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Examining the Effects of Gender on Capstone Team Cohesion

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Introduction

This paper builds on previous capstone research studying team inclusivity and utilizes the Team Learning Beliefs and Behaviors (TLBB) Model to evaluate how gender impacts social cohesion and task cohesion in senior engineering capstone teams, as well as the influence of gender on self-efficacy and, subsequently, role determination in groups. The goal of this study is to examine social factors impacting team performance, as well as the role of gender in team dynamics, in an effort to improve learning outcomes in capstone engineering courses in the future. Specifically, this research offers insight into challenges encountered by female senior engineering students at the start of the course and develops survey questions to further dissect how these experiences correlate with student learning outcomes and performance satisfaction at the end of the course.

Background

Teamwork and Team Effectiveness

The 2024 - 2025 ABET Engineering Accreditation Criteria defines a team as “more than one person working toward a common goal… [including] individuals of diverse backgrounds, skills, or perspectives” [1]. Given that over 95% of US employees reportedly work within teams, teamwork has become a core competency for the employability of higher education graduates and one of the top three skills employers seek in recruitment and selection [2]. Teamwork is integral to product development, process improvement, and manufacturing activities in industry settings, so future engineers must possess the ability to lead and work productively in teams [3]. Teamwork arises from the commonality of goals across members and the synergy that emerges from member interdependence (the belief that students within the team need each other for dealing with the assigned task) as groups work through the transition processes of mission analysis, goal specification, and strategy formulation, as well as the action processes of monitoring progress toward goals, backup responses, and coordination [2, 4]. In doing so, teams utilize interpersonal processes such as conflict management, motivating others, and emotional regulation and communication [2]. Furthermore, by integrating teamwork into the engineering curriculum, students gain exposure to group development, solicitation of member input, consensus building, and team leadership, while also experiencing disciplinary or cross-disciplinary projects emulating workplace settings [3, 4]. These experiences provide students with the skills necessary to “share a common goal, distribute workload based on expertise, and allocate time and financial resources” as they will do in the workforce following graduation [5].

Due to its widespread benefits, collaborative learning has been codified into the 2024 - 2025 ABET Engineering Accreditation Criteria to ensure that future engineers can navigate the social and interpersonal landscape of the engineering profession. The 2024 - 2025 ABET Criteria for Accrediting Engineering Programs requires engineering students to demonstrate “an ability to function effectively on a team whose members provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives” [1]. These requirements are reflected in engineering capstone courses, where undergraduates apply their conceptual knowledge to real-world industry design challenges [5, 6]. Many engineering students first encounter group work at the end of their undergraduate studies through these capstone programs [5]. However, recent research indicates that students who participate in collaborative coursework before capstone demonstrate "detectable, specific, and stronger teaming skills in capstone design" relative to students without prior teamwork experience, motivating institutions to incorporate additional collaborative learning experiences earlier in their engineering curricula [5]. Structured pedagogical strategies to promote inclusive and effective collaboration have proven to foster more positive learning outcomes and student attitudes, particularly those methodologies that focus on diverse team formation, development of common team vocabulary, incorporation of team building activities, evaluation of both individual and team reports, and use of peer evaluation and feedback [6]. However, further research must be conducted into team evaluation tools and factors affecting collaboration, and subsequently, team effectiveness [6].

Benchmarks for team effectiveness may be organized around three dimensions: performance, affective, and attitudinal, represented by the quality of the work, student satisfaction, and commitment to progress and project success [4]. However, many different factors may influence the aforementioned dimensions of effectiveness. Tonso reported that campus culture plays a pivotal role in daily teamwork interactions in engineering courses, particularly "the ways students [understand] belonging as an engineer on campus…[and the] structures, practices, and routines of campus life" which inevitably affect women's experiences on engineering campuses, and, subsequently, the effectiveness of design teams [7]. These practices are complex and incredibly difficult to distinguish from other confounding social factors (e.g., race, socioeconomic status, etc.). However, further analysis of the roles of gender and other social identities in team effectiveness is described below.

Self-Efficacy

Bandura defined self-efficacy as an individual's belief that they can successfully complete a task or endeavor [8]. Self-efficacy beliefs are recursive; student self-efficacy is often informed by prior performance feedback and stereotypes/expectations, and future academic performance has been shown to be influenced by self-efficacy, with negative self-efficacy resulting in "reduced interest and engagement during learning" [9]. Recent research has shown that women report lower self-efficacy than men in STEM subjects such as physics, chemistry, and mathematics in their first year of engineering studies [9]. Furthermore, Whitcomb *et al.* identified "discipline-dependent trends in the relationship between self-efficacy and course grades" reflected by a gender gap in physics that is not improved by the fourth year of engineering studies [8]. These trends have been shown to be consistent across different performance contexts (e.g., a lab setting, test-taking, working on projects, etc.) [9]. However, most research describing trends in self-efficacy focuses on improving retention early in undergraduate studies (e.g., first- and second-year), and these studies typically assess core courses rather than upper-level project-based learning courses, so little is known about the impact of self-efficacy in senior engineering capstone courses. A comparison of creative self-efficacy, mindset, and student perceptions reveals that women were less likely than men to believe that creativity cannot be improved [10]. Additionally, women's progression in the engineering major, and both groups' ability to succeed in their senior year "contributed to the increased belief that engineering is a creative field" [10]. These differences point to potential variations in mindset and learning outcomes in senior capstone engineering courses, which must be further explored.

Task Allocation

Gender and self-efficacy are significant factors in role determination and task allocation in collaborative learning settings. The Model of Inequitable Task Allocation in Project-Based Learning (MITA) suggests that "students' prior experiences inform their motivations for learning (i.e., their academic orientation)" such that students' valuations of their skills affect their motivations for learning and influence students to select tasks which align with their perceived skillsets [11, 12]. Given known gendered differences in self-efficacy for technical competencies, this self-selection often leads to non-gender-neutral task allocation. For example, Fowler *et al.* reported instances of gendered performance avoidance, with male students avoiding communication tasks (e.g., writing) and female students avoiding technical tasks (e.g., coding) within an introductory engineering design course due to differences in self-view of competencies [11]. Evaluation of writing abilities in project deliverables is particularly impactful to student experiences and learning outcomes in team settings. Mallette *et al.* explained that the pressures women faced to complete a greater proportion of the writing tasks than their male peers in a year-long senior capstone materials science and engineering course was due to "the prevailing perception…that women are the strongest writers, so the writing should fall to them," as well as the personal desire by female students to produce high-quality project deliverables and the adoption of technical tasks as a way to avoid writing by male students [13]. While these writing contributions, if visible and rewarded, are not inherently problematic, this task allocation practice may limit female students' opportunities to practice and build self-efficacy in technical competencies, and writing contributions are often undervalued in project-based learning settings — particularly when a written deliverable is not the primary output for evaluation [13].

These differences are further exacerbated by group negotiations and delegations, with "women both more likely to under-contribute (talk much less than teammates) and over-contribute (talk much more) in the engineering student team context" [11]. During task allocation discussions, gender greatly affects access to the conversational floor, students' spatial privilege, the merit of individual student contributions, and students' intellectual authority [12]. Henderson also described cases of role reassignments due to differences in self-efficacy and gendered perceptions of quality of work, where "contributions of women were more heavily scrutinized or were changed by men without a woman's knowledge" and technical roles initially filled by female students were usurped during the design process due to a loss of confidence in her abilities by the group [12]. Roles filled by female group members are also undervalued in the engineering design process. Meadows *et al.* observed that supporting roles, such as that of "organizers and note-takers," were fulfilled by women in first-year engineering project teams, and that these non-technical roles were viewed as undesirable to both men and women in the group, as they were perceived to be "insubstantial and boring" and even secretarial (e.g., scheduling meetings, distributing agendas, etc.) [14]. In mixed-gender groups with solo women, these tendencies intensified, with one woman describing her role as "mom" to the men in her group, "taking care of them and bringing baked goods to their meetings" [14].

Beyond the selection of tasks, quality and commitment to tasks have been shown to vary by gender as well. Female students in mixed-gender engineering capstone groups previously reported experiencing a disproportionate workload compared to their male peers due to false praise attribution, academic malalignment, and discouragement from participation in the technical aspects of the project [15]. False praise attribution may be observed when men claim their female counterpart "has neater handwriting" or "is a better writer," justifying an imbalance in workload distribution [15]. Camarillo *et al.* also highlighted the role of academic malalignment in engineering capstone groups, or differences in "ideas about timely submission of work and the quality of the work, especially in [the] submission of reports and presentations" that result in women completing a disproportionate share of the workload [15]. Ultimately, more research must be conducted into the significance of gender stereotypes and biases in role selection and/or delegation and task completion to better address inequities in team dynamics.

Exclusion and Attrition

Collaborative learning is important, not only to improve learning outcomes and workforce preparedness, but also for improving retention, diversity, and inclusion in engineering disciplines as well. Tonso reported that "in an especially comprehensive engineering education reform project aimed at the freshman level, incorporating contributed to dramatically reducing attrition" from undergraduate engineering programs [7]. Furthermore, mentorship and friendships established through collaborative learning experiences may allow female engineering students to develop support networks to succeed in the "isolated and individualistic environment" of engineering departments at the undergraduate level [16]. However, to succeed in this endeavor, concerted efforts must be made to ensure students do not "dominate teamwork settings, take advantage of their colleagues, or avoid performing their share of the work," particularly along gendered, racial, or other social divisions [7]. At the individual level, psychological safety refers to "how safe an individual feels in the team of interpersonal risk-taking" [17]. Psychological safety has been shown to be significantly influenced by the gender composition of engineering capstone teams, with women reporting higher psychological safety than men while "increased team gender-diversity led to a reduction in perceived psychological safety" [17]. Additionally, studies assessing psychological safety in mixed-gender teams found that men viewed conflict as positive team interactions, while women viewed conflict as a negative interaction that damaged their psychological safety on the team" [17]. Given the importance of conflict management to industry preparedness, psychological safety may play a critical role in women's ability to develop key conflict resolution skills necessary to succeed in the engineering workforce [18]. This intersection between conflict management and psychological safety may be an important driver in female attrition in the transition from higher education to work, though further research must be conducted to identify pedagogical strategies to improve female retention in engineering.

Interestingly, recent studies have indicated that the gendered acquisition of social competencies by women in engineering design teams may enhance their employability compared to their male counterparts, as "women were generally found to put more emphasis on the importance of transferable skills, such as communication skills, teamwork skills, and social skills" [19]. Mirroring the experiences of female students in collaborative learning environments, women demonstrate a greater understanding of "the societal requirements and expectations from employers" in an engineering workplace, relying on well-developed organizational and communication abilities [19]. Ultimately, the unequal division of labor in engineering design teams does a disservice to men who demonstrate performance-avoidance of "generic skills and competencies (communication, teamwork, and sustainability)," requiring a greater understanding of team dynamics and effectiveness to improve learning outcomes for future engineers [19].

Team Learning Beliefs and Behaviors Model

There are a variety of tools and frameworks developed to evaluate and characterize teamwork skills and team effectiveness, including the Teamwork Knowledge, Skills, and Abilities (KSA) Test (a psychological tool to assess the ability of an individual to work in a team) and the Comprehensive Assessment of Team Member Effectiveness (CATME) (a peer evaluation tool to deliver feedback in academic settings) [4]. However, among each of these models, there are inconsistencies in identifying critical teamwork competencies [6]. This paper utilizes the Team Learning Beliefs and Behaviors (TLBB) framework, which positions interpersonal and sociocognitive processes in team effectiveness, performance, and mutually shared cognition and emphasizes the importance of analyzing individual student behavior within the social and cultural context of the team [20]. Specifically, the TLBB model characterizes beliefs in interpersonal contexts (psychological safety, interdependence, group potency, and cohesion) as prerequisites for team learning behaviors (e.g., construction, constructive conflict, and co-construction) [20]. Furthermore, the TLBB framework separates cohesion into “social” and “task” cohesion categories, where “social cohesion” describes the sense of belongingness among team members and “task cohesion” describes the shared goals for success and performance, as well as conflicts that may arise when the team is not united in these aspirations [20].

Given that Pfluger *et al.* reported that capstone groups across institutions consistently identify the social-oriented attribute of interdependence to be the most important team quality by over 43%, followed by results-oriented task cohesion with 33% and social-oriented psychological safety with 20%, it is necessary to better understand what role gender plays in establishing these team qualities [6]. This paper builds on previous capstone research studying team inclusivity and evaluates how gender impacts social cohesion and task cohesion in senior engineering capstone teams, as well as the influence of gender on self-efficacy and role determination in groups from a small subset of engineering design students.

Methods

Research Questions

This paper will examine the following research questions:

1. How does team gender composition influence social and task cohesion in senior engineering capstone courses?
2. On an individual level, how do differences in self-efficacy based on gender influence role determination and team leadership in capstone teams?

Researchers' Positionality

Both authors self-identify as women and have experienced the impact of biased behaviors on team performance in undergraduate engineering courses. Madeline Szoo is a fifth-year Chemical Engineering and Biochemistry undergraduate at Northeastern University. Her experiences across multiple undergraduate engineering classes as a woman in predominantly male, or mixed-gender groups, greatly influenced her interest in this research topic and informed her decision to focus her analysis on gender as the social factor of interest, despite the notable influences of race and socioeconomic status which have been excluded from this study. Courtney Pfluger is a Teaching

Professor at Northeastern University and has taught design-related courses for over 10 years, with 6 years in First Year Engineering design courses, including developing and implementing the redesign of the first-year engineering curriculum incorporating design and problem-solving through data analysis using computer tools. Professor Pfluger has also taught unit operations laboratory courses for 3 years and senior capstone design for 4 years, and has conducted significant research into the importance of group formation and factors affecting team dynamics in undergraduate engineering coursework [6].

Site Description

Northeastern University is a large, private, R1 University in Boston, Massachusetts. Approximately 23,692 undergraduates were enrolled at the University in Fall 2023, with 2,625 students enrolled in the College of Engineering [21, 22]. About 40.65% of the undergraduate student body was white, and 56.42% identified as women [21]. Northeastern University has an established co-op program, where students are given the opportunity to work in academic and industrial settings to obtain valuable experiential, hands-on learning; 57% of undergraduate engineering students received a co-op offer in the 2023 - 2024 academic year, with 97% of engineering undergraduates in the 2023 graduating class having participated in at least one co-op [22]. All first-year engineering students are required to complete a two-semester Engineering Cornerstone course as an introduction to teamwork. This introductory engineering course introduces students to the engineering design process and algorithmic thinking using a combination of lectures, hands-on projects, and labs while encouraging critical thinking.

Capstone Courses

The Bioengineering Capstone is a two-semester course that offers students an opportunity to apply design principles to create a device or process to solve a relevant bioengineering problem. Students are formed into teams and paired with a faculty advisor and supporter. Teams develop, construct, and evaluate prototypes under real-world fiscal, regulatory, and safety conditions.

The Chemical Engineering Capstone is a one-semester course that offers students an opportunity to participate in an open-ended, project-based design class where teams design innovative solutions for a comprehensive chemical process. Teams generate proof of concept data from prototypes, experiments, or simulations of the process to show the design is feasible.

The Civil and Environmental Engineering Capstone is a one-semester course where students design a civil engineering project that primarily involves the environmental, structural, or transportation subdisciplines. Design teams are advised by a faculty member and engineering practitioners.

The Electrical and Computer Engineering Capstone is a two-semester course that requires students to select a project requiring the design and implementation of an electrical, electronic, and/or software system, including evaluation of multiple constraints and use of appropriate engineering standards in the design; formation of a team to carry out the project; and submission and presentation of a detailed proposal for the work.

The Mechanical and Industrial Engineering Capstone is a two-semester course that culminates the student’s education and experience with the design process. Students form teams and are assigned their design project and faculty adviser. A working prototype or simulation, as appropriate, of their solution is required to complete the course.

Data Collection

This study involved a 15-minute voluntary survey that included information about demographics and student perceptions of effective teams for current senior engineering capstone students across multiple engineering disciplines. TLBB dimensions were measured using scales taken from validated questionnaires [20]. This survey received human subject research permissions by the Institutional Review Board (IRB).

Findings and Results

Limitations

At Northeastern University, senior engineering capstone courses typically take place in the spring semester, with two-semester projects occurring in the summer and spring, and one-semester projects occurring in the spring semester only. As such, the response rate for this study was much lower than anticipated, particularly at the end of the semester. Given the scarcity of data, the pre-survey was predominantly utilized to predict student trends, so further research will be conducted to determine if start-of-semester perceptions correlate directly with end-of-semester outcomes.

Response Rate

The pre-semester survey (pre-survey) received 15 responses, including 8 men, 6 women, and 1 student who self-identified as Nonbinary/Genderqueer/Agender (non-gender, neutrois). These students were at the start of their Electrical and Computer Engineering (47%), Bioengineering (33%), or Mechanical and Industrial Engineering (20%) capstone course. Regarding capstone team composition, 60% of students reported working in a mixed-gender team, 27% reported working in an all-male team, and 13% reported working in an all-female team in the pre-survey. In contrast, the post-semester survey (post-survey) received 7 responses, including 4 women and 6 men. These students were at the end of their Bioengineering (28.5%), Electrical and Computer Engineering (28.5%), Mechanical and Industrial Engineering (28.5%), or Civil and Environmental Engineering (14.3%) capstone course. Regarding capstone team composition, 71% reported working in a mixed-gender team, 14% reported working in an all-male team, and 14% reported working in an all-female team.

Abilities and Perceptions

Entering the course, students were asked to rank the perceived importance of various qualities for team effectiveness, such as completion of team deliverables, positive interactions between teammates, clear team organization and management, high-quality work and refinement of deliverables, and technical knowledge and skills. Students ranked these five qualities from most important (1) to least important (5). As a cohort, students marked clear team organization and management as the most important quality for team effectiveness, followed by positive interactions between teammates, and technical knowledge of skills as the least important quality for team effectiveness (see *Fig. 1*). Differences in pre-survey importance rankings were not statistically significant when comparing responses from male and female students. Similarly, students were asked to rank their ability entering into the course to complete the following team competencies: lead completion of team deliverables, maintain positive interactions between teammates, set internal deadlines and assess timelines, refine and polish deliverables to a high quality, and contribute to technical knowledge and skills from most important (1) to least important (5). While there was not a statistically significant consensus from the full cohort for their incoming competencies, differences were observed when comparing student abilities by gender. Entering the engineering capstone course, female students reported greater confidence in their ability to lead the completion of team deliverables compared to male students, while male students reported greater confidence in their ability to refine and polish deliverables to a high quality compared to their female counterparts (see *Fig. 2*). These differences were statistically significant, despite the small sample size. However, by the end of the semester, there were no statistically significant differences in perceived teaming abilities between men and women; the full cohort indicated that by the end of the semester, they felt most confident in their ability to maintain positive interactions between teammates and least confident in their ability to refine and polish deliverables to high quality (see *Fig 3*).

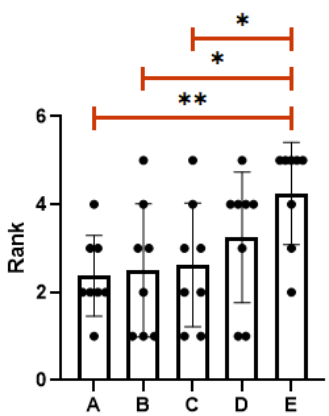

Figure 1. Pre-survey full-cohort perceived importance of team effectiveness qualities.

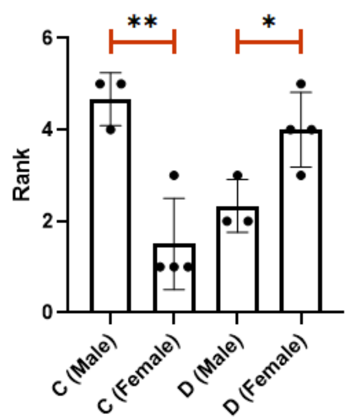

Figure 2. Pre-survey perceived abilities for team effectiveness compared by gender.

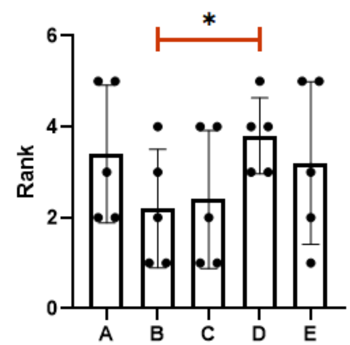

Figure 3. Post-survey full-cohort perceived abilities for team effectiveness.

1 = most important; 5 = least important.

A: Team organization and management of internal deadlines and timelines.
B: Maintenance of positive interactions between teammates.
C: Completion of team deliverables.
D: Refinement of deliverables to a high-quality.
E: Contribution to technical knowledge and skills.

*Averages and standard deviations depicted; t-tests performed for statistical significance, where * represents $p \leq 0.05$, ** represents $p \leq 0.01$, and *** represents $p \leq 0.001$.*

Organization and Motivation

In both the pre- and post-survey, students were prompted with Likert scale questions to evaluate their perception of team organization and management. Students were asked to rate how much they agreed with statements such as “the team leader should organize team meetings and plan internal deadlines”, “all members of the group should contribute to team organization and logistics”, “I should be motivated by members of my team to complete team goals”, and "members of the group should be intrinsically motivated to complete team goals" to elucidate student expectations for the roles of team leaders and individual group members. At the start of the course, students agreed that group work should be conducted communally more than they believed that it was the responsibility of the group leader to implement organization; this view was further supported by general student agreement that group members should be both intrinsically motivated to accomplish team tasks, as well as derive motivation from other group members (see *Fig. 4*). Interestingly, there did appear to be a gendered split when it came to the role of group leaders at the start of the semester, with female students more enthusiastically agreeing that the team leader was responsible for organizing group tasks, and male students remaining neutral on this subject (see *Fig. 5*). There were no notable differences across genders in the evaluation of communal organizing efforts or motivations. However, trends in the full-cohort analysis at the end of the semester indicate that student perception shifted slightly, with no statistically significant difference between agreeing with leader-based logistics or communal organizing efforts (see *Fig. 6*). This loss of communal organization as a statistically significant preference over leader-driven goal setting and task management within the full cohort by the end of the semester may point to an increasing desire to establish a social and logistical hierarchy, though the impacts of this phenomenon on team performance are currently unclear.

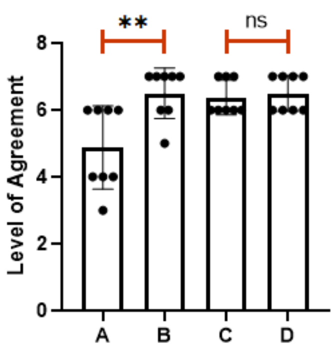

Figure 4. Pre-survey full-cohort organization Likert scale averages.

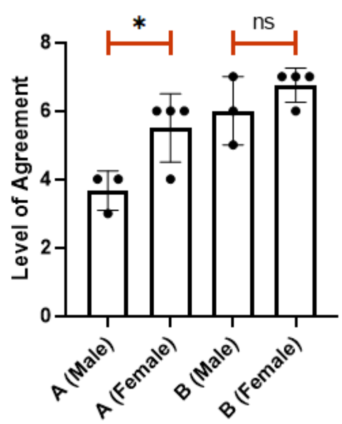

Figure 5. Pre-survey organization Likert scale averages compared by gender.

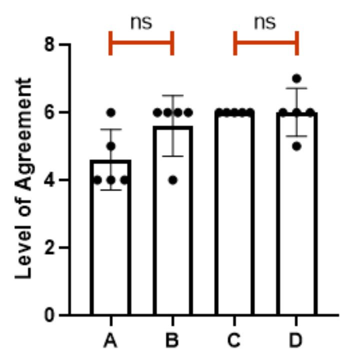

Figure 6. Post-survey full-cohort organization Likert scale averages.

1 = Disagree completely; 2 = Disagree; 3 = More or less Disagree; 4 = Neutral; 5 = More or less Agree; 6 = Agree; 7 = Agree completely.

A: Leader implements team organization.
B: Team communally implements organization.
C: Members of the team should be extrinsically motivated.
D: Members of the team should be intrinsically motivated.

*Averages and standard deviations depicted; t-tests performed for statistical significance, where * represents $p \leq 0.05$, ** represents $p \leq 0.01$, and *** represents $p \leq 0.001$.*

Social and Task Cohesion

To evaluate the roles that social and task cohesion play in team effectiveness, students again completed Likert scales reporting their levels of agreement or disagreement towards statements such as "I should be friends with the members of my team" or "the team should be united in trying to reach its goals for performance". As described by Pfluger *et al.*, social cohesion was evaluated through statements pertaining to friendships, common interests, and feeling important and/or accepted as a member of the group [6]. In contrast, task cohesion was evaluated with statements relating to achievement, ambition, commitment, diligence, goal-setting, and task completion [6]. Concerning social cohesion, students reported a strong preference for “getting along” with members of the team and feeling a “sense of belongingness,” as opposed to “being friends” with members of the team at the start of the semester (see *Fig. 7*). This preference was maintained throughout the semester, and no gendered differences were observed in the prioritization of socially-oriented values. As for task cohesion, students perceived an understanding of the task as a more critical competency for group members than the ability to complete the task (see *Fig. 8*). Furthermore, students prioritized the team being united in their goals for performance over their satisfaction with team performance at the start of the semester (see *Fig. 8*). There were no statistically significant changes from pre- to post-survey responses or across genders for social or task cohesion perceptions, though the sentiment that the team should be united in its goals for performance was the most agreed upon statement of all post-survey Likert questions (with an average score of 6.4 ± 0.49).

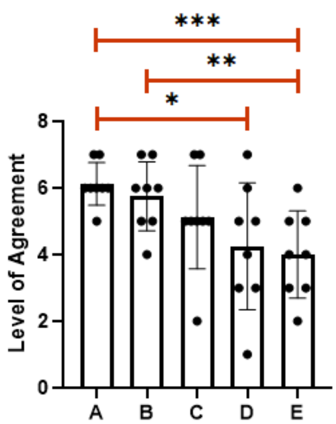

Figure 7. Pre-survey full-cohort social cohesion Likert scale averages.

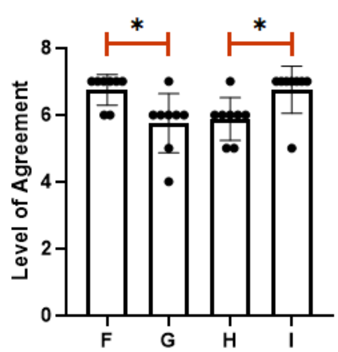

Figure 8. Pre-survey full-cohort task cohesion Likert scale averages.

1 = Disagree completely; 2 = Disagree; 3 = More or less Disagree; 4 = Neutral; 5 = More or less Agree; 6 = Agree; 7 = Agree completely.

A: I should get along with members of my team.
B: I should feel a sense of belongingness to my team.
C: I should like my team.
D: I should want to work with my team in the future.
E: I should be friends with my team.

F: We should have an understanding of the task.
G: We should know how to execute the task.
H: We should be satisfied with team performance.
I: We should be united in our goal for performance.

*Averages and standard deviations depicted; t-tests performed for statistical significance, where * represents $p \leq 0.05$, ** represents $p \leq 0.01$, and *** represents $p \leq 0.001$.*

Discussion

The results of this study support previous findings indicating the importance of the socially-oriented attribute of interdependence to the success of senior engineering capstone teams, as well as the significance of results-oriented task cohesion, based on differences in self-efficacy at the start of the semester. Based on the responses in this study, students enter capstone with variable confidence in their ability to manage both the logistical aspects of the project (i.e., completion and refinement of team deliverables) and the technical aspects. These differences have been assessed across genders, with female students reporting greater comfortability in leading the completion of team deliverables, and male students reporting greater comfortability in refining and polishing deliverables (though all students indicate a significant perceived preference for clear team organization and management at the start of the semester). While these qualities may not be mutually exclusive, these differences may be indicative of a dichotomy in self-efficacy across gender lines; women may exhibit greater confidence in their organizational and communication abilities (social abilities) compared to completing technical tasks, while men may pursue detail-oriented rather than systemic project goals due to performance-avoidance. While there were no statistical differences in self-reported team leadership based on gender, these results may indicate an undue burden on female engineering students to galvanize their teams in a leadership capacity at the start of the semester.

Additionally, how students perceived leadership in workload distribution and task determination at the start of the semester varied by gender as well. While male students emphasized communal organizational efforts at the start of the semester, female students reported agreement with the sentiment that team organization should be implemented by the group leader. Given the gendered differences in self-reported organizational and leadership competencies, these results further indicate a pressure on female students to drive goal-setting efforts at the start of the semester.

Interestingly, among gendered differences in project management and communication skills, men reported greater confidence in their ability to maintain positive interactions with their teammates and other social aspects at the start of the semester than women in their groups, on average. However, these differences were not statistically significant across genders, so further research involving a larger sample size must take place to determine how women's social experiences might differ from men's in capstone engineering teams, particularly in instances of mixed-gender groupings, and what impact (if any) these differences have on the distribution of workload.

Ultimately, students perceived being united on goals for performance as the most important factor for team effectiveness, even over satisfaction with team performance. This quality was conveyed both through Likert-scale questions as well as through students' written responses. As one student writes, "a variety of attributes are necessary [for an effective team], but I think that the most important thing is that everyone is on the same page about how much effort needs to be put in to [*sic*] the project." Students also emphasized the importance of getting along with teammates as opposed to being friends, with one student commenting that "respect and communication with each group member to hold each other accountable and value / integrate different opinions" is vital for effective teaming.

Implications

The results of this study indicate that gender may influence team dynamics in capstone engineering courses, with differences in leadership and goal-setting practices varying based on student gender and, potentially, team gender composition. As such, surveys similar to the Comprehensive Assessment of Team Member Effectiveness (CATME) may be beneficial in determining team assignments and ensuring diverse group compositions. Furthermore, beyond team formation, instructors may work to implement more equitable role formation practices as well, to prevent the unequal organizational/logistical and detail-oriented task assignments observed in this study, particularly at the start of the semester. Students in this study reported a variety of different role-determination practices, predominantly voluntary self-selection based on student interests, preferences, and perceived personal strengths, which may exacerbate performance-avoidance practices based on gendered differences in self-efficacy. Some groups reported no formal role delineation and no role reassignments throughout the semester, with one student writing “whoever took up [a] role, had it” and another commenting “I just ended up being the one in charge.” Providing students with rotating role expectations and emphasizing the importance of flexibility in team role assignments may help to mitigate gender bias in team leadership and promote psychological safety. As one student explains, “You might not always get a perfect mix of personalities in a group, so its [*sic*] super helpful when some of the members can operate/excel in different/varying roles. I find the flexible members are often the easiest to communicate with and everyone feels comfortable giving input which is the best group dynamic.”

Future Directions

Senior engineering capstone courses typically take place in the spring semester, with two-semester projects occurring in the summer and spring, and one-semester projects occurring in the spring semester only. As such, the response rate for this study was much lower than anticipated, particularly at the end of the semester. A follow-up study will be conducted focusing on Chemical Engineering capstone students in Spring 2025 with an anticipated response rate of over 50 students. This will allow for greater statistical testing across genders and the potential inclusion of other social factors, such as race. The follow-up study will be used to re-evaluate the results of this present study to determine if the same trends hold true with a larger sample size.

Conclusions

Ultimately, this study built on previous capstone research studying team inclusivity and utilized the Team Learning Beliefs and Behaviors (TLBB) Model to demonstrate how gender impacts self-efficacy, role determination, and goal setting in senior engineering capstone teams. Specifically, the results of this study emphasize the importance of unified performance goals for perceived team effectiveness and suggest potential benefits of instructor-assigned or rotating team roles to prevent gendered team leadership and work distribution based on performance-avoidance and perceived abilities, particularly at the start of the semester. Analysis of the responses reported in this study will lay the groundwork for future studies exploring these phenomena with a greater student population size.

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