AC 2011-1319: THE EFFECT OF SKEWED GENDER COMPOSITION ON STUDENT PARTICIPATION IN UNDERGRADUATE ENGINEERING PROJECT TEAMS

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The Effect of Skewed Gender Composition on Student Participation in Undergraduate Engineering Project Teams

Abstract

In the United States only about one quarter of all undergraduate students in engineering are female. Because there are significantly fewer female than male engineering students, the composition of small groups of engineering students assigned to complete group projects is likely to be skewed towards male-dominant membership. The underrepresentation of women both in the field of engineering generally, and in engineering group project teams specifically, can leave women vulnerable to *stereotype threat*, experiencing concern that one will be judged in terms of a stereotype. In this project, we investigate the effect of skewed gender compositions on active participation in group projects in a required introductory engineering course. Using video records of 175 final group design project presentations (4-6 students per group, 660 students total), we performed a systematic investigation of student's active participation, i.e., the roles and behaviors adopted by male and female students as a function of gender composition of the group. Independent judges viewing each videotaped presentation classified roles and behaviors adopted by participants. Parameters that were collected include presentation content type (on a spectrum from technical to non-technical), student roles in the mechanics of the presentation (e.g., as explaining technical aspects or simply introducing others), and perceptions of leadership, effectiveness and appearing knowledgeable as rated by the independent judges. These data were combined with ancillary data consisting of student demographics and overall GPA. In addition, we administered a survey instrument to a subset of the sample (n = 222) at the end of the Winter 2010 term. The questionnaire included student perceptions of their own leadership and performance on the group project. Evaluation of the videotaped presentation footage revealed that men presented more technical information for longer than expected periods during the oral presentations, while women presented significantly more of the non-technical material, speaking for a shorter than expected period of time. Although limited in scope, survey results show that male students tended to rate their leadership and performance higher when there were fewer other men in the group. This research suggests that male students adopt more active roles and may have better outcomes than female students in project presentation groups.

Introduction and Background

Although women are well represented among the total undergraduate population at the University of Michigan, female students are outnumbered by male students in the College of Engineering. In 2009 and 2010, the incoming class in engineering was 23% female, consistent with national trends and reflective of gender stereotypes depicting engineering as a "male" domain. Because there are fewer female than male engineering students, the composition of small groups of students, including those assigned to complete class projects, is likely to be skewed in favor of men. In this study, we draw on research findings from psychology on the influence of gender stereotypes and skewed gender compositions on women working in male-dominated fields as well as research on self-efficacy and active participation to investigate the effect of skewed gender composition in small class project groups. We address the question of whether being in the gender minority has a detrimental effect on active participation in group project teams for female engineering students.

Active participation is defined as taking an active role in collaborative work, and having the opportunity to explain the topic to another in one's own words[1]. Education research demonstrates that learning and understanding is optimized when students engage in active participation. However, a large body of social science research supports the idea that active participation may be lowered for women in male-dominated fields, due to gender stereotypes purporting than men have more ability than women in math and science fields, including engineering.

Laboratory studies on the topic of *stereotype threat* have demonstrated the significant detrimental effect of these stereotypes on women's performance in math and science fields, and on their intention and motivation to pursue math and science-related education and careers[2]. For example, in lab studies women score lower than men on a math test when cues in the setting raise awareness of the gender stereotype[3,4]. This low performance of women is said to occur because awareness of the stereotype leads women to worry that a poor performance would appear stereotype-confirming to others, and the threat of appearing stereotypic distracts them from concentrating fully on the test. Of importance, such studies also show that women's math performance outcomes can match that of men's when instructions are given that minimize the relevance of gender stereotypes in the testing situation, e.g., by describing the test items as non-diagnostic of inherent math ability, indicating that women have math aptitude similar to men, but that expression of this aptitude is impeded by the stereotype.

Among the situational cues found to induce stereotype threat is underrepresentation of one's social group (e.g., gender or race) in the academic environments. Such studies show than women perform worse on an oral exam when in an all-male testing group, compared to when other women are present[5,6,7]. The situation of being the "only one" of one's gender or race in a group is termed *solo status* and has been shown to be a negative experience for women in math and science. Indeed, the detrimental effects of solo status for women is compounded by testing in a stereotypic domain, such that women who are giving an academic performance among a group of men *in a domain in which women are negatively stereotyped* are particularly vulnerable.

Of importance to the current project, research has demonstrated that experiencing stereotype threat also leads women to disidentify from math and science fields, to develop more negative attitudes about these fields, and lowers their intention and motivation to participate and persist in these fields[8,9]. For example, in one study women science majors reported lower intentions to participate in an upcoming scientific conference if the conference attendees were depicted as being predominantly male. When the conference was shown as attracting equal numbers of male and female attendees, women had more positive attitudes about it and reported stronger intention to attend and participate in conference activities. This result is important in light of research evidence showing that active participation in educational activities enhances learning[10]. Thus, to the extent women in science and engineering experience stereotype threat and solo status, their learning outcomes can be diminished due to their lowered active participation.

A similarly large body of research in self-efficacy theory provides further insight into the importance of educational experiences that influence performance and persistence in engineering. Self-efficacy is defined as the judgment of one's own ability to perform a task within a specific domain[11] and is associated with the choices students make in their academic careers in terms of types of activities, levels of effort, and levels of interest. Bandura[12] demonstrates that beliefs about self-efficacy are derived through four primary mechanisms: one's previous performance or *mastery experiences*, observations of other's performance or *vicarious experiences*, persuasion, and psychological states. Recently, because of the appearance of variation in self-efficacy by gender[13,14], self-efficacy theory has been used as a construct for analyzing the experience of women in the engineering academic setting. For example, recent research[13] demonstrated that when students were asked to identify factors contributing to their self-image, women more often than men reported factors such as understanding and learning as influencing their efficacy beliefs. Further research[14] revealed that although both men and women report efficacy beliefs as being influenced by performance comparisons, the effects of these comparisons were more often positive for men (improving their sense of self-efficacy through a sense of superiority in comparison) and negative for women (diminishing their sense of self-efficacy through a sense of inferiority in comparison).

Recent qualitative research on first year engineering student self-efficacy[14] suggests that engineering students enter the academy with a high level of self-confidence based on previous high school successes and mastery experiences. However, after entering the college environment, rather than focusing on these mastery experiences, student shift their focus to vicarious experiences, seeking to find performance comparisons, since understanding of mastery experiences in this environment is minimal. While mastery experiences are the most influential source of self-efficacy belief, in situations where individuals have little or no experience, adequacy is often gauged by the performance of others[12]. In performance comparisons, students compare themselves to others engaged in similar activities and experienced heightened efficacy upon surpassing peers or diminished efficacy upon being outperformed. In addition to performance comparisons, individuals may also build their concepts of self-efficacy by witnessing the performance of others who are similar to themselves. Bandura[12] refers to this approach as modeling, because these experiences require the individual to determine their ability to model the behavior of the person being observed. In this situation, the persuasive power of these experiences increases with the degree of similarity the individual attributes to the performer and, thus, the result is strongly keyed to the individual chosen as the model. Of interest in this study are the differences noted between men and women in performance comparisons. Men most often report success based on their personal assessment of outperforming classmates. In contrast, women, when comparing their abilities to their peers, most often assess their performance as inferior, leading to diminished self-efficacy[14].

In light of research documenting the prevalence of gender stereotypes and solo status among women in male-dominated fields, it seems likely that that there are fewer opportunities for either performance comparison or modeling through observation for undergraduate women in engineering. Women may experience difficulties identifying female models for comparison and actively engaging in experiences that lead to mastery, leading to gender differences in self-efficacy and mastery experiences favoring male students. In this research project, we examine these issues as they relate to female students in engineering project groups.

Study Setting

Working in small groups on course projects is a common experience for undergraduates. In the University of Michigan College of Engineering, students in Engineering 100: Introduction to Engineering (required for incoming students) are assigned to 4 to 6 person teams to complete a semester-long introductory engineering design project. There are approximately 10 sections of this course each semester, offering a variety of project topics, designed to appeal to the broad interests of the incoming students and to allow students to learn about engineering in the context of a project of interest. The project topics cover several theme areas including sustainability and alternative energy, humanitarian applications, music technology, biomedical applications, computers and programming, and vehicle design competitions.

The sections of the course are team taught with a team consisting of one instructor from an engineering department and one instructor from the technical communications program. Female engineering instructors teach about fifteen percent of the sections, while female technical communications instructors teach approximately half of the sections.

Project teams in this course are created based on a variety of variables including gender, race/ethnicity, living location (as campus housing is concentrated in two different areas of campus) and skills sets. Known best practices in creating teams are advocated, e.g., faculty are discouraged from isolating students by identifiable characteristics. However, the potential remains for teams to be constructed in which women or men are isolated. Overall, teams are often, but not always skewed in favor of men, with a variety of team gender compositions within any given section.

At the end of each semester, teams are required to deliver a final oral presentation, which is routinely videotaped for archives. In these presentations, team members assume responsibility for a specific subset of material, varying from non-technical introductory slides to complex technical engineering content. Casual observations of several of these presentations brought to light an interesting phenomenon where in mixed gender teams, female students were more often presenting less technical material, while male students were more often presenting more technical material. This observation led to the development of a research plan to assess whether this gender difference did indeed exist in student presentation groups, and what implications this may have on active participation.

Research Methodology

There were two primary components to this research investigation. The first involved a systematic investigation of the roles adopted by students as a function of students' gender and the gender composition of their presentation group in the videotaped presentations. A coding scheme was developed for analysis of the archived videotapes of the group project presentations. Two independent judges were trained on the coding scheme and each judge evaluated each video to determine the contribution of each team member to the presentation content, breaking down the presentation slides into a series of 6 categories representing an array of technical levels:

1. Title Slide or Final Slide
2. Introduction or Summary or Recap

3. Background
4. Overview Description of Design Solution (What it looks like) or Alternative Designs or Conclusions or Recommendations
5. Detailed Description of Design Solution (What it does/How it works/Cost/Drawbacks and Refutation)
6. Technical Specifications (materials, properties) or Testing Results or Calculations

In addition, judges noted the amount of time that each speaker presented as well as their perceptions of student leadership (the student directing other students immediately prior to or during or after the presentation), effective speaking (the clarity of the information relayed by each student) and apparent knowledge of the subject (apparent depth of understanding of the project based on the information presented and the questions answered, if any). For this analysis 175 videotaped presentations were analyzed consisting of a variety of group gender compositions (see Table 1). These presentations included 660 students.

Team Composition	Teams on Video	Women on Video	Women Surveyed (no video)	Men on Video	Men Surveyed (no video)
All Women	3	12	4 (0)	-	-
Female Dominated	29	89	6 (3)	43	2 (1)
Gender Equal	37	81	6 (0)	81	8 (0)
Male Dominated	73	86	31 (5)	191	66 (7)
All Men	33	-	-	77	99 (41)
Total	175	268	47 (8)	392	175 (49)

Table 1. Team and gender composition of videotaped presentation and survey respondents. Some of the survey respondents were not videotaped (value in parentheses).

The second component involved administration of a questionnaire to students completing these group project presentations at the end of the Winter 2010 term (approximately 60 groups, totaling 222 individual students). The questionnaire was administered immediately following delivery of their final oral presentations and was designed to assess factors including the degree to which students perceived they adopted a passive (supporter) or active (leadership) participation role; satisfaction with one's role and with one's performance on the project; psychological factors that may predict or be related to role adoption and/or vulnerability to stereotype threat, e.g., traditional gender role attitudes[15], engineering identification[16], gender-engineering stereotyping[17], perceptions of sexism in engineering, and stereotype threat-related concerns, and self-rated degree of learning and understanding of project materials and concepts, e.g., how much students "got out of the experience".

In addition to evaluation of the archived presentation videos and surveys administered to a subset of students at the end of the Winter 2010 semester, we collected general data on the students including self-reported gender and race-ethnicity, age, citizenship, performance indicators including ACT/SAT scores, AP credit, course grade and GPA. These three data sets (video analysis, survey and general data) were merged into a single database for analysis.

Analyses from video footage (n = 581)

Out of the total sample of 660 students, participants who were not US citizens (n = 57) were excluded from the analyses as gender stereotypes about engineering ability are not evident in some non-US countries[18]. Data from 22 participants was not available because their portions of the presentations were not adequately videotaped for analysis. This resulted in a final sample of 581 students (with 135 completing the survey as well) of which 337 participants are men and 244 are women. Team composition was categorized into three groups for analysis: male dominated, gender equal, and female dominated, and cumulative GPA was included as a covariate.

Using the ANOVA, we analyzed the influence of student gender and team composition on a series of presentation indicators:

1. The number of presentation slides presented by the student that contained significant technical information (slide types 5 or 6)
2. The number of presentation slides presented by the student that contained non-technical information (slide types 1, 2)
3. The amount of time the student spoke compared to the amount of time expected based on overall time divided by number of team members
4. The total number of questions answered by the student
5. The leadership score, knowledgeable speaker score, and the effective speaker score from two independent judges (one male and one female)

In general, male students adopted greater technical roles (M = 1.45 slides) than female students (M = 0.85 slides) and students in male-dominated groups adopted more technical roles (M = 1.45 slides), compared to gender equal groups (M = 1.02 slides) and female dominated groups (M = 1.05 slides). We found a significant main effect of student gender, $F(1, 574) = 12.71, p < .001$, and a marginally significant main effect of group gender composition, $F(1, 574) = 2.61, p = .08$ on the number of technical slides presented by the student. No two-way interaction emerged. These statistics are summarized in Figure 1, along with the significant findings of the remainder of this preliminary video analysis. (All analyses reported here were also replicated using randomly chosen subsets of participants in male dominated groups equal to the numbers of female dominated and gender equal groups, for example, $F(1, 424) = 12.05, p < .01$, and $F(1, 415) = 9.59, p < .01$. This suggests that the overall greater number of male dominated groups did not account for our reported findings.)

Female students, on average, adopted more non-technical roles (M = 1.13 non-technical slides) when compared to male students (M = 0.83 slides). We found a significant main effect of student gender, $F(1, 574) = 4.99, p < .05$. No other significant effects or interactions emerged regarding non-technical roles.

Male students (speaking time/expected speaking time = 1.04) had longer speaking time ratios than female students (*M* = 0.97). Significant main effect of student gender, $F(1, 557) = 6.08$, $p < .05$. No other significant main effects or interactions emerged

We found significant main effects of student gender and group gender composition qualified by significant 2-way interaction, $F(1, 568) = 8.40$, $p < .001$ on the answering of questions. Male students answered more questions overall, fielding more questions in female dominated groups (*M* = 2.26) than in gender equal (*M* = 1.41) and male-dominated groups (*M* = 1.16). Questions answered by female students did not significantly differ in the male-dominated (*M* = 0.86), gender equal (*M* = 0.67) or male dominated groups (*M* = 1.18).

The independent judges' ratings of how much the students appeared as leaders were significantly correlated, $r(560) = .69$, $p < .001$, so scores were averaged across judges to form an overall leadership score. The independent judges attributed a significantly higher ($F(1, 573) = 22.41$, $p < .001$) leadership rating to male students (*M* = 5.33) than female students (*M* = 4.67). This attribute was not related to team gender composition.

The independent judges' ratings of how knowledgeable the students appeared were significantly correlated, $r(577) = .33$, $p < .001$, so scores were averaged across judges to form an overall knowledgeable score. Male students (*M* = 5.99) were rated as significantly ($F(1, 573) = 9.83$, $p < .001$) more knowledgeable than female students (*M* = 5.69), and students in male dominated groups were rated higher (*M* = 6.14) than those in gender equal (*M* = 5.67) or female dominated groups (*M* = 5.71) ($F(1, 573) = 7.69$, $p < .01$). No significant 2-way interaction emerged.

The independent judges' ratings of how much the students appeared to be effective speakers were significantly correlated, $r(578) = .39$, $p < .001$, so scores were averaged across judges to form an overall effective speaker score. We found significant main effects of student gender and group gender composition on the rating of speaker effectiveness, qualified by marginally significant 2-way interaction, $F(2, 573) = 2.39$, $p = .09$. Male students tended to receive higher ratings in female dominated groups (*M* = 5.81) than in gender-equal (*M* = 5.14) or male-dominated groups (*M* = 5.39). Women's ratings did not differ in the female dominated (*M* = 5.71), gender equal (*M* = 5.53) or the male dominated groups (*M* = 5.59).

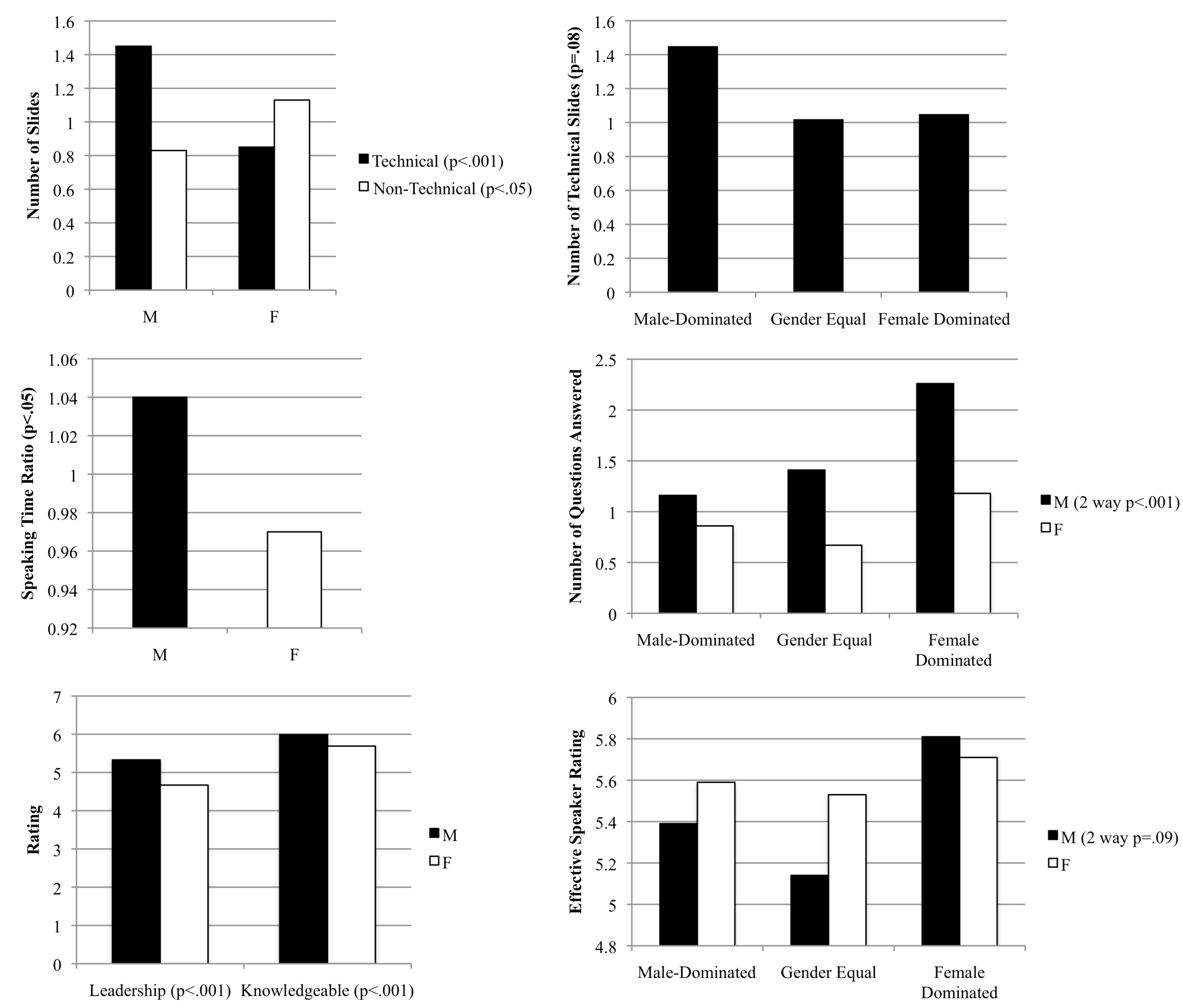

Figure 1. Graphical summary of statistically significant findings of video analysis.

Analyses from survey responses (*n* = 135)

Too few participants in some cells of the research design precluded the use of ANOVA to analyze the questionnaire data (e.g., only one male student who completed the questionnaire was in a female dominated group). Therefore, a regression approach was used in which dependent measures from the questionnaire were regressed on student gender, gender group composition, and their interaction term, with GPA entered at the first step as a covariate.

Using the regression approach, we analyzed the influence of student gender and team composition on a series of outcomes, all measured on a seven point scale from 1 (not at all) to 7 (very much):

1. The extent to which students rated themselves as a leader in their project team
2. The extent to which students thought they performed well on the project
3. The extent to which students thought they adopted a teacher (1) or a supporter (7) role on the project
4. The extent to which students were satisfied with the role they adopted on the project

5. The extent to which students felt they learned a lot from presenting their project
6. The extent to which students thought they would have gotten more out of the experience had they adopted a more active role
7. Psychological factors that could moderate the effects of student gender and group gender composition on the outcomes above, i.e., adherence to traditional gender roles, engineering identification, and belief that gender discrimination exists in engineering

Analysis of the project leader outcome revealed a marginally significant interaction between student gender and group gender composition, *beta* = -0.18, $p = 0.07$. Simple slopes analyses revealed that male students tended to rate themselves as project leaders more as the number of women in the group increased, $t(102) = 1.18$, $p = .24$. The project leader ratings of female students did not differ as a function of group gender composition, $t(31) = -.25$, n.s. This result did not differ depending on the student's adherence to traditional gender roles, engineering identification or belief in gender discrimination in engineering.

Analysis of the project performance outcome revealed a marginally significant interaction between student gender and group gender composition, *beta* = -0.16, $p = 0.10$. Simple slopes analyses revealed that male students tended to rate their project performance higher as the number of women in the group increased, $t(102) = 1.83$, $p = .07$. Female students also tended to rate their project performance higher as the number of women in the group increased, $t(31) = 1.56$, $p = .12$. This result did not differ depending on the student's adherence to traditional gender roles, engineering identification or belief in gender discrimination in engineering.

No significant results emerged for the remaining variables (i.e., teacher/supporter role, role satisfaction, learning from the project, and belief that one could have learned more if adopted a more active role).

Discussion

What emerges from this preliminary analysis is a landscape of the dynamic interactions in groupwork in an introductory engineering course across a spectrum of group gender compositions. Evaluation of the videotaped presentation footage reveals that men consistently present more technical information for longer than expected periods during the oral presentations, while women present significantly more of the non-technical material, speaking for a shorter than expected period of time. This finding suggests that women are much less likely to observe other women or personally experience the act of presenting technical material in the final oral presentation.

Men were also rated as appearing more knowledgeable about the subject and as showing more leadership than women during their presentations, as rated by two independent judges. Although these patterns did not differ by the gender composition of the project group as might have been predicted, the number of questions answered by men and women did. Men fielded more audience questions about their group presentation than women particularly when they were in groups where men were the minority. This aligns with some research showing that being in the minority in terms of gender can promote behavior stereotypically associated with one's gender[19]. It appears that when men are only or one of few men in their presentation group, their gender may become salient to them, and their behavior aligns with the stereotype, i.e., they become more assertive in taking on questions posed to the group as a whole.

Evaluation of the survey data was limited by the small sample size. For example, only one male student and three female students in female dominated presentation groups completed the survey. However, regression analyses that treated group gender composition as a continuous rather than a categorical variable revealed three interesting findings. First, men tended to rate themselves as having performed well in groups with more women. In other words, as the number of women relative to men in the project group increased, men's self-ratings of their own performance increased. So although observations of men's videotaped performance (as rated by independent judges) did not differ by the number of women present in the group, their own perceptions of their performance did. To the extent that learning and motivation are enhanced by self-perceptions of one's mastery experiences, it may be that men's group project experience is enhanced to the extent that their gender is highlighted in the group.

Second, women tended to rate themselves as having performed best in groups with more women, i.e., as the number of women in the project group increased, women thought their own performance increased. This result is consistent with research on solo status, which showed that women's performance is better in all-female groups than in groups in which the participant is the only woman.[6] In addition, this aligns with research on business team performance where women paired with women on two-person teams performed best in an all-female competition environment.[20]

Finally, students' self perceptions of their leadership in the group showed that men considered themselves to be leaders most when in groups with more women. Women's self-rated leadership did not differ by group gender composition. Overall, the results from the survey may suggest that men's perceptions of their own performance and leadership are improved when they are in groups with fewer other men, whereas women's perceptions are less influenced by group gender composition. However, due to the very limited survey data from women (n = 32 with only three in female dominated groups), it may be that any effect of group gender composition on women failed to be detected due to small sample size.

It is interesting that no significant gender differences emerged for self-perceptions of teacher vs. supporter role, role satisfaction, learning from the project, and belief that one could have learned more if adopted a more active role. Although caution is warranted (due to the very small number of women who completed the survey), this may imply that women do not perceive that they are taking non-technical supporting roles and also do not relate these roles to their learning. Future research should clarify these results with larger samples.

Conclusion and Future Directions

This project provides insight into situational factors that influence both women's and men's participation in engineering education. Student understanding of technical material has been shown to be enhanced by active participation and the opportunity to explain the topic to another in one's own words[11]. The final oral presentation opportunity offered in the Engineering 100 course provides students with ongoing practice and development in their understanding of the technical material associated with their design challenge. In addition, communication skills are key to achieving success in the field of engineering[21], and perceptions of competency among students are correlated with frequency of performance[22]. When female students are in the gender minority in an academic domain, they are likely to experience solo status and ensuing perceptions of stereotype threat, which can lead them to adopt stereotypical (i.e., passive) roles in group learning projects. The results shown here suggest that, perhaps by virtue of being underrepresented and the target of negative stereotypes in engineering, women are more likely to adopt passive, supporting roles, and men to adopt active roles in which they have the opportunity to "learn by teaching others". By disproportionately missing the opportunity to explain the technical aspects of the project to an audience, women students may be at a disadvantage both in terms of their technical understanding and their perceptions of self-efficacy in engineering.

This initial analysis provides insight that gender can influence the roles that both women and men take in group educational activities. Further examination of this unique data set should be undertaken to explore linkages between other factors of influence, such as the race/ethnicity of the participant, the gender of the technical faculty member, or the project topic addressed in the course, as women preferentially choose sections of this course that host environmental and humanitarian topics. The survey should be re-administered to gain a more robust dataset for analysis of student self-perceptions of learning. In addition, we recommend a longitudinal study of these students to explore long-term effects of choices for mastery experiences in the first year.

This work aligns with the mission of the college in creating and encouraging a robust learning environment for a diverse student body. A recent college curriculum review[23] identifies the loss of interest in engineering among U.S. students, and more notably among under-represented students in engineering, as a primary concern of the college. Clearly, it isn't enough to attract these students to the door; we must also consider the retention and success of these students in the field, so that their unique contributions are realized. Thus, the development of teaching practices that create a welcoming environment for under-represented students is key to the success of our teaching programs.

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