Active Learning Group Work: Helpful or Harmful for Women in Engineering?

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Abstract

Active Learning is a trending engineering education technique used at universities across the country. This educational approach fosters students' technical and non-technical skills through group projects that require teams to apply their collective knowledge to solve various "real world" problems. Its collaborative, hands-on nature is appealing to instructors who are interested in better preparing their students for the increasingly complex and dynamic world of engineering. However, group settings have shown to put additional stresses on women in engineering, an already marginalized group in STEM fields. The results of this study, conducted at the University of Colorado Boulder, show that many women enjoy active learning because it helps them develop long-term material retention and problem-solving skills, as well as because they find it rewarding to see the effects of their engineering in action. However, women also reported that they face several challenges in team settings, especially being pressured to take on non-technical roles in group projects. In order for active learning group work to realize its full potential, the challenges that women face in team settings must be addressed in the classroom. If the issues are mitigated, active learning will become an increasingly successful way to prepare men and women for group work in the future.

Introduction

Active learning remains at the forefront of new engineering pedagogies. This exciting approach uses hands-on and collaborative learning activities to give students technical and non-technical experiences including development of project scope, budget, and professional presentations that mirror the work of engineering design teams in industry. Many universities across the country have implemented active learning classes because there is ample evidence that they stimulate long-term material retention, critical thinking, and communication skills [1-3]. Unfortunately, these positive attributes may also mask a hidden problem. Past research has shown that certain aspects of team dynamics, particularly student roles on teams and peer interactions with teammates, can leave women unsure of their engineering abilities [4-8]. These findings are concerning not only for the retention of women in engineering, but also for the success of active learning programs as a whole. The mission of active learning is to prepare students for working with diverse groups of people in a respectful, professional manner. This goal cannot be achieved until women feel respected and comfortable in team settings.

The University of Colorado Boulder recently started a degree-granting program called the Engineering Plus (e+) program that specializes in active learning courses. Students in the program are required to take three engineering projects courses and are encouraged to take active learning sections of engineering core classes. In light of the available literature, the e+ department is exploring the effects that team dynamics within active learning environments have on the confidence levels of women. Since the program is so heavily based on active learning techniques, the faculty is eager to identify challenges for women in such environments to improve the program as a whole.

This paper investigates causes of stress for women in active learning settings. Our primary research question is: *How do team dynamics in an active learning environment affect a woman's confidence as an engineer?* This research requires a mixed-methods approach including quantitative and qualitative analysis of student peer evaluation data and qualitative analysis of student focus groups. Anonymized peer evaluations were used to collect quantitative and qualitative data. The quantitative data from the peer evaluations were analyzed to find discrepancies between peer perceptions of female teammates and female self-perceptions as a teammate. Qualitative peer evaluation data were used to determine what types of roles men and women take on in team settings. Co-ed and women-only focus groups were convened to gather additional qualitative data to further explore team dynamics and how they affect women's confidence levels. The goal of this study is to discover what challenges women experience in terms of team dynamics within active learning courses. If these problems are identified, educators can effectively work toward making their classrooms more comfortable for women. In doing so, active learning experiences will become more useful for women and men alike.

Background

Several studies have investigated the effects of active learning on general student engagement, the confidence levels of women in engineering, and student interactions in the classroom. A comprehensive review published by researchers at the Oregon Institute of Technology revealed that although active learning group work is praised for improving students' long-term retention and problem-solving skills, women often end up taking on stereotypically feminine roles, such as team secretary, when put in groups [3]. The University of Michigan reported similar findings with their first year engineering students; women presented 25% fewer technical slides than men during presentations, and men answered far more questions from the audience during presentations than women did, regardless of if the team was mostly men or mostly women [4].

A lack of self-confidence has been linked to lowered retention rates for students pursuing engineering degrees [5-6]. This is particularly true for women in STEM [7-8]. Of the women who do graduate with an engineering degree, many seek jobs outside of the engineering industry more often than their male counterparts. Many reports indicate that women leave engineering jobs in part because of low self-confidence in their technical abilities. A study published by the American Sociological Review shows that women express and feel less professional role confidence than men when in engineering [9]. This study, along with others, affirm that women in engineering careers often have lowered self confidence in their technical competencies even if they persisted through getting an engineering degree [9-10]. Lowered self-efficacy coupled with an extra pressure for women to prove their technical abilities to their male coworkers [11] is a large factor in that women hold less than 25% of the STEM jobs in the United States even though they make up almost half of the work force [12].

Methods

The data collected in this study were taken from students enrolled in e+ program courses. Students in e+ are required to take three engineering projects courses. *First Year Engineering Projects* introduces students to the engineering design process and to problem-solving while working in teams. Second Year Engineering Projects, *Engineering for the Community*, is a course in which student teams are assigned a client and must prototype a product that solves that client's problem. Third Year Engineering Projects, *Invention and Innovation,* is a class in which student teams design a product and a business in parallel. Team size for projects classes typically ranges from five to eight students.

In addition to the required projects classes, students in the e+ program are encouraged to take active learning sections of engineering core classes such as *Statics and Structures*, *Thermodynamics*, *Materials Science*, and *Circuits and Electronics*. In these courses, students learn the respective course material through a combination of lecture and hands-on exercises rather than lectures alone. Groups in the engineering core classes are typically three to five students. Students do not have to be enrolled in the e+ program to enroll in any of these courses.

Research Questions

The primary research question addressed in this study is: How do team dynamics in active learning environments affect a woman's confidence as an engineer? To supplement this research, secondary questions include:

- How do students define active learning, and with what connotations?
- What types of roles do men and women take on in group projects?
- How do men and women evaluate each other on a team?

We used quantitative and qualitative peer evaluation data, as well as qualitative data from student focus groups to explore the research questions. Each of the methods of data collection and analysis are discussed below. Surveys, focus groups, and interviews for students were conducted under the University of Colorado Boulder's Institutional Review Board (IRB) approval, evaluated by external and internal evaluators. Student names have been removed to conceal their identities.

Peer Evaluations - Data Collection Methods

Peer interaction and perception data were collected using post-semester peer evaluations which were examined for patterns of responses between male-to-female and female-to-female teammates. The peer evaluation method employed asked students to divide 1000 points (in the form of bonus dollars) among their team members, based on their contribution to the team project. The instructions also asked students to provide an explanation for their distributions, as follows:

> *Your team has been awarded a(n imaginary) $1,000 bonus for your outstanding work on your project. YOU must decide how the bonus will be allocated. Distribute the $1k among your team members, including yourself. Take into*

consideration time commitment, special contributions, leadership, unique skills, etc. Provide a rationale for your allocations.

For example, an individual on a team of five students could allocate $200 to each student, conveying that each team member equally shared the project workload. In contrast, another individual on this same team of five could score one or more team members below $200, indicating they did less work than their peers, and others more than $200, indicating that those team members carried more than their equal share of the workload. Rationale comments ranged from generalized comments on team dynamics to specific skills and tasks that an individual brought to the team and project.

Administered via Qualtrics® Research Suite online survey software or as a paper copy, the Fall 2017 peer evaluations from three engineering projects courses were analyzed for this paper — *First Year Engineering Projects* (n= 25), *Engineering for the Community* (n=31), and *Invention and Innovation* (n=18). Peer evaluations are administered mid- and post-semester to determine individual team-member effort. All respondents could opt out of using their peer evaluation results for this research study (*First Year Engineering Projects* n=5, *Engineering for the Community* n = 2, and *Invention and Innovation* n= 0).

Focus Groups - Data Collection Methods

Students enrolled in any e+ program course during the 2017-2018 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 their past experiences in team settings. A complete list of focus group questions is provided here:

1. Why did you choose the e+ program?
2. Think about your first engineering projects class. What were your thoughts on the experience?
3. How would you describe your interactions with your teammates?
4. How would you describe your role(s) on your team(s)?
5. Have you experienced or witnessed sexism in your active learning courses?
6. What could be done differently in the e+ program courses to make them more inclusive and respectful?
7. What does the term ‘active learning’ mean to you?

Two focus groups were convened during the last month of the last semester in which students were enrolled in engineering projects or other active learning classes. There were three women participants and two women facilitators in the first focus group. For the second focus group, there was one man and one woman participating and two women facilitators. Both focus groups were audio and video recorded to allow for future analysis. The audio was subsequently transcribed to text and personal identifiers were removed prior to analysis by the full research team.

Findings

Peer Evaluations - Quantitative Data

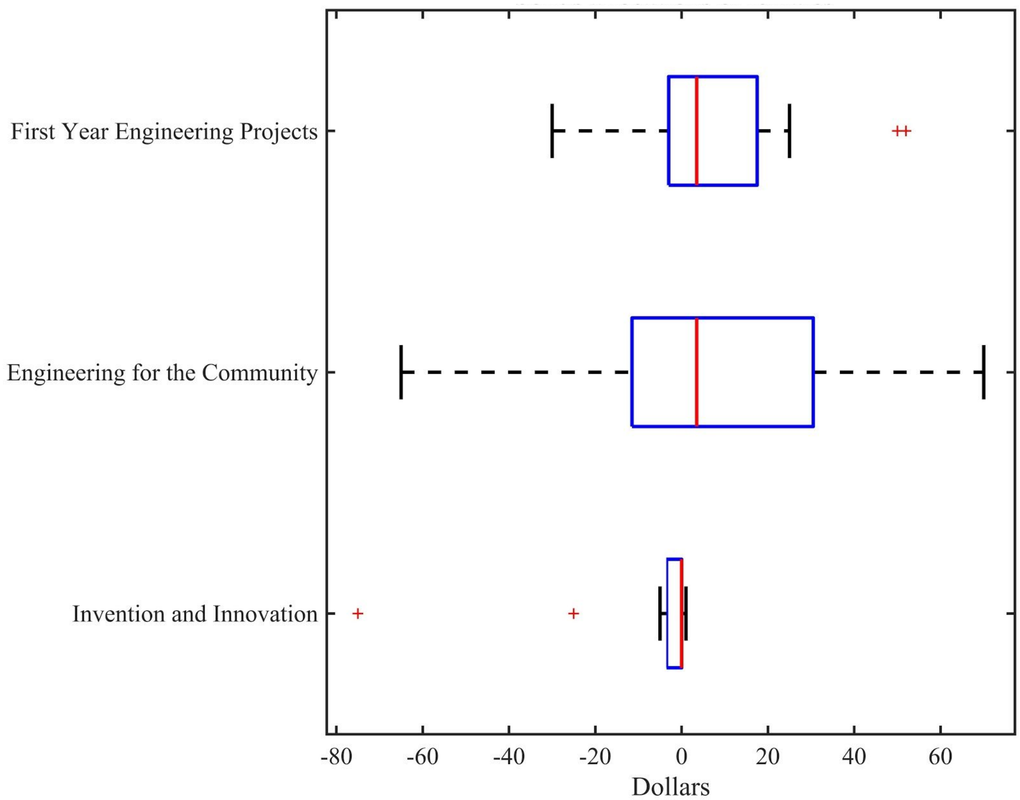
Peer evaluations for each projects course were entered into a spreadsheet and apportioned dollar amounts and categories of gender by both the person receiving the bonus and evaluator. We compared dollar amounts by counting the number of times a woman's bonus to herself exceeded, met, or was less than her male and female teammates (see Table 1). Initial analysis of the peer evaluations showed some interesting trends in how women rated their contributions to the team project as compared to their male teammates. Comparisons of womens' bonus dollars for themselves were often higher than their peers in the *First Year Engineering Projects* and *Engineering for the Community*. Women in *Invention and Innovation* more often allocated themselves the same or a lower bonus than their female and male teammates.

Table 1. Comparison of women's' peer evaluation scores of self versus other team members, by gender.

	First Year Engineering Projects (n= 21 male and 9 female ratings)	***Engineering for the Community*** (n= 36 male and 11 female ratings)	***Invention and Innovation*** (n= 20 male and 12 female ratings)
%Women allocated themselves a higher bonus than male peers	57%	64%	5%
%Women allocated themselves a higher bonus than female peers	44%	82%	25%
%Women allocated themselves the same bonus as male peers	3%	19%	60%
%Women allocated themselves the same bonus as female peers	0%	0%	92%
%Women allocated themselves a lower bonus than male peers	10%	8%	35%
%Women allocated themselves a lower bonus than female peers	22%	9%	50%

To examine the initial trends in more detail, peer evaluation bonuses were also aggregated by gender. Each individual received an average bonus from female teammates and male teammates. The averages were then compared to determine if there exists a difference between how men and women evaluated each individual woman on their team. A graph of men's average bonus allocated subtracted from women's average bonus allocated for each woman is shown in Figure 1. In this figure, the red middle line is the median difference in bonuses, the edges of the box are the 25th and 75th quartiles, and the edges of the dotted lines are the minimum and maximum of the data sets, or differences in bonus amounts allocated. Outliers are denoted as +'s. For example, two women in *First Year Engineering Projects* have an average bonus amount from their female teammates that is $50 higher than the average bonus received from their male teammates, but the 25th and 75th quartiles for the class overall are $-4 and +20, respectively.

Figure 1. Difference in average dollars between female to male peer bonus allocations of females



This plot shows that across all three projects courses, the median difference between men's and women's assessments through bonus distribution of female teammates is similar, meaning there is little overall difference in how men and women assess their female teammates. However, the range in bonus money allocation is much wider in *First Year Engineering Projects* and *Engineering for the Community* than in *Invention and Innovation.* In particular, the *First Year Engineering Projects* course had bonus discrepancies in which the average women's bonus suggestion was up to $30 less than what the men on the team suggested for an individual female teammate. In *Engineering for the Community*, price discrepancies ranged from -$64.5 to +$68.2, which means that men's and women's assessments varied greatly for some female teammates. By *Invention and Innovation*, men's and women's assessments of their teammates are consistent with one another. In other words, more women gave lower bonus amounts to female teammates in their first projects class, higher and lower amounts to females in their second projects class, and relatively equal bonuses to females in the third projects class.

Peer Evaluations - Qualitative Data

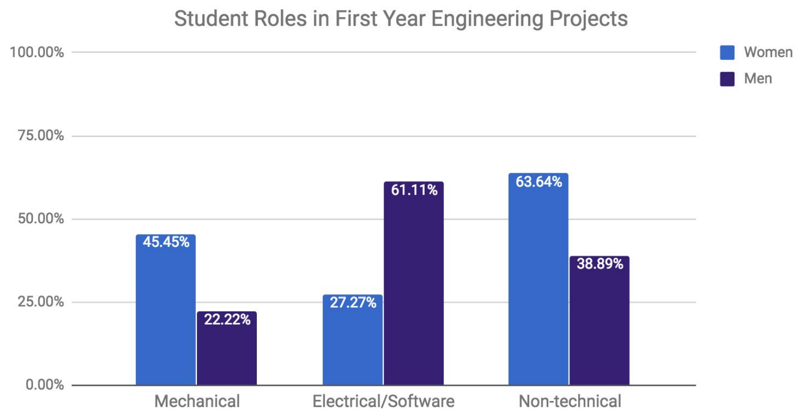
To further explain the differences in the peer evaluations, we analyzed rationales for the allocations. For this analysis, we generated three categories of team roles based on a review of the overall set of comments. Subsequently, we analyzed each student's self and peer evaluations for keywords that indicated what type of role(s) he or she took on for the project. In the first attempt to analyze this data, two members of the research team analyzed the peer evaluation comments and categorized roles based on if a student appeared to lead or assist on a certain aspect of the project. After comparing analyses, the team found several inconsistencies in the categorization process. The second attempt was more successful. The concept of ‘lead’ vs. ‘assist’ was eliminated. Instead, comments were analyzed to determine what types of tasks students took on in a project. These tasks were categorized into three roles: Non-technical, Mechanical, and Electrical/Software. The task descriptions for each category are shown in Table 2 below. A student was considered part of a category if he or she had at least two separate mentions of working on a certain task. There was no limit set on how many roles a student could take on. A student could also not have a role if there was no mention of specific tasks that he or she completed.

Table 2: Student Roles on a Group Project

Role Type	Non-technical	Mechanical	Electrical/Software
Activities performed	● Writing report ● Managing budget ● Organizing ● Designing poster ● Client communication ● Running errands or gathering supplies	● 3D-printing ● Laser cutting ● Computer aided design (CAD) ● Using lathe and mill ● Welding	● Design and layout of circuitry ● Soldering ● Coding ● Using microprocessors and microcontrollers such as Arduino or Raspberry Pi

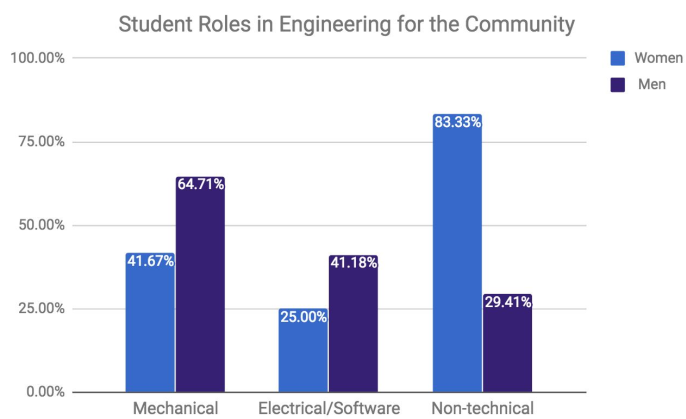
From this analysis, women in each level of engineering projects classes took on non-technical roles more often than men. In *First Year Engineering Projects*, 43% of women took on non-technical roles as compared to 39% of men. The discrepancy between men and women in non-technical roles increased significantly in *Engineering for the Community*, in which 83% of women took on non-technical roles as compared to 29% of men. Figures 2, 3, and 4 represent the roles of men and women across these three courses based on their peer evaluations. In *Invention and Innovation*, the discrepancy between men and women in non-technical roles remained high with 50% of women partaking in non-technical roles in comparison to 10% of men.

Figure 2: Student Roles in *First Year Engineering Projects*



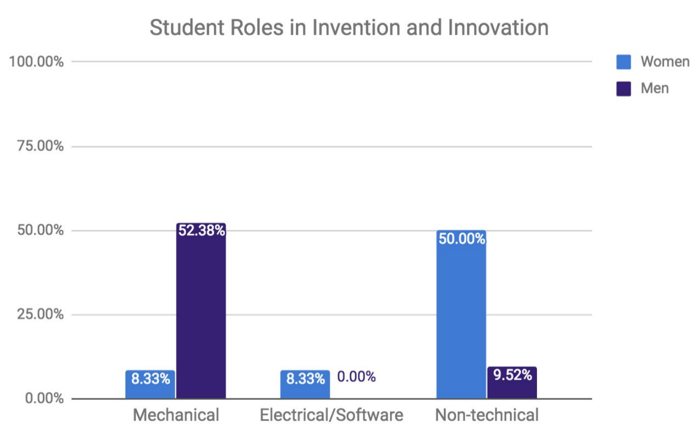
Note: Percentages do not add up to 100% because students were not limited to one role on a team.

Figure 3: Student Roles in *Engineering for the Community*



Note: Percentages do not add up to 100% because students were not limited to one role on a team.

Figure 4: Student Roles in *Invention and Innovation*



Note: Percentages do not add up to 100% because students were not limited to one role on a team.

Some variance exists between the different courses and peer comments. The peer evaluations in *Invention and Innovation* were formatted differently than the peer evaluations in the other two courses. *Invention and Innovation* students were not asked to qualitatively evaluate each member of the team. They instead were given a series of questions in which students rated their peers on scales of 1-5, and then given room to provide comments if wanted. Many students did not leave any comments about specific roles that each team member took on.

Generally, women who took on non-technical roles were praised by their male peers. One male student said, in regards to his female teammate: "[Female teammate] did a lot of the work that everyone else necessarily didn't want to do as well as making sure everybody else was doing what needed to be done and knew the upcoming deadlines. She took on kind a project management role." Women themselves also responded positively to being in a non-technical role. One woman in *First Year Engineering Projects* said:

> For the final project, I feel like I learned a lot and and really grew as an engineer. I was in charge of a lot of the writing assignments and posters. In the past I have struggled with this type of writing and using the correct wording and I feel like I really grew in these aspects. I also contributed a lot to the construction of our project, in designing and putting everything together.

Focus Groups

The focus group transcripts were passed among the research team for multiple iterations to identify common themes in student responses. For the first pass, each member of the research team read through the transcripts and extracted passages that they thought were relevant to the study. After comparing the notes from each person, we generated a list of recurring themes. In the second pass, we reread the transcripts and noted passages that supported and/or countered the identified themes. The passages that directly related to team dynamics, women's confidence levels, or active learning classes were analyzed further.

From the focus groups, we determined that overall, active learning environments are enjoyed and often even preferred by women. The women and men in the focus groups described active learning as 'hands-on' and 'tangible' processes. They said that this type of learning environment fosters problem-solving in an iterative fashion which helps them remember concepts better than a lecture does. When we asked women if taking a first year engineering projects course encouraged them to take additional projects classes, they all said yes. Their reasonings included that projects classes give them confidence in their engineering abilities and that projects classes allow them to practice working in teams. In regards to a recent projects class, one woman explained:

> I may not know everything that I need to know, but I've watched myself come from this point of having absolutely no idea of where I was going to start, to having done all the research, built something really beautiful, and have felt that I can do anything, you know, at this point… So I love [projects classes].

However, the active learning process is not without flaws. There were several accounts of male-to-female interactions that have put additional stress on women. Both men and women reported that women often get talked over in group settings. In terms of team roles, there is a definite pressure for women to take on non-technical tasks. Women reported that in *First Year Engineering Projects*, they took on non-technical roles sometimes because they felt they did not have any technical skills to add to the team. In *Engineering for the Community* and in courses outside of the e+ program, women were also pressured to take on non-technical roles by their male peers. Pressure intensities ranged from subtle to overt. One female student mentioned that she was never looked at by her male peers when her group was delegating technical tasks. Other female students mentioned that women are sometimes explicitly told by their male peers not to take part in the technical tasks or to write the reports.

Even when women do take on technical roles, their contributions are not always respected by their male peers. One student recalls a 'blatant' interaction she recently had in a different department's projects class in preparation for a Design Review presentation:

> A specific [male] member of our team … said to the other girl in my group and I "I would prefer if you didn't answer any questions tomorrow." And I said "Well, why? I've worked on the code, I coded all the MATLAB and files to measure whether certain parts would fail." I was pretty knowledgeable on those sections because I had been working *hours* that day working on the both of them. And I said, "Well what about one of the sections I calculated?" And he said, "Well I would prefer that both of you don't answer because if they [the course instructors] have questions, it means they have concerns which need to be addressed properly."

Most of the women we interviewed mentioned the importance of vocalizing their interests in the project. For example, one woman recalls a typical experience in one of her labs:

> In labs, it always comes back to labs! They would say "oh do you guys wanna work on the code?" or something and they would never make eye contact with me and would be looking at the other guys. I'm like "I'm right here!"... I'm like "I'm already certified, I've had experience with this" but I have to vocalize that, [or else] they would never look at me.

In fact, women having to advocate for themselves was a common theme mentioned by most of the women in the focus group. Each woman talked about how she realized that she needed to actively voice her desire to work on technical roles. Many women also mentioned that they took skill-building workshops to learn skills such as welding or Arduino microprocessor programming. These workshops helped women secure technical roles on their teams. For example, one woman said "When I learned how to weld, it gave me some value to the team that I didn't quite have yet. And then every time [the team] was like 'Okay who's going to weld? Well you're certified, you got taught, so this is your part.'"

The women who said they had to advocate for themselves also mentioned some form of support system to help guide them. Women spoke of both male and female professors as being mentors. Support ranged from a professor intervening when a woman started to get talked over in a group to a professor taking a skill-building workshop with a group of women. Women also look to their female peers when in need of advice. From the focus group accounts, there were two specific instances of female-to-female peer interactions in which a woman was encouraged by another woman on her team.

These accounts of women battling for technical roles and for the respect of male peers is not universal, however. One woman that we interviewed recalls her projects teams as being fairly equal. She said “I was in a project group with two other guys and I did the majority of the code and they didn’t think that was weird, and I didn’t think that that was weird. Another guy put together the report. And so yeah I guess different experiences but good, positive.” Another woman said she actually preferred to take on non-technical roles because she wants to be a project manager for a career. Furthermore, a man we interviewed praised a woman that he recently worked with, saying “I think [she] is a great example of that type of person who you know just plethora of social skills, plethora of technical skills, and like the drive and the motivation to make what they want to happen, happen.”

Overall, the focus groups revealed that active learning can and does inspire women and encourage them to persist in engineering. However, there is still room for improvement to reduce stress on women in these types of environments. Although not universally true, many women reported accounts of negative male-to-female interactions and being pressured to take on non-technical roles in projects classes. Women attribute vocalizing their goals as a key component in their success with team projects.

Study Limitations

It is important to note that there are some limitations of the research design. First, the study is focused on students in the e+ program, which is openly known for its alternative teaching approach. As such, students within the program all have some degree of positive feelings toward active learning, which may lead to some bias not consistent with a more general population’s perception of active learning environments. Therefore, the conclusions found in this study may not be easily applied to more traditional engineering programs. Additionally, because the peer evaluations were completed for a grade, the level of honesty and accuracy in student responses may be skewed to either overestimate or underestimate the actual contributions of any one student.

Conclusions

We investigated three main questions throughout the research process. The conclusions to each of those questions are summarized below.

How do students define active learning, and with what connotations?

Both the men and women we interviewed defined the term ‘active learning’ as a hands-on approach to learning that is based on solving “real-world” problems. Women reported that this type of environment is beneficial for many reasons, including being able to: i) experience the effects of engineering on the community ii) practice interpersonal skills, and iii) apply engineering concepts in a tangible manner. Overall, both men and women enjoy active learning classes.

What types of roles do men and women take on in group projects?
Peer evaluations and focus groups revealed that women take on non-technical roles disproportionately more often than men on team projects. This phenomenon is especially true for students in the more advanced engineering projects classes. It is possible that women take on non-technical roles more often in some classes because there are more non-technical tasks to complete. For example, many women in *Engineering for the Community* were reported as being the liaison between the client and the design team. Similarly, many women in *Invention and Innovation* were reported to have been in charge of the business aspects of the project. Both client communication and business planning are introduced in these subsequent courses.

Another explanation for the trend of women disproportionately taking on non-technical roles is because they lack technical confidence. This explanation corresponds to possibilities discussed in the focus groups. Women in the focus group believe that women are more likely to take on non-technical roles in teams because of three main factors: i) they feel that they do not have enough technical experience to be useful to the team, ii) they are not asked by their male counterparts to take on technical roles, or iii) men explicitly tell them that they cannot take part in the technical aspects of a project.

How do men and women evaluate each other on teams?
The hypothesis that women take on more non-technical roles in more advanced projects classes because they lack technical confidence is also supported by the discrepancies between bonus allocations between men and women. In *First Year Engineering Projects* and *Engineering for the Community*, there was a wide range of differences between the bonuses that men and women gave to an individual female teammate. In *Invention and Innovation*, the majority of women allocated bonuses to female teammates at the same or lesser amount than what their male counterparts allocated them. For the women who had large, positive discrepancies, it is possible that women over-inflated their bonus allocations in fear that their teammates would not score them well. For the women who had a large negative discrepancy, it is possible that they did not believe they were valued as much because they did not partake in major technical work. Further analysis of why women evaluate themselves higher or lower on peer evaluations than men rate them will help to fully understand this data.

Future Work
The suggestions put forth by students in the focus groups will be implemented alongside other recommended interventions in future course offerings, including: teaching students to make eye contact with their classmates, encouraging women to take skill building workshops, and redirecting student roles on teams so that men and women get equal opportunity to try out various technical roles. The role definition that commonly occurs in *Invention and Innovation* will be introduced in *First Year Engineering Projects* and *Engineering for the Community* for consistency, and coaching in project planning tools will help students to experience leading different parts parts of the product design process. In future studies, these instructional changes will be evaluated for their effectiveness in improving the engineering courses and active learning environment for women.

Key Takeaways
The results of this study show that active learning does have the potential to retain women in engineering. The women in the focus groups all agreed that active learning classes help them to build confidence in their engineering abilities. However, there exist some team dynamics issues that must be addressed. Most of the women said they were pressured to take on non-technical roles in teams, especially in their first few engineering projects classes and labs. These pressures were either caused by male teammates not asking the women to partake in technical tasks, or by women themselves not believing that they possessed the technical skills needed to complete technical tasks. To address these issues, the students in the focus groups generated suggestions for active learning course improvements. These suggestions are discussed below.

Some of the women mentioned that many male students and male instructors do not make eye contact with women when addressing a group. Instructors should model the process for equally addressing everyone in their group and remind students often to use it. Exercises for students to practice eye contact and active listening, particularly during brainstorming activities, should be implemented.

Instructors should also encourage women to take skill-building workshops. These workshops give women technical foundations and confidence to take on technical tasks in group projects. The workshops can also provide students with a skill that is unique and valued within the team, thus securing that woman a technical position for the project. Encouragement from instructors can come in many forms, including instructors attending the workshops alongside students or reassuring women that struggling is part of the learning process.

Perhaps the most crucial takeaway from this research is that advocating for oneself is an important skill that women must develop in order to work in diverse engineering groups. It is likely that many women do not have the courage to and/or experience with advocating for themselves, which may explain why many women in the study took on non-technical roles. Instructors must investigate team dynamics and determine when women need encouragement to go out of their comfort zones and to advocate for themselves. Peer evaluations and informal, individual student-instructor interviews are two ways in which instructors can gain insight to team dynamics. It is particularly important for instructors to look for women who gravitate towards the non-technical aspects of a project, as these women are often among the students who need the most help with self-advocating.

Active learning remains at the forefront of engineering pedagogies because of its potential to help engineering students learn in a complex social and academic setting. These types of environments show promise in increasing women's retention rates in engineering. Upon resolving the problems women face in group settings, both men and women will be better prepared for the exciting and complex world of engineering.

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