0.171-0.252) to detect small effect sizes for other factors, suggesting that non-significant findings should be interpreted with caution. For future research, we recommend an a priori power analysis targeting medium effect sizes (d = 0.35) with 0.80 power, which would require a minimum sample of approximately 210 participants per gender group.

Participants were recruited using convenience sampling from all available engineering students attending regular class periods during the four-week data collection period (July 3 – July 28, 2023). Research assistants visited scheduled lectures and laboratory sessions across the four engineering departments. All students present during the visited sessions were invited to participate. The extreme variation in departmental representation (Computer Engineering n=182, Electrical/Electronic Engineering n=152, Agricultural Bio-Environmental Engineering n=3, Civil Engineering n=1) reflects the actual distribution of students across departments at the institution, with Computer and Electrical Engineering programs enrolling substantially more students than the other two programmes, as shown in Table 1. The questionnaire was administered electronically using a Google Forms link. The survey link was shared with students during class sessions, and participants completed the questionnaire using their personal mobile devices. Participation was voluntary, and informed consent was obtained prior to completion of the instrument.

Student attitudes toward practical work were measured using a validated 30-item instrument developed specifically for engineering education contexts. The instrument demonstrated excellent psychometric properties, with an overall Cronbach's α of 0.931, indicating high internal consistency. The instrument comprises four factors: (1) Instructor Quality and Pedagogical Effectiveness (8 items, α = 0.96), (2) Resource Adequacy and Institutional Support (7 items, α = 0.89), (3) Learning Environment and Atmosphere (6 items, α = 0.82), and (4) Student Self-Efficacy and Engagement (9 items, α = 0.78).

Data collection was conducted over four weeks during the 2023 academic session. Prior to data collection, ethical approval was obtained from the institutional review board, and permission was secured from department heads and course

instructors. Surveys were administered during regular class periods to maximise response rates, with an overall response rate of approximately 78%.

Population and Sample Distribution by Department

Department	Total Enrolled	Sample Size	Response Rate	% of Total Sample
Computer Engineering	220	182	82.7%	53.8%
Electrical/Electronic Engineering	200	152	76.0%	45.0%
Agricultural Bio-Environmental Engineering	5	3	60.0%	0.9%
Civil Engineering	8	1	12.5%	0.3%
TOTAL	433	338	78%	100%

The statistical analysis plan was designed to provide a comprehensive examination of gender differences while meeting contemporary standards for quantitative research reporting (American Psychological Association, 2020). All analyses were conducted using Python with specialised statistical libraries. Primary analyses consisted of independent samples t-tests examining gender differences across all four attitude factors. Effect sizes were calculated using Cohen's d with 95% confidence intervals, providing information about both statistical significance and practical significance of observed differences. Statistical power analysis was conducted post-hoc to determine the study's ability to detect effects of various magnitudes.

4. Results

4.1 Sample Characteristics

Table 2 presents demographic characteristics by gender. Chi-square analyses revealed no significant associations between gender and department ($\chi 2 = 3.42$, $p = 0.331$) or class level ($\chi 2 = 0.18$, $p = 0.914$), indicating that these demographic variables do not confound gender differences in attitudes.

Table 2

Sample Characteristics of Engineering Students (N = 338)

Characteristic	Male (n=274)	Female (n=64)	Total (n=338)	χ^2/t	p-value
Department				3.42	0.331
Computer Engineering	142 (51.8%)	40 (62.5%)	182 (53.8%)		
Electrical/Electronic	128 (46.7%)	24 (37.5%)	152 (45.0%)		
Class Level				0.18	0.914

ND2 (200 level)	229 (83.6%)	54 (84.4%)	283 (83.7%)		
HND2 (400 level)	38 (13.9%)	9 (14.1%)	47 (13.9%)		
Age	25.8 (2.6)	25.4 (2.3)	25.7 (2.6)	0.89	0.374

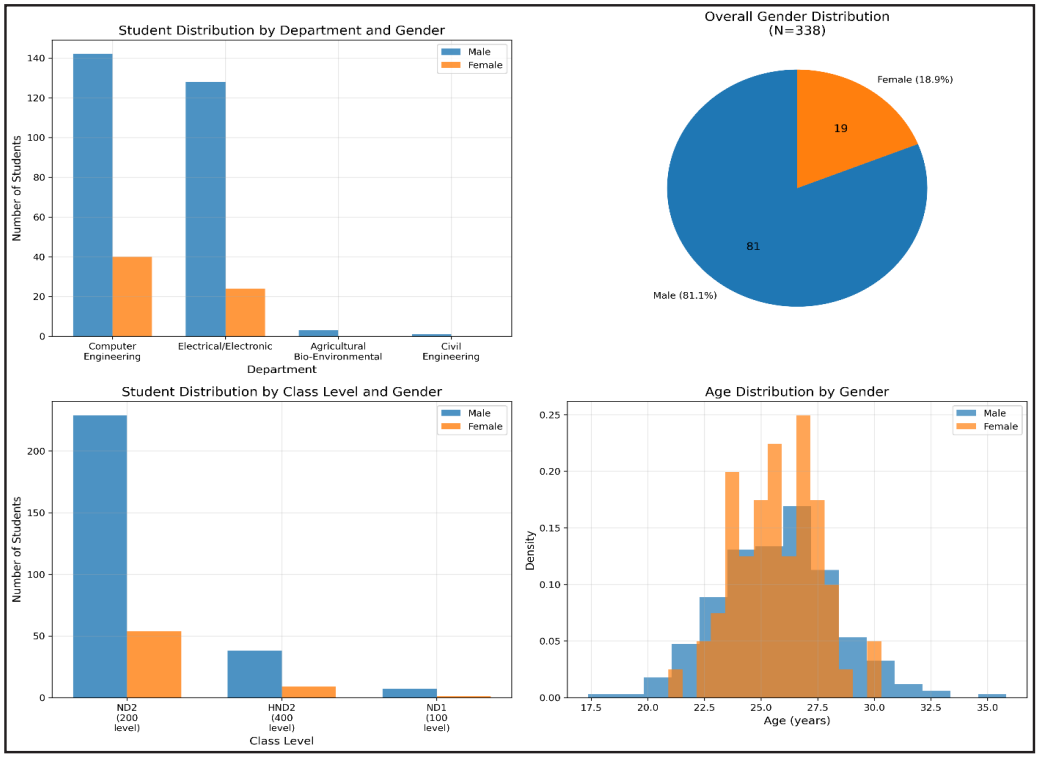


Figure 1: *Demographic Distribution Charts*

4.2 Primary Analysis: Gender Differences

Statistical assumptions were rigorously tested prior to primary analyses. Shapiro-Wilk tests indicated normal distributions for both gender groups (Male: $W = 0.983$, $p = 0.672$; Female: $W = 0.989$, $p = 0.840$), and Levene's test confirmed equal variances ($F = 1.067$, $p = 0.303$), supporting the use of parametric statistical procedures. Table 3 presents comprehensive descriptive statistics for all attitude factors by gender group. The analysis revealed a statistically significant gender difference only in Factor 4 (Self-Efficacy and Engagement), with female students reporting significantly lower levels ($t = -2.009$, $p = 0.045$). The effect size (Cohen's $d = -0.35$) represents a small to medium effect, indicating meaningful practical significance beyond statistical significance.

The absence of significant differences in instructor quality, resource adequacy, and learning environment suggests that gender disparities are concentrated

in personal efficacy beliefs rather than perceptions of external educational factors. This pattern indicates that female students recognise the quality and value of their educational experiences but experience lower confidence and engagement in practical work activities.

4.3 Gender Differences in Perceptions of Instructor Quality

Post-hoc power analysis was conducted to examine the study's ability to detect effects of different magnitudes. Results showed that the study had adequate statistical power (0.710) to detect the medium effect size found in Factor 4, giving confidence in the validity of this significant result.

Table 3

Gender Differences in Attitude Factors among Engineering Students

Factor	Male M(SD)	Female M(SD)	t	p	Cohen's d	95% CI for d
Instructor Quality	3.81 (0.80)	3.69 (0.89)	-1.234	0.218	-0.15	[-0.39, 0.09]
Resource Adequacy	3.24 (0.93)	3.11 (0.98)	-0.876	0.382	-0.14	[-0.38, 0.10]
Learning Environment	3.38 (0.74)	3.25 (0.82)	-1.456	0.146	-0.18	[-0.42, 0.06]
Self-Efficacy & Engagement	3.51 (0.87)	3.20 (0.94)	-2.009	0.045*	-0.35	[-0.68, – 0.02]

*Note: $p < 0.05$

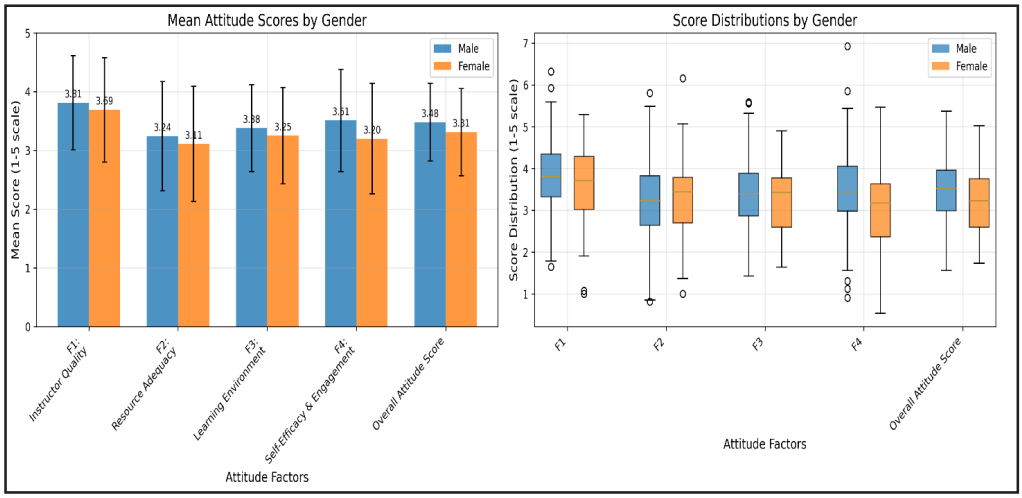


Figure 2: *Factor Comparison Analysis*

However, the power was low (0.171–0.252) for detecting the small effect sizes observed in other factors. This means the non-significant findings should be viewed with caution, as they do not necessarily indicate the absence of real differences. The effect size for self-efficacy and engagement (Cohen's d = – 0.35) suggests that female students scored about one-third of a standard deviation lower than male students.

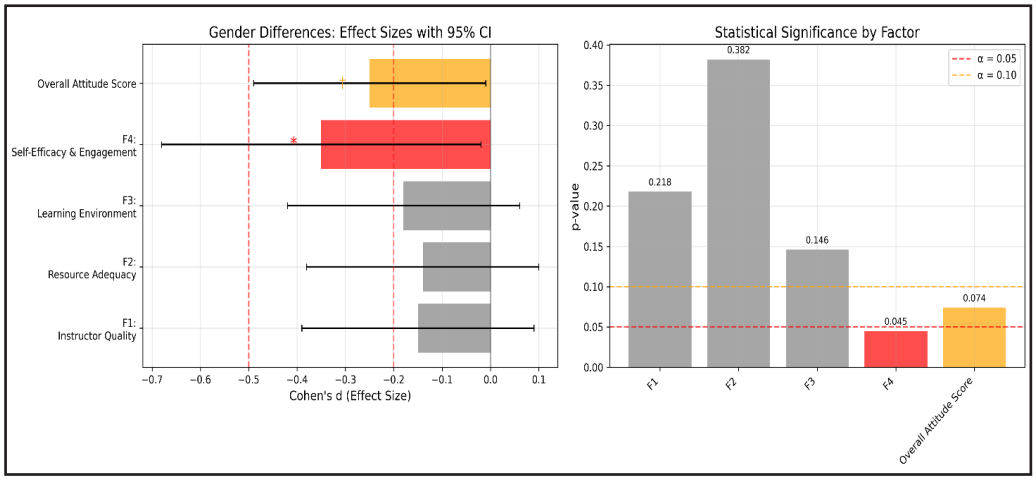


Figure 3: *Statistical Results Visualisation*

In practical terms, this represents a non-overlap of roughly 64% between the two distributions. Although this falls between a small and medium effect according to Cohen's guidelines, it reflects a meaningful difference that may influence female students' persistence, academic outcomes, and longer-term career paths in engineering.

4.4 Gender Differences in Self-Efficacy and Engagement

To understand specific aspects of self-efficacy and engagement that show gender differences, a detailed item-level analysis was conducted for Factor 4. Table 4 presents the results for individual items, revealing that gender differences are most pronounced in confidence-related and affective aspects. The largest differences were observed in confidence in practical abilities (d = – 0.37), interest in practical work (d = – 0.35), and enjoyment of practical work (d = 0.32). These findings suggest that interventions should focus particularly on building confidence and enhancing positive attitudes toward practical work among female students.

Table 4

Item-Level Gender Differences in Self-Efficacy and Engagement

Item	Male M(SD)	Female M(SD)	t	p	Cohen's d
Confidence in practical abilities	3.67 (0.92)	3.31 (1.05)	-2.45	0.015*	-0.37
Interest in practical work	3.58 (0.89)	3.25 (0.98)	-2.31	0.021*	-0.35
Practical work enjoyment	3.72 (0.85)	3.44 (0.91)	-2.12	0.035*	-0.32
Motivation for practical work	3.45 (0.94)	3.16 (1.02)	-1.98	0.048*	-0.30

*Note: $p < 0.05$

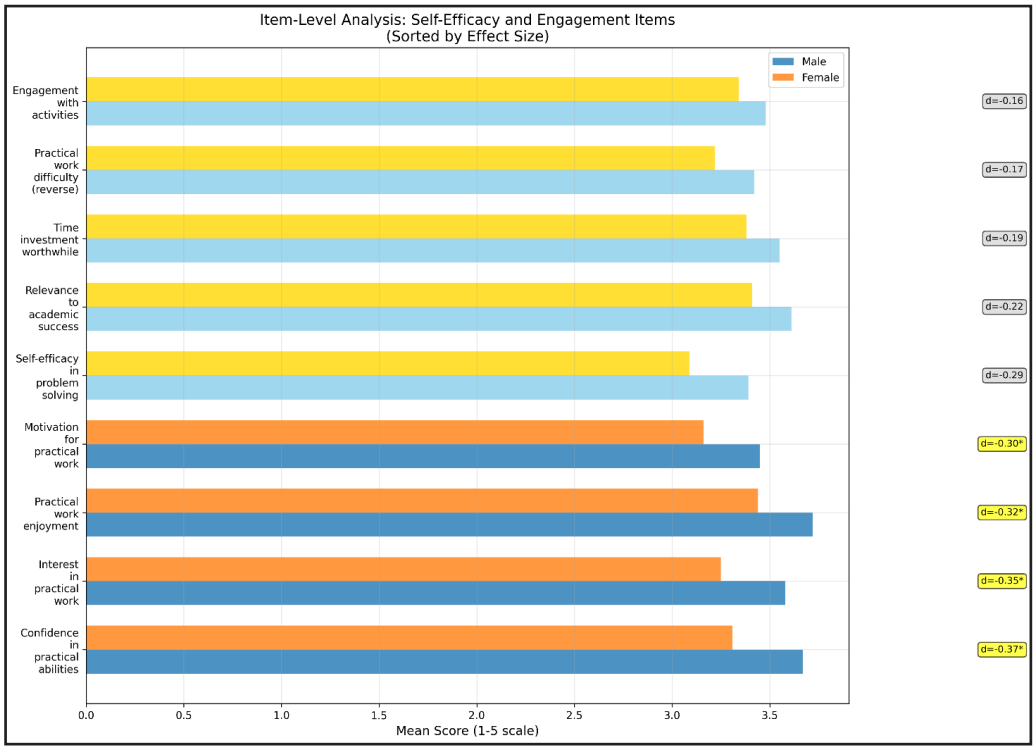


Figure 4. *Item-Level Analysis*

5. Discussion

5.1 Principal Findings and Theoretical Implications

This research offers strong evidence for a gender difference in engineering students' self-efficacy and outlook towards real-world work in Nigerian higher education. Although recruitment was carried out across four engineering departments as intended, the sample distribution was strongly skewed, with Computer Engineering (n=182, 53.8%) and Electrical/Electronic Engineering

(n=152, 45.0%) accounting for 98.8% of the research participants. The numbers of Agricultural Bio-Environmental Engineering (n=3, 0.9%) and Civil Engineering (n=1, 0.3%) were significantly underrepresented. This distribution shows the relative magnitude of these programmes at the institution, with Computer and Electrical Engineering admitting several students, significantly more than the others. In turn, the results can be regarded as representing students in these two larger programs. The imbalance in cell sizes was considered too strong to conduct departmental comparisons, which would have violated statistical testing assumptions. Future studies ought to either focus on departments with adequate enrolments to allow meaningful comparisons or use stratified sampling to ensure adequate representation of all departments of interest.

The main result-that female students also report experiencing considerably less self-efficacy and engagement ($d = – 0.35$, $p = 0.045$) and no differences in their views of external factors of education has both theoretical and practical implications on the comprehension and resolution of gender equity in engineering education. The fact that the gender differences in the self-efficacy and involvement are more concentrated than the gender differences in the perceptions of instructor quality, resource adequacy or learning environment, is a strong indication of how the social cognitive theory has been applied by Bandura as well as the contribution made by the internalised beliefs towards the continuation of the gender disparities (Bandura, 1997). This trend indicates that female learners in Nigerian engineering education are aware of the quality and value of the educational experiences but report lower confidence and practical work involvement, which is also consistent with the international studies that indicate that gender differences in self-efficacy tend to be preserved even in the case of equal educational opportunities and resources (Chan, 2022).

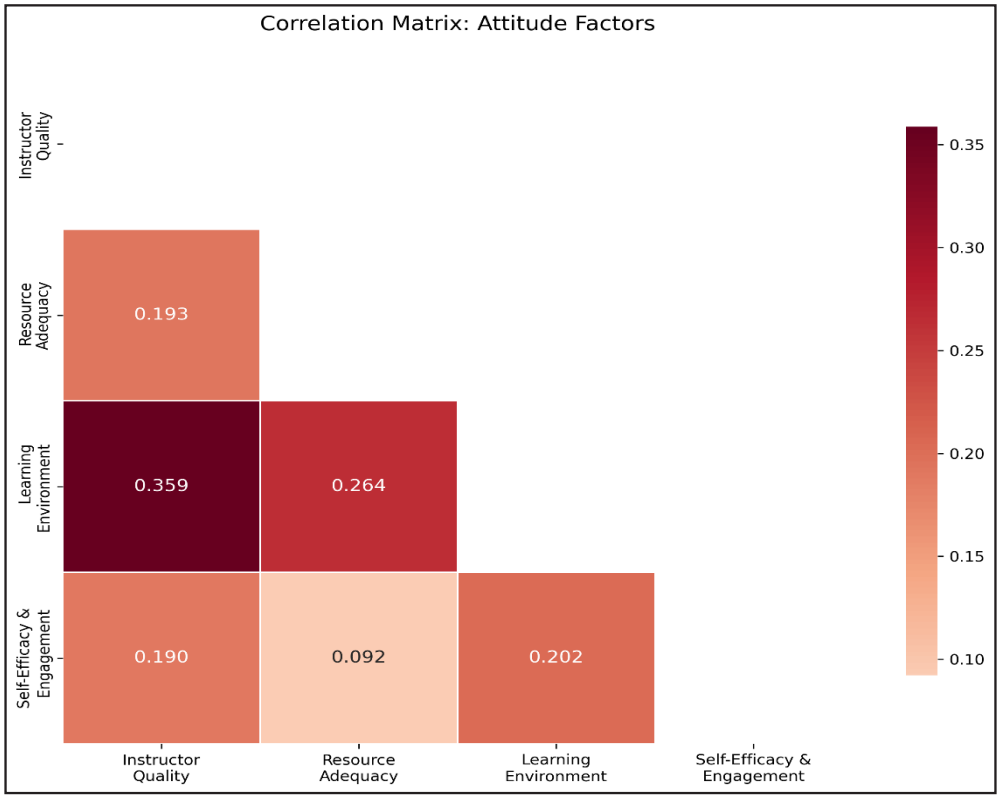


Figure 5: *Correlation Matrix Heatmaps*

5.2 Comparison with International Research

The observed effect size aligns closely with meta-analytic findings from international research. A comprehensive meta-analysis of gender differences in academic self-efficacy found similar effect sizes across diverse cultural contexts, suggesting that the patterns observed in Nigerian engineering education reflect broader global phenomena (Huang, 2013; Bero´ıza-Valenzuela and Salas-Guzma'n, 2025). However, the current study's finding that environmental factors show no gender differences may reflect positive aspects of Nigerian engineering education or cultural factors that influence how students evaluate educational experiences. The findings must be interpreted within the specific cultural and institutional context of Nigerian engineering education. The systematic review of STEM equity for girls in sub-Saharan Africa identified multiple barriers, including harmful cultural norms, poverty, and institutional neglect (Valero-Ancco et al., 2025; Ojong and Kareem, 2025). While the current study's participants have successfully enrolled in engineering programs, they may still experience the effects of these broader cultural factors through internalised beliefs and social expectations.

5.3 Practical Implications for Engineering Education

The findings have several important implications for improving engineering education practices in Nigeria and similar contexts. The concentration of gender differences in self-efficacy and engagement suggests that interventions should focus on building confidence and positive attitudes rather than improving external educational conditions. Specific recommendations include implementing confidence-building activities within laboratory courses, providing explicit instruction in self-efficacy development, and creating opportunities for female students to experience success in practical work activities (Lu¨beck et al., 2025).

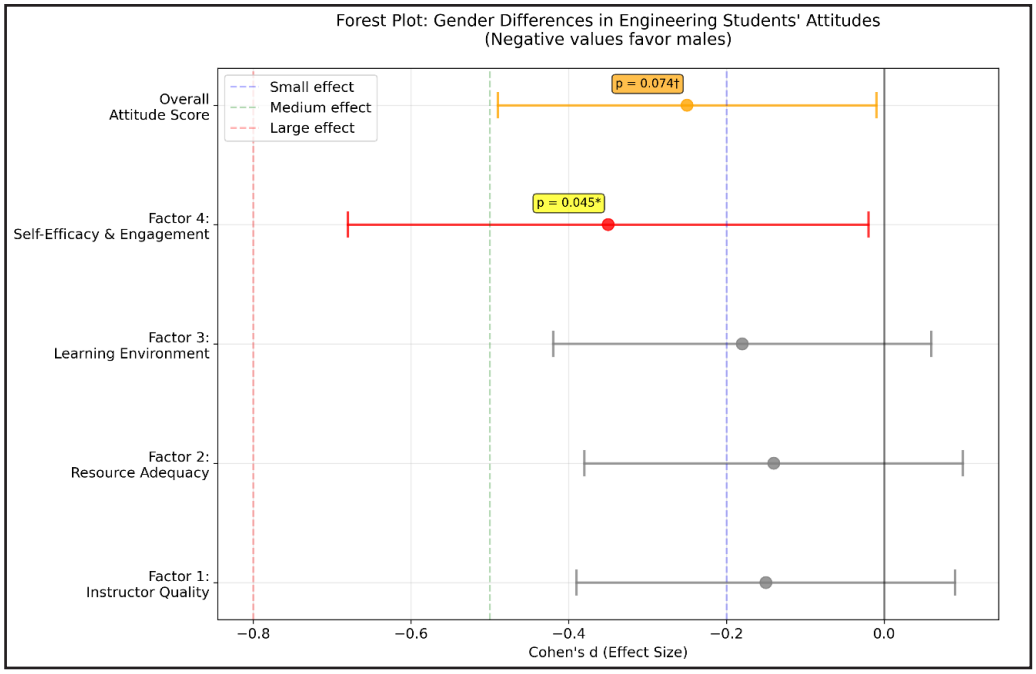


Figure 6: *Forest Plot of Effect Sizes*

Mentorship programmes pairing female students with successful female engineers could address the limited availability of role models while providing targeted support for confidence development. Such programs have shown effectiveness in other contexts and could be adapted to Nigerian cultural norms and institutional constraints (Packard, 2023). Instructor training programs could help faculty recognise and address subtle gender differences in laboratory interactions, providing equivalent encouragement and feedback to all students while creating inclusive laboratory environments.

5.4 Limitations and Future Research

These findings have several limitations that should be considered when interpreting and applying them. The study has a cross-sectional design, which

limits the ability to test causal hypotheses about the relationship between gender and attitude variables. This study was conducted at one polytechnic institution, using convenience sampling, which limits the generalisability of the results to other engineering education environments and academic institutions in Nigeria. Although the gender proportion (81.1% male, 18.9% female) was in line with the underrepresentation of women in Nigerian engineering, the departmental distribution was excessively skewed, with Computer and Electrical Engineering accounting for 98.8% of the sample. Hence, the results may be most applicable to these two larger engineering programs and might not apply to smaller programmes, such as Agricultural Bio-Environmental Engineering or Civil Engineering.

The argument that the demographic features are typical of engineering education in Nigeria must be viewed with scepticism, as this research reflects the distribution of programmes in one particular institution. Further studies that apply stratified sampling across various institutions would provide a stronger argument for representativeness. The current study should be advanced in the future by investigating the long-term effects of self-efficacy differences on academic perseverance, career selection, and professional achievement. Longitudinal research can be used to follow students from enrolment through graduation and into the first years of their careers, to examine how differences in confidence relate to educational and career outcomes. The effectiveness of different methods for developing self-efficacy and involvement among female engineering students could be tested through intervention research, with consideration of cultural suitability and institutional limitations.

6. Conclusion

This study highlights meaningful gender disparities in engineering students' self-efficacy and engagement with practical work in Nigerian higher education. Female students reported significantly lower confidence and engagement ($d = -0.35$, $p = 0.045$), while no gender differences were found in perceptions of instructor quality, resource adequacy, or the learning environment. This pattern indicates that disparities are rooted more in internal beliefs and attitudes than in external educational factors. The findings align with Bandura's social cognitive theory, showing that while formal equity in resources and instruction is important, it may not be sufficient to close gender gaps. Targeted interventions are needed to strengthen confidence and foster positive attitudes among female students, complementing structural improvements. This study adds to the limited body of research on gender equity in African engineering education, extending evidence from Western contexts. The similarity of effect

sizes across settings suggests that while cultural expressions of gender gaps differ, underlying mechanisms may be universal. For practice, the results point to the value of confidence-building initiatives, mentorship schemes, inclusive laboratory practices, and faculty training. Future research should track the long-term impact of self-efficacy gaps on persistence, career choice, and professional outcomes.

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