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Perceptions and Participation: Gendered Experiences in Engineering Education

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Abstract
Gender differences influence how students interpret participation, authority, and belonging within engineering education, even when academic performance is comparable. Prior research has documented gendered disparities in confidence, participation, and persistence in STEM [12], [13]. However, less is known about how students themselves make sense of these experiences in everyday engineering contexts. This qualitative study examines how male and female undergraduate engineering students interpret classroom participation, faculty interaction, and teamwork within laboratory and design settings.

Semi-structured interviews were conducted with undergraduate students across multiple engineering disciplines and academic levels, including students with varied prior experiences such as internships, research, and limited pre-college technical exposure. Using thematic analysis, the study identifies consistent gendered patterns in how students evaluate participation and engagement. Male participants typically framed participation as a low-risk, competence-driven behavior, while female participants described participation as a socially evaluative act requiring greater certainty. These differences extended beyond lecture settings into faculty interactions and team-based design environments, where informal leadership and early participation often shaped role distribution and visibility.

Participants did not attribute their experiences to explicit bias but instead gendered differences emerged through interactional norms governing when participation felt appropriate, how mistakes were interpreted, and how authority was established. Team-based laboratory and design contexts were found to amplify these dynamics rather than neutralize them, challenging assumptions that collaboration alone promotes equity.

By utilizing students' interpretive processes, this study advances understanding of how gendered experiences are produced and sustained within undergraduate engineering education. The findings highlight participation, faculty interaction, and team structure as critical sites for intervention and suggest that instructional practices emphasizing structured participation, relational engagement, and transparent role assignment may support more equitable learning environments in engineering programs.

Introduction and Background

Gender differences influence how students experience and interpret educational environments, particularly in STEM fields where expectations around ability, participation, and persistence are strongly emphasized [4], [17]. Prior research has consistently shown that men and women often perform similarly in STEM coursework yet differ in how they perceive their competence and place within these disciplines [2], [10]. One of the most robust findings in the literature is the misalignment between objective performance and self-efficacy among women [1]. Whitcomb et al. demonstrated that women in engineering and physics frequently match or outperform male

peers academically while reporting significantly lower self-efficacy [1]. This pattern reflects differences in interpretation rather than differences in ability. These disparities can be traced back to earlier educational experiences, as one study found that adolescent girls experience sharper declines in confidence following academic setbacks than boys, creating vulnerabilities that persist into higher education [2].

A growing body of research highlights the importance of recognition and belonging in shaping STEM identity. Li, Whitcomb, and Singh showed that perceived recognition from instructors and peers was a stronger predictor of physics identity than prior achievement, with students who felt unrecognized experiencing declines in confidence regardless of performance [3]. Classroom participation patterns further reinforce these dynamics. Men consistently dominate classroom participation, while women reported greater anxiety about evaluation [4]. Feng et al. found that women participated more equitably and produced higher-quality work in all-female groups, underscoring the influence of social context rather than inherent differences [5]. These participation patterns are shaped early as it has been observed that boys received more frequent and higher-level academic interactions in middle school classrooms [6], while another study showed that girls' academic confidence depended more heavily on supportive teacher relationships [7]. Together, these studies suggest that self-efficacy, belonging, and participation are socially constructed through interaction and recognition.

Academic pathways into STEM further structure these gendered experiences. Access to advanced coursework strongly determines which students perceive STEM as viable. Tyson et al. found that completing upper-level mathematics and science courses substantially increased the likelihood of earning a STEM degree [8], while Card and Payne showed that gender gaps in STEM applications narrowed significantly once high school course-taking patterns were accounted for [9]. Comparative academic strengths also matter. One study demonstrated that girls who perform well in both math and reading but excel more in reading are less likely to choose STEM fields, even when math achievement is high [10]. College application data reinforce these findings, as the differences in first-choice STEM majors largely reflect prior preparation rather than intrinsic preference [11]. Pathways are not strictly linear, however, as many students, particularly women, enter STEM through nonlinear routes after encountering supportive mentors or coursework [12]. Early experiential factors, such as boys' greater exposure to mechanical activities, further shape perceptions of fit [13].

Institutional climate and pedagogical structure also play a critical role. Women respond more positively to learning environments characterized by clarity, transparency, and predictable communication [14]. When institutional expectations are ambiguous, women report greater dissatisfaction, suggesting that disorganization can function as a structural barrier to academic satisfaction [15]. Pedagogical and technological design similarly shape engagement: online environments and gendered instructional agents can reduce anxiety and increase perceived

support for women [16]. At the organizational level, universities operate as gendered systems that privilege masculine norms of competition and independence, shaping recognition and advancement opportunities [17].

Despite extensive quantitative evidence documenting gendered differences in confidence, participation, and persistence in STEM, less is known about how students themselves interpret these experiences in their day-to-day academic lives, particularly within engineering programs. Large-scale studies identify patterns and predictors, but they often cannot capture the interpretive processes through which students decide whether to speak in class, approach faculty, or view themselves as legitimate members of the discipline. Understanding these processes is critical, as engineering education relies heavily on participation, teamwork, and continued interaction with instructors. This study is motivated by the need to examine how male and female engineering students make sense of participation and faculty relationships, and how earlier educational experiences shape those interpretations. By focusing on students' own narratives, this work seeks to connect broad patterns of gender disparity with the everyday experiences through which those patterns are reinforced or challenged in engineering classrooms.

Methodology

This study employed a qualitative interview-based design to examine how undergraduate engineering students interpret classroom participation, faculty interaction, and academic difficulty. Semi-structured interviews were selected to balance consistency across participants with flexibility to explore emergent themes in depth.

Participants were recruited from a large public research university through voluntary participation and word-of-mouth referral. Initial participants responded to informal outreach within engineering courses and peer networks. The sample for this study included six undergraduate engineering students (three men, three women), primarily in their junior or senior year. Participants represented multiple engineering disciplines and a range of academic experiences.

The interview protocol was developed using an iterative, literature-informed process. Prior research on gender differences in STEM self-efficacy, participation, recognition, and belonging informed the identification of core domains. Questions were intentionally open-ended and avoided direct reference to abstract constructs such as "confidence" or "belonging," instead eliciting descriptions of observable practices, decisions, and interactions.

Interviews focused on students' experiences with classroom participation, help-seeking, group work, responses to difficulty, and prior exposure to engineering-related activities. Interviews were conducted individually in a private setting and lasted approximately 45–60 minutes. With participant consent, interviews were audio-recorded and transcribed verbatim. Transcripts were de-identified prior to analysis.

Transcripts were analyzed using an inductive thematic approach informed by the constant comparative method. Initial coding focused on recurring actions, decision-making processes, and interactional patterns rather than abstract attitudes. Open coding was conducted line-by-line to identify emergent categories grounded in participants' language.

Coding was conducted by the primary researcher. To enhance analytic rigor, codes were revisited iteratively across transcripts, with earlier transcripts re-coded as categories were refined. Constant comparison was used both within and across gender groups to identify recurring patterns and divergence in interpretive frameworks.

Themes were first developed independently within male and female participant groups to identify common patterns without cross-group influence. Following within-group development, themes were compared across groups to identify convergence and divergence. Categories were refined through iterative comparison and consolidation.

Analytic rigor was supported through iterative protocol refinement, balanced gender sampling in this phase, continuous cross-case comparison, and transparent documentation of coding decisions. Findings are presented as analytic generalizations that explain patterned differences in interpretation rather than statistical claims.

Results

Some participants reported exposure to engineering through internships, undergraduate research, or hands-on technical work before college, while others described entering engineering with limited prior technical experience. Across interviews, students described similar instructional environments; however, male and female participants consistently interpreted participation, teamwork, and faculty interaction through different evaluative frameworks. Three interrelated themes emerged: participation as confidence versus participation as risk, faculty as evaluators versus relational resources, and teamwork and design spaces as amplified participation contexts.

Male participants consistently framed classroom participation as a low-risk and routine component of learning. Speaking in class was described as an act primarily dependent on understanding the material rather than as a socially consequential act. One male aerospace student explained that participation depended on whether "you know the answer or not," emphasizing correctness rather than peer perception. Mistakes were described as expected and often productive, with several men noting that answering incorrectly was simply "part of figuring things out."

Female participants, on the other hand, described participation as a socially evaluative act carrying both academic and interpersonal consequences. Across interviews, women emphasized heightened awareness of being judged by peers, particularly in male-dominated courses.

Participation was frequently contingent on a high level of certainty. As one female aerospace student explained, she avoided speaking unless she was “really sure,” reflecting concern that an incorrect response would reinforce negative perceptions. Importantly, female participants did not describe themselves as less prepared or less capable, they framed participation decisions as strategic responses to anticipated evaluation. Several women noted that they often knew the answer but chose not to speak unless confident it would be well received.

Gendered differences also emerged in how participants perceived faculty. Male participants tended to describe professors as generally approachable provided they were fair, knowledgeable, and consistent. Faculty interactions were framed as transactional and competence-based. One male student explained that if a professor “knows their stuff and grades fairly,” approaching them felt straightforward. Discomfort with a professor rarely deterred help-seeking.
Female participants evaluated professor approachability through relational cues. Approachability was described as something built through interaction, such as professors asking follow-up questions, inviting discussion, or demonstrating personal investment in student learning. One female participant noted that professors who “just lecture and leave” felt inaccessible, even if technically available during office hours. Several women referenced earlier educational experiences when describing faculty relationships, suggesting that expectations regarding authority and support were shaped prior to college. Professors who explicitly encouraged questions or normalized uncertainty were perceived as significantly more approachable.

Team-based laboratory and design projects emerged as settings where gendered participation dynamics were intensified. Male participants often described group work as an extension of classroom participation norms, emphasizing efficiency, task completion, and informal leadership. Leadership roles were frequently described as naturally assumed, often by those who spoke first or appeared most confident. One male mechanical engineering student described group dynamics as “whoever jumps in first kind of leads.”

Female participants described teamwork as higher-stakes participation environments in which visibility, contribution recognition, and interpersonal dynamics were heightened. Several women expressed discomfort speaking early in group discussions, particularly when technical decisions were made quickly. One female participant described feeling sidelined during initial brainstorming phases, despite later contributing substantively to analysis and documentation. However, women reported more equitable participation in teams where roles were clearly defined or when working with familiar peers. Smaller groups and structured collaboration reduced evaluative pressure and increased confidence.

Across themes, internal consistency was strong within gender groups. Men interpreted participation and faculty interaction as primarily competence-driven, while women interpreted

these interactions through relational and evaluative lenses. These differences were not attributed to explicit bias but rather to patterns of interaction and expectation.

Theme	Female Quote	Female Interpretation	Male Quote	Male Interpretation
Participation: Risk vs Confidence	"I don't wanna look stupid in front of other people." – Student 4	Participation framed as social risk; high certainty threshold required.	"You either know the answer or not." – Student 1	Participation framed as competence demonstration; low social risk.
Help-Seeking	"Who I go to for help is entirely dependent on trust." – Student 3	Help-seeking filtered through peer evaluation and trust.	"If I'm stuck… I'll just ask the professor." – Student 6	Help-seeking normalized and task-oriented.
Faculty Interaction	"Because it's their job to teach me… But other people will be like, 'Oh, why does she not know?'" – Student 4	Peer evaluation prioritized over faculty authority.	"I go straight to the source." – Student 2	Faculty viewed as functional knowledge authority.
Belonging and Struggle	"I kind of struggled… and I was like, 'Maybe I don't belong here.'" – Student 4	Difficulty interpreted as potential identity misfit.	"Just the workload and how hard the tests were." – Student 2	Difficulty interpreted as short term and external
Team Contexts	"I tend to be the one keeping track of how all the parts connect." – Student 3	Assumes coordination/ integration role rather than dominant voice role.	"Group projects work best when everyone just does their part." – Student 2	Takes ownership of discrete technical component.

Table 1: Summation of interview responses and interpretations.

Discussion

Rather than identifying new participation disparities, this study contributes by revealing how students interpret participation itself, showing that identical instructional environments are experienced through fundamentally different evaluative lenses that persist across classrooms, faculty interactions, and team-based engineering contexts. Male participants consistently framed classroom participation as a routine, low-risk learning behavior, whereas female participants described participation as a socially evaluative act requiring greater certainty and self-monitoring. This distinction aligns with prior literature showing that women's engagement in STEM is more strongly influenced by perceived judgment and classroom climate than by objective performance.

Gendered perceptions of faculty further illuminate these dynamics. Female participants emphasized relational cues, such as instructor engagement, encouragement, and visibility, when assessing approachability. These findings support research identifying recognition and interpersonal validation as central to women's academic identity development in STEM. Male participants described faculty relationships in transactional terms, viewing instructors primarily as resources whose approachability depended on fairness and competence rather than relational connection.

Engineering education places heavy emphasis on collaborative problem solving, yet these contexts are often assumed to promote inclusion through teamwork alone. The findings here suggest otherwise. Teamwork environments can intensify participation inequities when leadership and technical authority are informally assigned. Women described early group interactions as particularly consequential, with initial participation shaping long-term role distribution and visibility. Without structured role assignment, group dynamics frequently mirrored classroom participation patterns, reinforcing confidence-based leadership.

Importantly, participants did not attribute these experiences to explicit gender bias. Instead, gendered patterns emerged through interactional norms governing who speaks first, how mistakes are interpreted, and what behaviors signal competence. This is similar to prior work suggesting that inequities in engineering education persist through everyday practices rather than overt exclusion. Competitive participation norms, rapid verbal exchanges, and unstructured teamwork may unintentionally privilege students who are already comfortable asserting authority.

These results have direct implications for engineering pedagogy. Instructional practices that clarify participation expectations, normalize uncertainty, and structure team roles may reduce evaluative pressure and support more equitable engagement. Faculty behaviors that signal availability and encourage dialogue may be particularly impactful for students whose confidence

depends on relational cues. In laboratory and design settings, explicit role rotation and structured collaboration may mitigate the amplification of participation disparities.

Conclusion and Future Studies

This preliminary study explored gendered differences in undergraduate engineering students' perceptions of classroom participation and faculty interaction. Conducted as an exploratory phase, the primary purpose of this analysis was to identify recurring interpretive patterns that could inform refinement of the interview protocol for a larger study. Findings highlighted how men and women interpret similar academic environments through distinct evaluative frameworks. Participation and help-seeking were shaped by relational cues, perceived social risk, and prior educational socialization. Female students more often described participation as a socially evaluative act and relied on relational signals to assess faculty approachability, whereas male students framed participation as a routine learning practice and described faculty interactions in more transactional terms. These preliminary patterns suggested that gendered experiences may be produced through everyday classroom norms and interactional expectations rather than explicit bias.

As an exploratory phase, this study was intentionally limited in scope. The sample was small and drawn from a single institutional context, and recruitment occurred through voluntary participation and peer referral. Because findings were based on self-reported experiences, interpretations may reflect recall limitations or selective disclosure. However, the internal consistency of patterns across interviews indicated that the themes identified were sufficiently robust to guide refinement of the subsequent interview instrument.

Insights from this phase informed the development of more targeted follow-up questions in the expanded study, particularly regarding participation decision-making, perceived evaluative risk, role differentiation in group work, and pathways to validation. By clarifying which interpretive processes warranted deeper examination, this preliminary analysis strengthened the methodological design of the larger project.

Future research should build on these findings using larger and more diverse samples across institutions and engineering subdisciplines. Longitudinal qualitative designs may further examine how interpretive frameworks evolve over time, particularly as students encounter design projects, internships, and capstone experiences. Integrating qualitative insights with institutional data may further illuminate how engineering education environments can be structured to support equitable participation and persistence across gender.

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