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# Female Student Attitudes Towards Engineering: Are They Influenced by the Roles They Take on Project Teams?

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*Keywords:* Women in STEM, Self-Efficacy, Active Learning, First-Year Projects Courses, Team Roles, Team Dynamics

## Introduction

The increase of diversity in STEM fields is a growing conversation and source of concern for engineers. While universities report that the number of women students graduating with an engineering degree has increased, there still exists a surprising lack of women in engineering careers nationwide [1]. Strategies such as active learning and collaborative learning have been at the forefront of curricular change, in part due to evidence that these interventions improve long-term material retention and critical thinking skills [2], [3]. Many engineering universities allow undergraduate students to take a hands-on project course during their first year or as a senior capstone as part of their degree, in which they work on a team with students from a variety of backgrounds to achieve a common goal. During these project courses, the students gain valuable experience working on teams and presenting their work to reviewers intended to prepare them for careers post-graduation. These courses are often evaluated through end-of semester surveys and questionnaires that query their course experience and skills gained. For several years, the first-year projects course in the University of Colorado Boulder's College of Engineering and Applied Science has included additional questions around identity and intent to complete engineering careers in their course surveys.

Course surveys do not fully capture the quality of the students' experience in a project design course. While correlation of completion through subsequent engineering semesters exists, we posit that the courses may create a confidence gap due to perceived value of the student's role on the team that impacts their identity and retention. Throughout this course, students concurrently complete peer evaluations of their teammates and answer questions around the types of roles each team member is taking on over the course of the main project. This paper will compare the identity and team course survey items for students enrolled in a first-year projects course at the University of Colorado Boulder to trends with scores on peer evaluations and team member role identification from the same sections of the course. We also further analyzed the peer evaluations and team roles identification of nine women students to determine if there is differential value placed on specific team roles. Together, these data will help give insight to the experiences of female students in engineering team-based projects classes.

## Background

In January 2021, the U.S. Census Bureau reported that women make up almost 50% of the workforce but have held less than 27% of the STEM jobs in the United States [1]. Specific to engineering, their report shows that computer and engineering occupations make up the largest portion (80%) of the STEM workforce, though females working in engineering occupations has increased only to 15% in 2019 [1]. Additionally of concern, women who enter undergraduate

degree programs in STEM are less likely to complete their degrees than men; one study found among college sophomores who declared STEM majors, 42.5% of women went on to complete a STEM degree, compared with 58.2% of men. [4]. These trends are undeniably concerning, especially as our workforce needs more diverse perspectives to solve rising challenges in STEM innovative capacity.

Low self-efficacy for engineering concepts and technical abilities is a significant factor in explaining the current attrition rates for undergraduate engineering degrees across demographics [5], [6]. While low self-efficacy of female students impacts career goals and retention in STEM, several interventions have been shown to positively impact student self efficacy and identity with the engineering profession. Among these are internships, skill-building workshops, and hands-on projects [6], [7].

Additionally, engineering program accreditation emphasizes integrating collaboration and communication into undergraduate engineering education, and there is little question that teamwork is an integral component in university senior capstone courses and first-year engineering design courses. ABET requires that engineering degree-granting programs demonstrate student outcomes to better prepare our engineering graduates to enter the professional engineering workforce post graduation, including "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [8]. Representation of women in STEM should not only be reflective of the larger population but should also include representation across leadership levels to best improve progress towards global competitiveness.

With the increased focus on relevant teamwork experiences in engineering undergraduate programs comes a focus on how to navigate team dynamics and students' roles on project teams. Specifically, faculty are curious on how to evaluate their students based on the roles they take on within teams. According to previous research in applied psychology and social sciences, team members take on different roles over the span of the course or project that correspond to specific behaviors [9]. Often these team roles are classified as being more technical or non-technical and are categorized loosely into "technical" versus "professional" roles.

Leadership identity construction is another important aspect of team development, as an individual's role on a team drives their motivations and actions [10]. After a team is assigned, team members often adopt their defined roles through a granting and claiming process, where they either "claim" a role on the team or are "granted" a role by other team members based on specific skills or personality traits [10]. Over time, assumptions on what individuals in each role should "look like" or behave become normalized across groups. For engineering students, this may contribute to a decreased ability to redefine team roles across a broader range of individuals, leading to conflict between team members and less motivation for some students to contribute to the project. Additional research suggests prior knowledge and "impressions" of a student's ability and personalities influence what role they are granted by team members [11] and what a person is perceived to know about the topic based on their identity (such as being male or female) influences the decision-making process on diverse teams [12].

This is especially concerning for female students if perceptions of ability or previous experience keep them from claiming or being granted leadership roles on their teams. Prior studies call for more research around increasing team members' "role repertoires" or the number of different roles an individual can take on based on what is needed by the team as a potential benefit to team performance [9].

The connection between increasing diversity in STEM fields, student retention, and students' ability to practice different team roles during their undergraduate careers is worth investigating. According to the University of Colorado Boulder, since 2010 the number of female students in undergraduate engineering degrees has risen while their retention and graduation rates have remained relatively stable [13]. This is amidst the rise in research-based interventions, hands-on projects-based course offerings, active learning in core courses, and increased skill workshops available to students. For example, University of Colorado Boulder engineering students have the option to take more hands-on projects courses as part of their degree, in which they work on a team with students from a variety of backgrounds to achieve a common goal. This should present itself also as an opportunity for increasing students' role repertoire, allowing them to better value the different roles that engineers can take on teams.

**Research Objectives**

Our recent review of first-year survey data shows a slight decrease in identity and efficacy with engineering for some groups of students in our project classes, including female students. Subsequently, students enrolled in any first-year engineering projects course during each academic year were solicited to participate in 45-60 minute focus groups with 3-5 students total. Within these focus groups, we asked the students about their thoughts on active learning courses and team dynamics, as well as suggestions of improvement for the course. The focus group data was used primarily to determine the areas of research needed around the female student experience at the university and program levels. Both of these previous efforts led us to partner with our School of Business to understand factors influencing teamwork and team dynamics that may lead to a gap in confidence and persistence due to perceived value of the student's role on the team.

The overarching goal of this research project was to delve into the impacts on women students' engineering identity and experience with their team alongside the roles they take on during the project. Specifically, sections of the spring 2021 semester of the College's first-year engineering projects class were analyzed. We examine the identity and team survey questions for students enrolled in a first-year projects course and compare those trends with trends in peer evaluations around value and roles taken from the same sections of the course to give insight of changes in student professional identity and satisfaction with team-based projects within our engineering undergraduate program.

We are curious if team roles have an impact on students' satisfaction with their teams and persistence in engineering. The primary research question addressed in this study is "How do the roles that female students take on team-based project courses impact their connection to and experiences with engineering?" To support this research, additional questions include:

- How do female students' identity with engineering at the conclusion of participation in a team-based projects course compare to their male peers?
- How do female students' levels of satisfaction and acceptance on the teams compare to their male peers following a team-based project course?
- What roles do female students typically take on engineering design project teams?
- Is there a difference in the value placed on the team roles taken by female students and male students on an engineering design project team?

**Methodology**

*Setting for Analysis*

The analysis for this research takes place in the University of Colorado Boulder's College of Engineering's first-year engineering projects course during the spring 2021 semester. This course, described through previous research, engages ~45% of the college's first-year students each year and brings students from different disciplines, ethnicities, genders, and backgrounds together through a semester-long, team-based design project [14]. The course is a team-based projects course, and each student is placed into a team of 4-5 students within each section to complete the semester-long project. Each section has a capped enrollment of 30 students, or approximately six teams per section. This project did not require specialized physical space or resources, as the vast majority of the data was collected via online surveys and peer evaluation data.

*Student Team Development*

There is significant variability among team experiences, as individual professors refine their method of team formation and amount of team communication training to fit with their project focus. Teams for this course are formed by individual faculty based on a short skills survey offered during the first week of class. The skills survey asks students to identify their major, area of project interest and previous experience with prototyping and manufacturing skills, such as Computer Aided Design (CAD), programing, 3D printing, electronics, and machining. Faculty are instructed to form teams by diversifying the majors and skills of students on each team. Students also engage in a short communications style workshop during the first week of the semester to initiate discussion around team communication. Students do not receive pre-assigned roles or required training on the types of team roles prior or during team development, so selection of team roles occurs naturally over the duration of the semester.

*Data Collection*

The majority of data for this research has been collected from first-year projects course sections in the form of course surveys taken by the students and peer evaluations. We narrowed the responses by gender, first-generation and URM (Under-Represented Minority) - identifying students and looked for correlations between the responses of the pre/post semester course surveys. For course evaluation and improvement, we determine if the course ended up having a positive or negative impact based on change in responses over time. In addition to the course surveys, student teams fill out peer evaluations at both the midterm of the semester and at the end of the course, which

include questions about roles on the team. Team members are first asked to score their teammates in relation to each other and then decide which roles their peers either "fall into" or "take hold of" on the team.

This combined data lends itself to multiple analyses. We first looked for trends in data across the overall pre/post course surveys, and then compared that data to individual level peer evaluation data to determine additional team role-level factors that might influence the students' attitudes towards their team members and overall team experience.

This research requires a mixed methods approach. We used quantitative Likert scale survey data, as well as qualitative survey data, individual student open-ended survey questions, and focus groups to narrow into our research questions for this paper. Programs such as Excel, Google Sheets, Matlab, and other data processing software were used to more easily comprehend and analyze the data. Each of the methods of data collection and analysis are discussed in more detail below. Surveys and focus groups from students were conducted with approval from the University of Colorado Boulder Institutional Review Board (IRB). Student names have been removed or given pseudonyms to conceal their identities.

*Course Surveys*

This data collected through the surveys could certainly open up opportunities to look at impacts of these courses for other groups, such as underrepresented groups or first-generation college students. For this paper, however, we primarily focused on comparing responses from students who self-identify as female and male in their survey responses. While course surveys are given to students during the first and last weeks of the semester, for the purposes of this study, only post-semester data was used. Questions from post-surveys that were analyzed include:

- Engineering Identity: Adapted from the Engineering Identity Survey developed by Chachra et al., which assesses the degree of participants' group identification with engineers (source of 8 items) [15]
- Engineering Team Satisfaction: Developed by course faculty to assess the degree of students' satisfaction with their team (5 items)

For Likert-style questions, data was aggregated and analyzed into three categories (Strongly Agree and Agree; Somewhat Agree, Neutral or Somewhat Disagree; and Strongly Disagree and Disagree) for comparison purposes. Percentages and number of respondents are used to illustrate student attitudes towards community and engineering identity.

These surveys were distributed through Qualtrics, and the data focused on aligning the data sets into a usable format and analyzing one pilot semester (Spring 2021).

*Peer Evaluations Survey*

Peer interaction and team-role data were collected using mid- and end-of-semester peer evaluations which were subsequently anonymized and examined for patterns of responses between teammates. The peer

evaluations were delivered during the course in the form of an online survey that asked students to divide 1000 points (in the form of bonus dollars) among their team members, based on their contribution to the team and project. The survey also asked students to provide an open-ended rationale for their distributions. This value was used as a proxy for the grade students would give their teammates and often considers accountability, skills knowledge, attending team meetings, active participation in class, and overall professionalism and likeability.

Each team member was given a score for "self" and "others" on their team according to the points received on the peer evaluations. For this study, student and team scores were analyzed by the amount of points or "dollars" above or below what each team member would receive if the workload was shared evenly, which we describe as a "baseline" score. For example, a baseline score for each member on a team of four is 250 points out of 1000 (or dollars) and each team member on a team of 5 would be 200 points out of 1000.

Following the bonus dollars valuation of their teammates and rationale, students are asked to rate (on a Likert scale of 1-5) how well their teammate performs three actions within each of seven technical/task-oriented or non-technical/team-oriented team roles as defined by Mumford and colleagues [9]. These roles include: Facilitator/Conflict Management Role, Organized Leader Role, Supportive Team Player Role, Creative Problem Solver Role, Thinker Role, Communicator Role, and Expert Contributor Role.

Development of students' roles on their time occurs naturally over the course of the semester. No formal instruction is given on team roles during the course. Course faculty use the peer evaluation data to have meaningful conversations with the students about their roles on the team, while the research team uses anonymized and aggregated data to look for trends by demographic.

**Results**

Course survey and peer evaluation results showed that a variety of factors are used to define team roles and influence identity with engineering in first-year projects courses.

*Pre/Post Course Survey Findings*

*Engineering Identity*

To assess engineering identity, an 8-item measure was used. Items and codes are shown in Table 1 below.

Table 1. Engineering Identity Measure Used for Analysis

| Code | Item |
|---|---|
| ID1 | I identify with engineering students. |
| ID2 | I am proud to be an engineer. |

| | |
|---|---|
| ID3 | I can be myself and be an engineer at the same time. |
| ID4 | It is my intention to pursue a career in engineering. |
| ID5 | Almost anyone can succeed in engineering with enough hard work. |
| ID6 | In general, being an engineering student is an important part of my current self-image. |
| ID7 | Being an engineering student is an important reflection of who I currently am. |
| ID8 | Being an engineering student is important to my sense of what kind of person I am now. |

A stacked bar chart visually compares the percent of students' response on a Likert-scale of 1-7 for each of the statements. Engineering identity results for women are depicted in Figure 1; Figure 2 displays the results for male students.

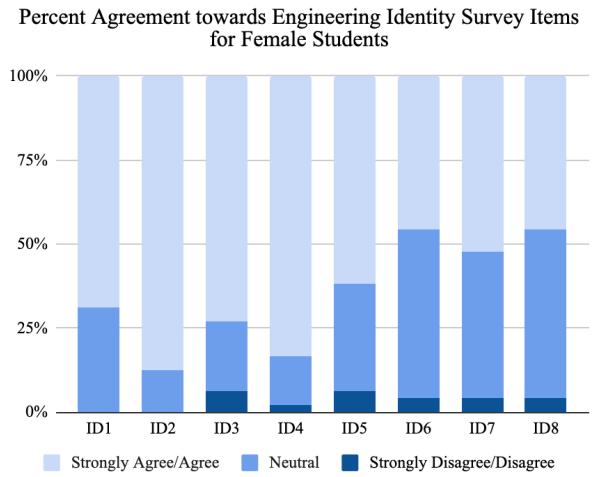


Figure 1. Percent Agreement towards Engineering Identity Survey items for Female Students (n = 48)

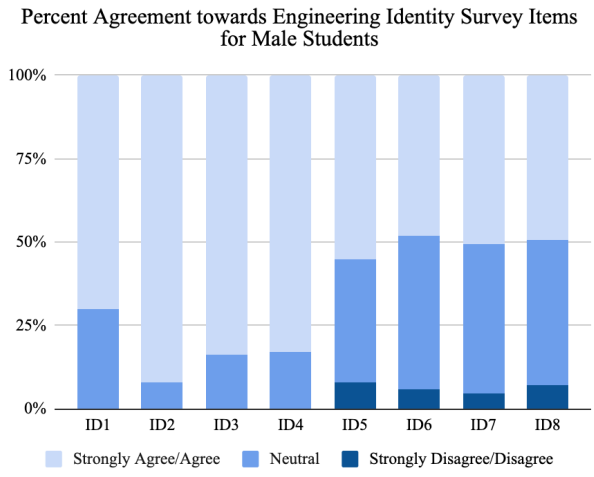


Figure 2. Percent Agreement towards Engineering Identity Survey items for Male Students (n = 87)

The largest percent agreement (combining Agree and Strongly Agree) for both female and male students on the engineering identity items was for "I am proud to be an engineer" (ID2; 88% agreement women, 91% agreement men). Other items with high agreement for female students include, "I can be myself and be an engineer at the same time" (73% agreement; ID3) and "I identify with engineering students" (69% agreement; ID1). For male students, "I can be myself and be an engineer at the same time" (82% agreement; ID3) and "It is my intention to pursue a career in engineering" (82% agreement; ID4) scored the next highest.

The lowest agreement for female students is in “In general, being an engineering student is an important part of my current self-image” (46% agreement; ID6), and “Being an engineering student is important to my sense of what kind of person I am now” (46% agreement; ID8). Male students also had a low score for “In general, being an engineering student is an important part of my current self-image” (48% agreement; ID6). These responses suggest that all first year engineering students are already confident in their connections to, and identity with, engineering. However, many students do not define engineering as the only important influence of their identity.

*Engineering Team*

To assess engineering team experience and belonging, an overall rating of experience and a 4-item measure were used. The questions and codes are shown below in Table 2.

Table 2. Codes and Engineering Team Satisfaction Measure Used for Analysis

| Code | Item |
|---|---|
| TS1 | Rate your experience on your project team this semester |
| TS2 | I felt comfortable on my project team. |
| TS3 | I felt that I am a part of my project team. |
| TS4 | I felt that I am supported on my project team. |
| TS5 | I felt that I was accepted on my project team. |

Another set of stacked bar charts visually compares the percent of students’ response on a Likert-scale of 1-7 for each of the statements. The chart for Engineering Team Statements of women students is in Figure 3 and male students in Figure 4.

On these charts, there is little disagreement with any of the engineering team belonging statements. Both female and male students had their largest agreement (combining Agree and Strongly Agree) for “I felt that I was accepted on my project team.” (88% agreement female students, 80% agreement male students; TS5). Another item with high agreement for both female and male students include, “I felt comfortable on my project team.” (83% agreement female students, 91% agreement male students; TS2;). There were no responses that were below 75% agreement for any of the engineering team statements.

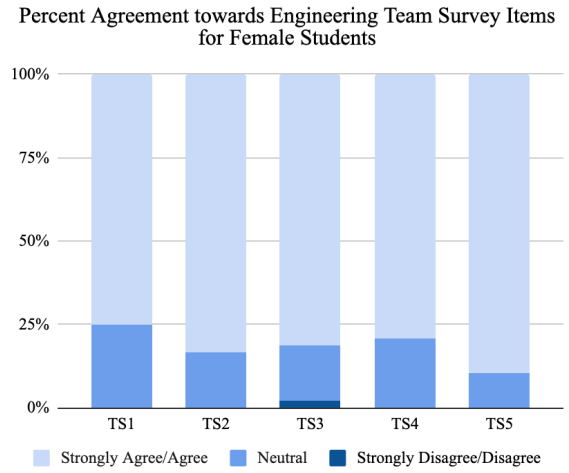


Figure 3. Percent Agreement towards Engineering Team Survey items for Women Students (n = 48)

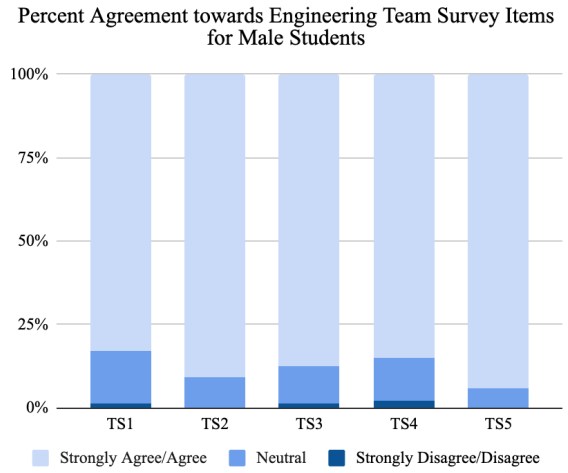


Figure 4. Percent Agreement towards Engineering Team Survey items for Male Students (n = 87)

*Peer Evaluations Survey*

Peer evaluations gathered from mid-semester to end-of-semester were analyzed to determine the value placed on team roles by students over time. As described above, student and team evaluation scores were analyzed by the amount of points above or below what each team member would receive if the workload was shared evenly, which we call a "baseline" score. For teams of four students, the baseline score was 250 bonus points, and for teams of five students, the baseline score was 200 points.

The following Table 3 describes the difference from the target score the women and men gave themselves at the mid-semester and end-of-semester evaluations as compared to the baseline scores from their teams.

Table 3. Descriptive Statistics of self- and teammate evaluation scores for female and male team members over mid-semester and end-of-semester peer evaluations.

| Variable | N | Peer Evaluation Self Mean (SD) | Peer Evaluation Team Mean (SD) | Mean Difference of Self and Team |
|---|---|---|---|---|
| **Difference from Baseline score for Mid-Semester Evaluation** | | | | |
| Female | 44 | 9.77 (46.28) | 4.31 (33.82) | **-5.46** |
| Male | 82 | 4.92 (38.12) | 6.03 (26.76) | **1.11** |
| **Mean Difference of Female and Male** | | **4.85** | **-1.73** | |
| **Difference from Baseline score for End-of-Semester Evaluation** | | | | |

| | | | | |
|---|---|---|---|---|
| Female | 27 | 9.29 (37.62) | -7.15 (26.46) | **-16.44** |
| Male | 40 | 8.66 (39.30) | -16.05 (40.86) | **-24.71** |
| **Mean Difference of Female and Male** | | **0.63** | **8.90** | |

Notes: Cell entries contain mean scores and standard deviations for student peer evaluation scores; by gender

We can see from this table that on average, female students gave themselves a higher score (5.46 and 16.44 points higher, on average) on their evaluations than their averaged score from their teammates. Male students gave themselves a similar amount of points as their team gave them on their mid-semester evaluation (1.11 points higher) and gave themselves on average 24.71 more points than their teammates gave them on their final evaluation.

Next, the difference from the baseline scores the female and male gave themselves was also compared to how they scored other teammates by gender on the mid- and end-of-semester surveys. It is important to note when comparing how genders rated a different gender, all single-gender team data was removed. Table 4 describes these relationships.

Table 4. Descriptive Statistics of self- and teammate peer evaluation scores for female and male team members over mid-semester and end-of-semester peer evaluations (women-women, men-men, and women-men/men-women).

| **Variable** | **N** | **Peer Evaluation Self** **Mean (SD)** | **Peer Evaluation Team** **Mean (SD)** | **Mean Difference of Self and Team** |
|---|---|---|---|---|
| **Women Rating Self and Women rating Women difference from Baseline Score** | | | | |
| Mid | 36 | 14.03 (34.55) | 13.75 (40.88) | **0.28** |
| Final | 24 | 16.58 (35.19) | -0.03 (28.67) | **16.61** |
| **Mean Difference of Mid and End-of-Semester** | | **2.55** | **-13.78** | |
| **Men Rating Self and Men rating Men difference from Baseline Score** | | | | |
| Mid | 36 | 4.16 (38.67) | 5.35 (28.54) | **0.28** |
| Final | 24 | 12.49 (38.14) | -4.53 (38.73) | **17.01*** |
| **Mean Difference of Mid and End-of-Semester** | | **8.33** | **-9.88** | |
| **Women Rating Self and Men rating Women difference from Baseline Score** | | | | |
| Mid | 35 | 11.86 (50.19) | 4.15 (35.94) | **7.71** |
| End of Semester | 18 | 4.5 | -8.26 | **12.76** |

| | | | | |
|---|---|---|---|---|
| | | (24.60) | (26.50) | |
| **Mean Difference of Mid and End-of-Semester** | | **-7.36** | **-12.41** | |
| **Men Rating Self and Women rating Men difference from Baseline Score** | | | | |
| Mid | 79 | 4.16<br>(38.67) | 5.35<br>(28.54) | **-1.19** |
| End of Semester | 37 | 12.49<br>(38.14) | -4.53<br>(38.74) | **17.01*** |
| **Mean Difference of Mid and End-of-Semester** | | **8.33** | **-9.88** | |

Notes: Cell entries contain mean scores and standard deviations for student peer evaluation scores; by mid-semester and end-of-semester

*Significant at the $p<0.10$ level, paired t-test

Here we notice that both female and male students give themselves and teammates of the same gender identity a similar score on the mid-evaluation. During end-of-semester evaluations, female students scored themselves 16.58 points higher than the baseline scores, versus only -0.03 points difference than the baseline scores for female teammates. Male students responded similarly on the final evaluations as they scored themselves on average 12.49 points higher than the baseline score and scored their male teammates -4.53 points difference than the baseline score. In other words, female students scored themselves 16.61 points higher on average than other female teammates score them, and male students self-score is 17.01 points higher than their male teammates scored them at end-of-semester.

When comparing their self-evaluations with their teammates of different genders, the gaps in scores widen as male students score their female teammates and female students score their male teammates. Now female students score themselves 7.71 points higher than their male teammates score them on mid-semester evaluations and score themselves 12.76 points higher than their male teammates score them at the end of the semester. In turn, male teammates score their female teammates 12.41 points lower between the mid- and female-semester evaluation. In turn, male students score themselves very similarly to their female teammates on mid-semester evaluations and score themselves 17.01 points higher than their female teammates score them at the end of the semester.

*Team Roles*

After assigning their peers a “bonus” amount, the students are asked survey questions pertaining to each of the seven team roles — Facilitator/Conflict Management, Organized Leader, Supportive Team Player, Creative Problem Solver, Thinker, Communicator, and Expert Contributor. Each team role consists of three survey questions on a 5-point Likert scale and averaged to get a team role score. Higher scores for a team role indicate more affinity for that role during the team project.  Descriptions of team roles are shown below in Table 3.

Table 5. Descriptions of Supportive Team Roles

| Team Role | Descriptive Team Statement |
|---|---|
| Facilitator/Conflict Management | Helps the team get along together by helping to settle conflicts, deal with difficult problems, and be respectful. |
| Organized Leader | Organizes the work and keeps others focused on getting it done efficiently. |
| Supportive Team Player | Supports the team and other team members in their work even if they would have personally done it differently. |
| Creative Problem Solver | Has new and creative ideas for solving problems and getting the work done. |
| Thinker | Thoroughly thinks through what the team is doing to make sure they are not rushed and consider both positive and negative aspects. |
| Communicator | Communicates clearly, honestly, and respectfully with others, making the work atmosphere more comfortable because they are pleasant to work with. |
| Expert Contributor | Shares information and advice with the team in areas where they have a lot of experience. |

Team role comparison results for a subsection of the students (n=23) are shown in Figure 5 and Figure 6 below. These results are aggregated for students over five teams who participated in the mid-semester and end-of-semester peer evaluation surveys and comparing students who self-identify as female and male in their survey responses.

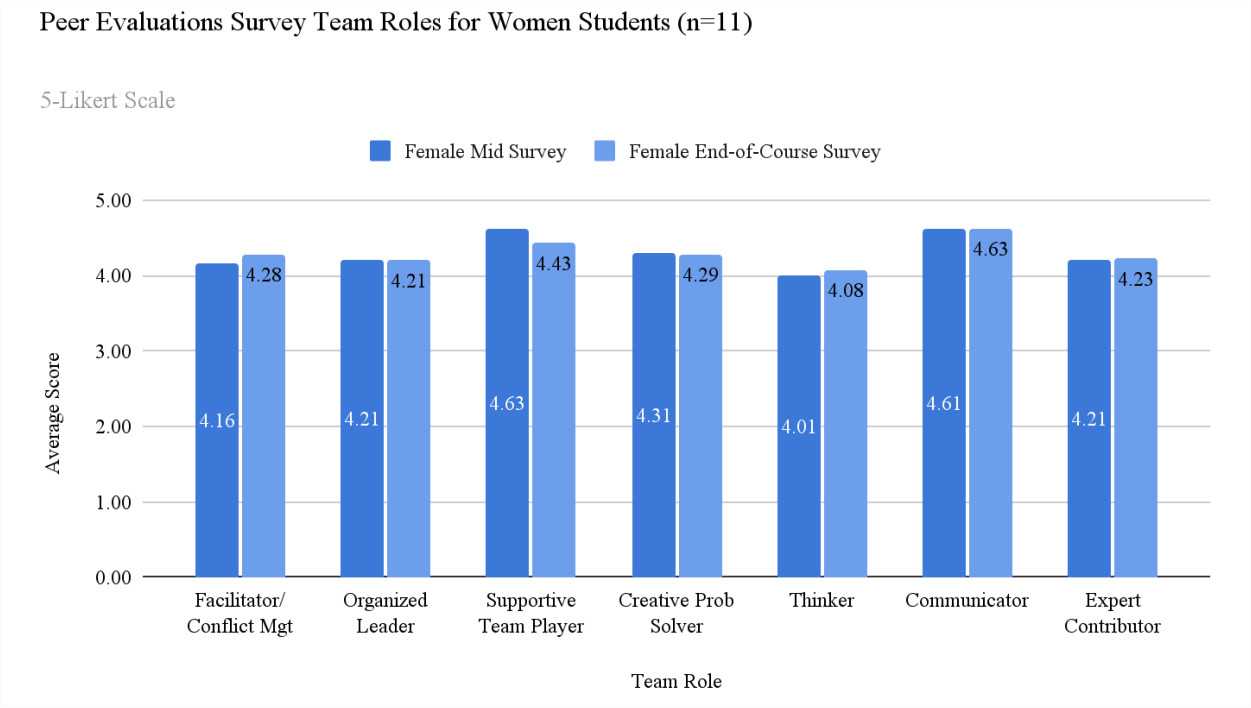


Figure 5. Peer Evaluations Survey Team Roles for Women Students (n=11)

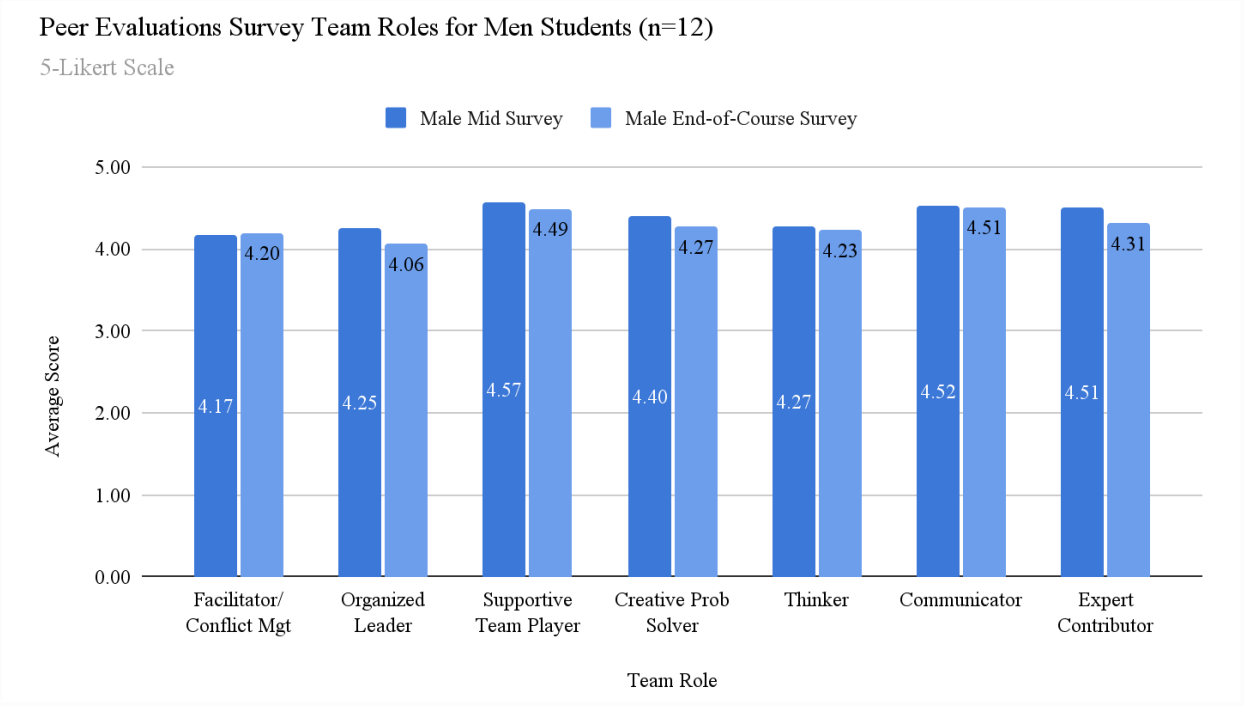


Figure 6. Peer Evaluations Survey Team Roles for Men Students (n=12)

Overall, the most common role among women and men from mid-semester peer evaluations was *Supportive Team Player* (scores: 4.63 and 4.57, respectively, out of 5), and the most common role performed by female students and male students from the end-of-course peer evaluation was *Communicator* (scores: 4.63 and 4.51, respectively, out of 5).

The least common role among female students from both mid-semester and end-of-course peer evaluations was *Thinker* (score: 4.01 and 4.08, respectively), while the least common role among male students from mid-semester peer evaluations was *Facilitator* (score: 4.17) and at the conclusion of the course was *Organized Leader* (scores: 4.06).

Additionally, the *Supportive Team Player Role* was the only role that was rated substantially lower in the post-semester evaluation survey on average compared to the mid-semester evaluation survey for female students, with the most growth in the *Facilitator/Conflict Management* role mid- to post- semester (score delta: 0.20).

Male students saw minimal growth over the semester for any roles; the *Organized Leader Role* and *Expert Contributor* roles saw the most decline in the post survey from the mid survey.

*Deep Dive into Peer Evaluations and Team Roles of Nine Women Students*

Based on the supportive team roles outlined above, further analysis was conducted on 9 of 11 female students working on 5 separate teams during the spring 2021 semester (two of the female students were removed from analysis for incomplete self evaluations).

This analysis included a comparison of the "bonus dollars" value score for "self" and "others," alongside their main supportive team roles and self-reported rating of their experience on the

project team (TS1 on Table 4). Each role included a description as well as three Likert scale questions to determine the extent to which a student matched that role. The descriptions of the roles are included in Table 3. The value score is reported as the percentage above or below the baseline "bonus" points someone could receive for that evaluation. For example, a value score of 50% means that the individual scored over the average value for that survey. This comparison allows us to learn more about the perceived value of the student's role on the team by gender.

Table 6. Comparison of 9 women students bonus amounts and team roles for Spring 2021 semester

| Student | Survey administration | Percent score above/below average value (self) | Percent Score above/below average value (others) | Top team role(s) during mid- and post- evaluation | Experience on Project Team (out of 7) |
|---|---|---|---|---|---|
| 1 | Mid | 25% | 25% | Supportive Team Player | 5 |
| | Post | 50% | 25% | Organized Leader | |
| 2 | Mid | 15% | 24% | Facilitator/Conflict Management, Supportive Team Player | 7 |
| | Post | 25% | 25% | Supportive Team Player, Creative Problem Solver, Communicator | |
| 3 | Mid | -20% | -10% | Expert Contributor | 7 |
| | Post | -20% | -33% | Facilitator/Conflict Management , Supportive Team Player, Expert Contributor | |
| 4 | Mid | 50% | 30% | Communicator | 6 |
| | Post | 25% | 30% | Facilitator/Conflict Management, Supportive Team Player, Communicator | |
| 5 | Mid | 25% | 29% | Expert Contributor | 6 |
| | Post | 100% | 38% | Creative Problem Solver | |
| 6 | Mid | 13% | -16% | Organized Leader, Communicator | 6 |
| | Post | -20% | -20% | Communicator | |
| 7 | Mid | -20% | -22% | All categories | 6 |
| | Post | 0% | -06% | Facilitator/Conflict Management, Organized Leader, Supportive Team Player, Communicator, | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Expert Contributor | |
| 8 | Mid | -20% | -25% | Facilitator/Conflict Management, Supportive Team Player, Communicator | 7 |
| | Post | -26% | -20% | Facilitator/Conflict Management, Communicator | |
| 9 | Mid | -20% | -11% | Facilitator/Conflict Management, Supportive Team Player | 6 |
| | Post | -20% | -40% | Communicator | |

One pattern that emerged early is that female students were primarily associated with non-technical roles on their team: Facilitator/Conflict Management, Supportive Team Player, and Communicator. The Thinker Role did not show up in the top role of any of the female students, while the more task-oriented roles of Organized Leader (3 times), Creative Problem Solver (2 times) and Expert Contributor only showed up a few times (3 times). For a few of the students (1, 2, and 7), these latter roles showed up in the end-of-semester peer evaluations and increased the value score of the student who had taken on these roles. Two students (8 and 9) took on Facilitator/Conflict Management, Supportive Team Player, and Communicator roles and were scored below baseline for both their self evaluation as well as their teammates evaluation, though they ranked their experience on their teams as a good experience. Students 3 and 6 both started with expert roles during the mid-semester evaluation (Expert Contributor and Organized leader, respectively) and then took on more supportive roles for the latter part of the semester, which coincided with decreased scores on the end-of-semester evaluation as well. Lastly, the highest gains in value scores were given to students who had taken on Organized Leader, Creative Problem Solver, and Expert Contributor roles during the latter part of the semester, with the exception of student 3 who had started the semester with a top score in Expert Contributor and then added Facilitator/Conflict Management and Supportive Team Player during the latter part of the semester.

All nine female students ranked their experience on their project teams as high for the semester, with scores ranging from 5 to 7 out of a 7-point Likert scale.

**Limitations of the Study**

The findings of these analyses must be considered within the limitations of the study. The data presented in this study is self-reported by students, and therefore inherently subject to bias.

These analyses represent only one semester of data collected, during the spring 2021 semester. This semester was influenced by a hybrid learning model in which most students started the semester in-person with seat distancing and facial mask coverings while several teammates were

remote over zoom with their project teams. Due to the time necessary by section to compile data from all sections of the course and differences in formatting of some of the surveys, our sample size of women and men for team roles is limited. Though pleased with the peer evaluation participant and survey response rates, we acknowledge that these are small sample sizes and recognize additional research is needed.

**Key Findings**

Some interesting patterns emerged from these analyses on first-year engineering students and the roles they take on project teams. First, both female and male students during the semester self-reported that they have a strong identity with engineering and are "proud to be an engineer." While they strongly identify with engineering, they also do not feel that being an engineering student is a strong part of their self-image. Our students perceive that they bring many skills to the team beyond just being an engineering student.

With respect to using their skills within a project setting, students came into their semester projects team taking on the role of *Team Player* and *Communicator* and found themselves focused more on the skill of *Communicator* by the end-of-course peer evaluation. Most often, our female students did not start out strongly as *Organized Leaders* and men did not start with taking on the *Facilitator* role. By the end-of-semester, the teams had reorganized with only one or two recognized *Organized Leaders.* Most of the team roles for female students showed some growth over the semester, with the most growth in the *Facilitator* role mid- to post- semester. This supports previous research that team roles can shift throughout the course of a team's life cycle, and initial roles might occur as a result of previously established skill or familiarity with types of team roles.

The final data from these analyses more of the story around how students value the different team roles. When students took on Facilitator/Conflict Management, Supportive Team Player, and Communicator roles, female students scored less on their peer evaluations, often in their self evaluation as well. This suggests that some team roles were considered to be "less valuable" than others, as we hypothesized.

The lower value of taking on certain team roles is not reflected in the students' ranking of their experience on the team, which suggests that students can have a good team experience outside of the role they take on a team. This also might suggest that there are widespread values placed on team roles that are pervasive to how we teach students; certain team roles are regarded as less important regardless of how much impact on the final deliverable or time taken on tasks associated with that role. For example, the most growth in roles taken for female students over the semester was "Facilitator," though less value was placed on that role.

Students who took on Organized Leader, Creative Problem Solver, and Expert Contributor roles during the latter part of the semester were given a higher score or "bonus dollars," suggesting that those roles are perceived as more important to the team. However, this was still the least common role for female students by the end of the semester.

Lastly, we established that most students come into their first-year engineering program and projects courses with pride of being an engineering student. Our female students also indicate that they have an additional sense of self and self-image outside of engineering. While our students acknowledge that they bring more experiences and skills to their teams than some of the technical knowledge required in engineering design, they already may have preconceptions as to the value to their teams of those outside skills.

**Discussion and Recommendations for Future Work**

The engineering workforce and engineering program accreditation emphasizes integrating collaboration and communication into undergraduate engineering education. Teamwork has increasingly become an integral component in university senior capstone courses and first-year engineering design courses. ABET requires that engineering degree-granting programs demonstrate student outcomes that include the ability to function effectively on a team and "whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [8]. The ability to take on various technical and non-technical team roles is a desired characteristic by the engineering workforce for today's students graduating undergraduate engineering degree programs.

Results from the analyses presented in this paper will inform the future work of engineering projects faculty and (we hope) other faculty negotiating first year courses and team-based projects courses to meet the needs of their students, with the aim of improving the awareness of and training of students in different technical and supportive team roles. Survey results revealed that the students are proud of being in engineering and bring additional experiences and identities to their teams. The students also assign different amounts of value to team roles, with more supportive and team-oriented roles perceived as having less value than more leadership and technical roles. The roles taken on the team do not have a direct relationship to the experience or satisfaction with the team.

This work also suggests that roles shift on teams over time, stressing the importance of examining engineering teamwork patterns longitudinally in addition to cross-sectionally. We urge scholars to continue examining team role patterns over time as individual role transitions likely have a lasting impact on team members. For instance, team members may "claim" roles that they are comfortable with, limiting their ability to expand their skill set and develop new knowledge, skills, and abilities. Expanding access to team roles is an underlying objective of project team courses; thus, it is an important phenomenon to continue investigating.

Future analyses could include comparisons of the gender makeup of the team (primarily male, primarily female, and balanced male-female teams) and the impact views on engineering, as well as subject interviews from each section of the course, especially in the cases where students had a significant change from pre- to post- surveys. We intend future analyses to also consider survey data collected around non-binary genders, engineering majors, first-generation and students of color in our projects courses.

Faculty and researchers will continue collecting formal and informal quantitative and qualitative data, ultimately allowing for a broad look at the experiences of diverse students on engineering teams. We are hopeful that this commitment to analyze our data coupled with timely program improvements will help our students become better prepared to enter the workforce. We anticipate that future analyses to include many semesters of data will help us offer targeted training on roles and the importance of creating collaborative teams and inclusive environments.

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