

The Effects of Group Size on the Experiences of First-Year Engineering Students in Mixed Gender Groups

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I, Ioana Tiu, am a sophomore at Binghamton University studying biomedical engineering and I am currently an undergraduate assistant in the freshman engineering course. I have always had a passion for academia and started participating in research during my freshman year of college. I also continued to partake in research over the summer at Gates Vascular Institute in Buffalo, NY. During this great opportunity, I studied the effects of aneurysms on rats and mainly worked on a code that would be able to measure the size of the aneurysm and in what direction it grew over the course of a year or more. In the year 2022, I was given a chance to run my own research. I have always been passionate about encouraging more women to participate in STEM fields, specifically engineering. I decided to see if there was an effect on how girls succeeded in their engineering classes given the ratio of women to men in their specific groups. For this initial project I mainly focused on the freshman engineering course since it was heavy on projects, but in the future, I hope to collect more data including higher-level classes with increased difficulty.

The Effects of Group Size on the Experiences of First-Year Engineering Students in Mixed Gender Groups

Abstract:

Recognizing the importance of collaborative learning in engineering education, this research seeks to understand how different group sizes and the gender ratio within the groups influence group dynamics, communication, inclusiveness, and overall student satisfaction. By examining the experiences and perceptions of first year engineering students in mixed gender groups, this study investigates the complexities of group interactions. Understanding how dynamics shift with gender ratio and group size can help form strategies to improve educational outcomes and ensure a supportive learning environment for all students, emphasizing the critical role of group composition in academic settings.

This study investigates the effects of group size and gender composition on the experiences of first-year engineering students in mixed-gender project groups. Conducted at a research-intensive university where students completed multiple projects throughout their first year. During their fall semester, students were assigned to medium-sized groups (3-5 students) and completed both a reverse engineering project and an Arduino-based design project. In the spring semester, students completed a semester-long conceptual engineering design project in large teams (5-7 students) and spent a few weeks of the semester assigned to small, sub-teams, of 2-3 students. Data was collected through a single comprehensive survey distributed following the completion of their first-year program which measured several important aspects such as group gender composition, member comfort, communication effectiveness, collaboration, respect, and project success.

During the semester's four-student and six-student group assignments, the female-to-male ratio appeared to influence female students' perceptions. In larger groups, the gender ratio had a more pronounced impact on communication dynamics and group interactions compared to the two-student groups surveyed during the spring semester. In smaller groups, individual personalities and interpersonal dynamics were more evident, reducing the effects of gender ratios. Alternatively, in larger groups, gender ratios exhibit a more visible correlation with students' perceptions and experiences. The study suggests that while gender ratios have a minimal effect on smaller groups, they play a more significant role in shaping the dynamics and perceptions within larger group settings.

This study examines the connections between groups size, gender composition, and the overall experiences of first-year engineering students in collaborative learning environments. By exploring how these factors influence dynamics, communication, and perception, this research provides valuable insight into the education system. Ultimately, fostering inclusive and supportive group settings is crucial for enhancing students' engagement, academic success, and cultivating the next generation of diverse and talented engineers.

Introduction

This study aims to contribute valuable insights into how group size affects students' experiences and interactions within engineering teams, thereby informing future educational practices. Understanding the effects of gender ratio and group size on both female and male-identifying students is crucial for creating an optimal learning environment for the entire class. At Binghamton University, only about 26% of undergraduate engineering students identify as women, highlighting the need for this research.

In a 2020 article in the *International Journal of Emerging Technologies in Learning*, Al Mulhim et al. extensively explored how group size directly impacts student success in projects and final grades. The study compared large groups (7-8 people) and smaller groups (3-4 people), finding that students generally perceived larger groups more positively and tended to perform better. However, the paper emphasizes that other underlying factors contribute to the success or challenges of these groups, underscoring the need for further research to identify these variables. [1]

Another study by Griffin et al. focused on group size effects in a capstone senior design project revealed similar results. Over two semesters, students in larger groups achieved high grades and reported better experiences than those in smaller groups. [2] The upcoming sections of our study will delve into the possible reasons behind these outcomes, including the impact of personalities in smaller groups versus factors like work distribution in larger groups.

In a preliminary study to this one, the authors' examined the impact of gender composition within medium-sized groups. This study seemed to indicate that students in groups with an even gender distribution often seemed to have a better experience than those in more uneven groups the students. [3]

While research exists on the impact of group size on student success, the underlying reasons for these outcomes remain unclear. As seemed to be indicated in a previous study, gender composition could be a significant factor. Despite the evidence that female students are underrepresented in engineering programs and experience unique barriers [4] [5] [6], little research has explored how the gender-ratio within groups affects project success. This gap suggests that current learning environments may not be optimally organized to ensure the success of all students. Continuing from previous work, this study seeks to answer the question; *How does group size and gender composition impact student experiences in a project-based first-year engineering course?*

Methods:

This study examines the effects of group size on the experiences of first-year engineering students working in mixed-gender groups. This research involves analyzing data collected from students following their first-year experience in the Watson College of Engineering and Applied Science at Binghamton University in the 2023/2024 academic year. During their first year, these students took part in project-based curricula each semester.

There are three main components of this first-year engineering program, a large lecture with 200-400 students, activity/laboratory sections of about 24 students each, and a discussion sections

with those same 24 students. While the students are introduced to tools and material that are applied in their projects during the large lectures, the teams are formed, and most of the project-work is done in the 24-student sections.

In their first semester, in medium sized teams of about 4 members, the students completed both a Reverse Engineering project as well as an Arduino-based design project. For this semester, teams are formed alphabetically by the instructors prior to the first week of classes. The same team completes both projects together. Throughout the course of both projects in the fall semester, teamwork management and conflict resolution techniques are covered in the classes.

In the following semester, the students completed a conceptual design project in larger teams of about 6 members. These large teams are formed by the instructors in response to the students' ranking of the possible project topics. Mid-semester, the teams temporarily split into small groups with about 2 members each that work together for several weeks on focused alternative designs solutions for their semester project. The small sub-teams are self-selected by the students during the semester project. Once the sub-teams have completed and presented their alternative designs, they recombine into the larger teams to evaluate the alternatives and incorporate the strongest elements into their team's final design.

Participants were recruited through an email sent out during the summer following the completion of their first year. Only students that completed both semesters of the course in the same academic year were invited to participate in the study. Two prescheduled reminder emails were sent out to encourage a higher response rate. The survey was administered using Google Forms and was anonymous, requiring no identifying information. Before beginning the survey, participants provided a digital consent by indicating their acceptance of the terms outlined in the consent form.

In the survey, students were asked to self-identify their gender and the gender-composition of their groups (6-person, 4-person, and 2-person) during both the Fall 2023 and Spring 2024 semesters. Following that information, for each of the groups, participants were asked the following five Likert-scale questions, rating each on scale from 1 - 5:

How comfortable did you feel speaking up and participating in group discussions related to the project?

How would you rate the overall communication and collaboration within your group during the project?

Did you feel respected during group conversations?

Was the work in the group split up evenly?

How successful do you think your project team was?

These anonymous responses were analyzed to compare student experiences across different group sizes and to identify any trends or patterns in groups dynamics and student efforts.

This study was issued an Exempt approval waived under Section 45 CFR 46 104(d)(2)(i) of the Code of Federal Regulations.

Data and Analysis:

From a student population of 315 students that completed both the fall and spring semesters of the first-year engineering program at Binghamton University in the 2023/2024 academic year, 53 participants responded to the anonymous survey. Three responses were removed due to incomplete or inconsistent responses. This resulted in a sample size of 50 responses corresponding to a 15.8% response rate.

Below, in Table 1 a summary of the sample population and their team categories is included. The table is broken down into three sections, the first is based on the total number of respondents, which shows how many total respondents reported being a part of each Team Category. The second and third sections of the table show the distribution of the Team Categories for specifically male- or female-identifying respondents. Several subcategories had few, if any responses. Although the columns are labeled as 6-, 4- and 2-Person teams, sometimes these teams had one fewer, or additional, team member. This occurred where a class section was under-or-over enrolled resulting in a situation where it is not possible to have all teams in the section be exactly 4 or 6 students. This means that the category labeled as 6-Person teams were primarily teams of 6 members, but also included some teams with 5 or 7 members. Likewise, the 4-Person and 2-Person teams included 3-5 and 2-3 team members, respectively.

Table 1: A detailed breakdown of the participant team categories.

Population	Team Category	6-Person Teams	4-Person Teams	2-Person Teams
Total	All Male	7	12	22
	Majority Male	36	22	3
	Even	4	10	16
	Majority Female	3	5	0
	All Female	0	1	9
	Total	50	50	50
Male	All Male	7	12	22
	Majority Male	19	11	1
	Even	1	4	5
	Majority Female	1	1	0
	All Female	0	0	0
	Total	28	28	28
Female	All Male	0	0	0
	Majority Male	17	11	2
	Even	3	6	11
	Majority Female	2	4	0
	All Female	0	1	9
	Total	22	22	22

The sample of 50 participants consisted of 28 males and 22 females. While it's evident that more male students participated, the survey still represents a high percentage of female respondents, 44%, compared to their percentage of the class population, which stands at around 26%. While the survey included other options for participant gender identity, only female- and male-identifying students completed the survey.

Response Summaries

Using Box-and-Whisker plots, summaries of the participant responses are presented below. In the plots, the black circles denote the median values, while the red triangles represent the mean values. The questions assessed comfort, communication, respect, division of work, and overall success within the group. The plots each highlights the varying gender ratios within these groups and shows both the range and average ratings given by students on a scale of 1 to 5. When referring to averages, unless stated otherwise, this paper will primarily focus on the means of each group for data comparison. In cases where the mean and median vary greatly from each other, the difference will be noted.

Starting with an overview of the responses of all participants presented together, Figure 1 shows the summary of responses rating the participants' experience in a 6-Person group. Figure 2 and Figure 3 show the same summaries, but for 4-Person and 2-Person groups respectively. In these overview plots, due to the small number of responses for some of the sub-populations a lack of granularity is present. The variety in the number of responses for each category also presents some issues in comparisons.

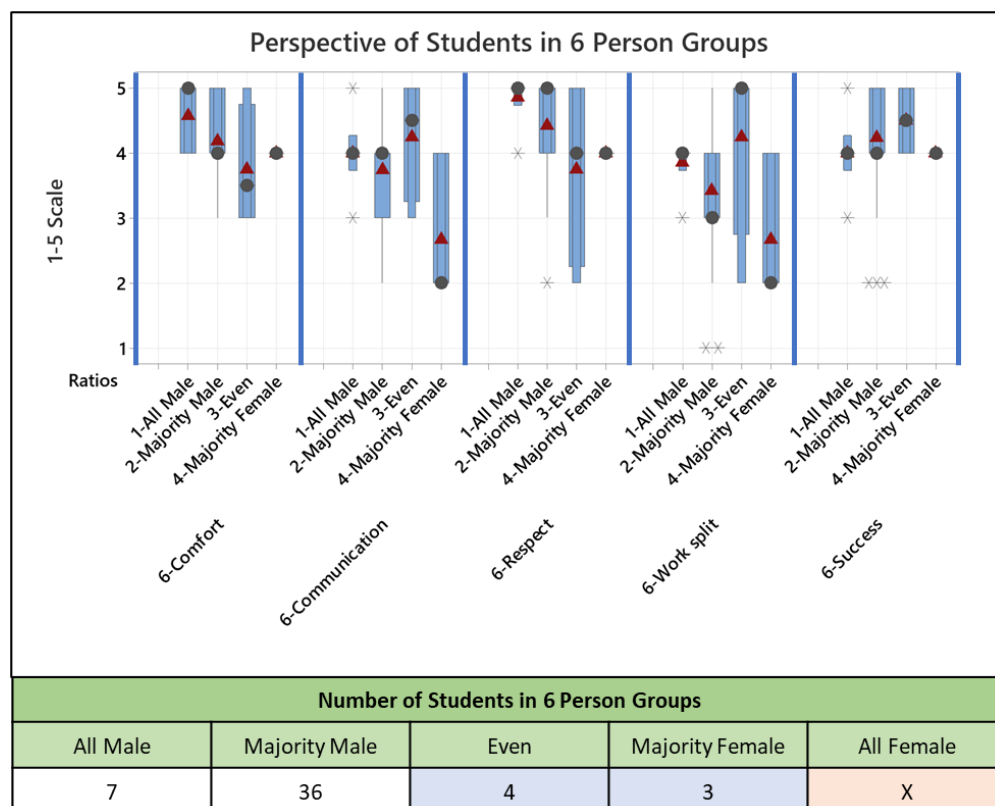


Figure 1. Both Female and Male Student Perspectives in 6 Person Groups

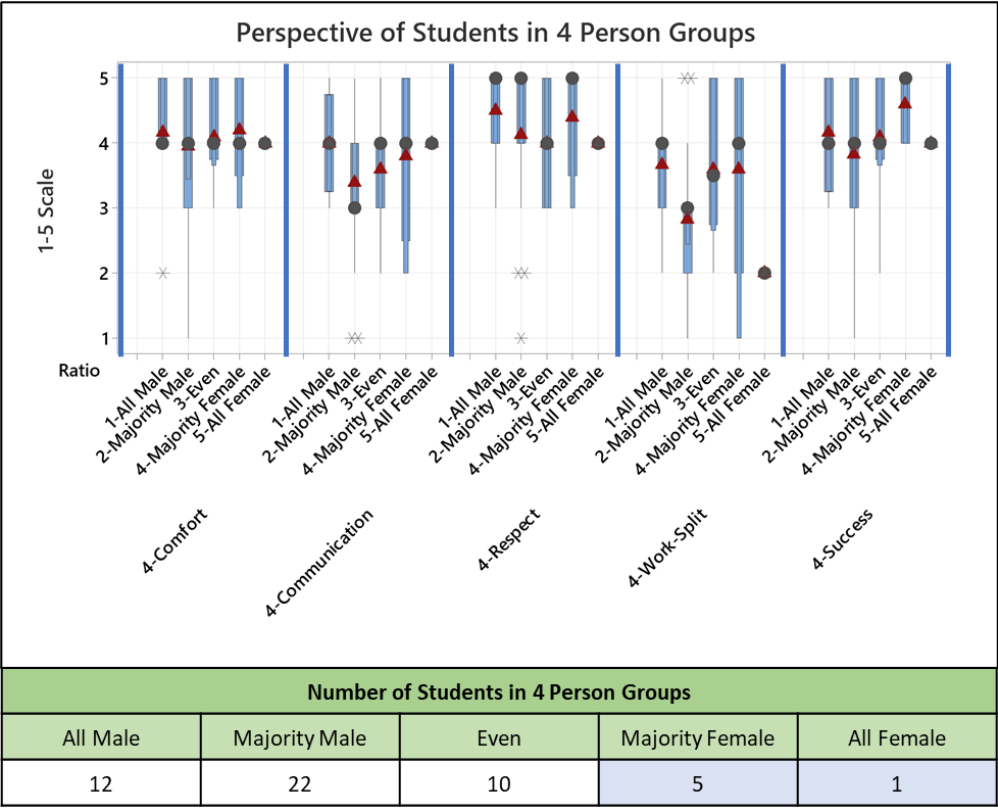


Figure 2. Both Female and Male Students Perspectives in 4 Person Groups

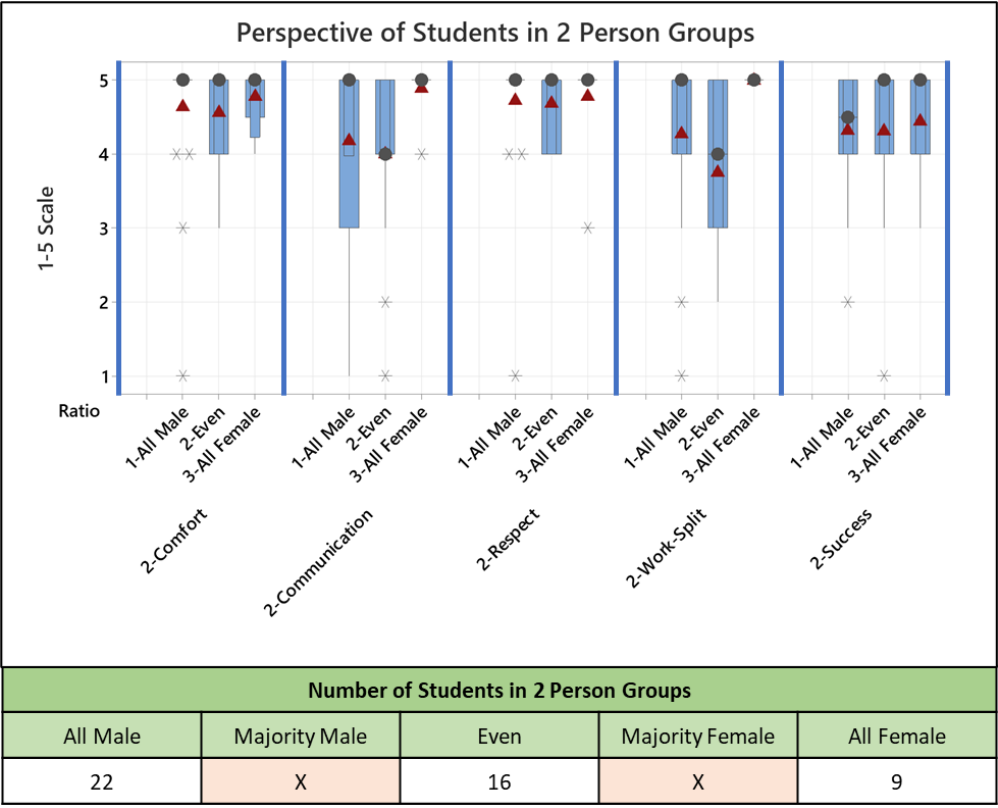


Figure 3. Both Female and Male Students Perspective in 2 Person Group

6-Person Groups:

Focusing on the responses related to the 6-Person groups, Figure 4 and Figure 5 show the responses from the perspective of female and male students, respectively.

Figure 4 illustrates how female students perceived their 6-person groups (including themselves). Starting on the left, the plots reveal that female-identifying students generally felt comfortable in all group categories, with these groups receiving an average rating of 4. When it comes to communication, female students rated it highest in evenly gender-balance groups. Respect was also perceived most positively in these evenly ratioed groups. This trend continued for the distribution of work was considered most fair and equitable in groups with an equal number of male and female members. Finally, in terms of overall success, most groups received ratings between 4 and 5. It's important to note that most female students were placed in majority-male groups, which is reflective of the larger male population in the class.

We also observed that there are outliers in how female students perceived the success of their predominantly male groups, rating it as low as 2. This is noteworthy despite the mean ratings being consistent across all group ratio types.

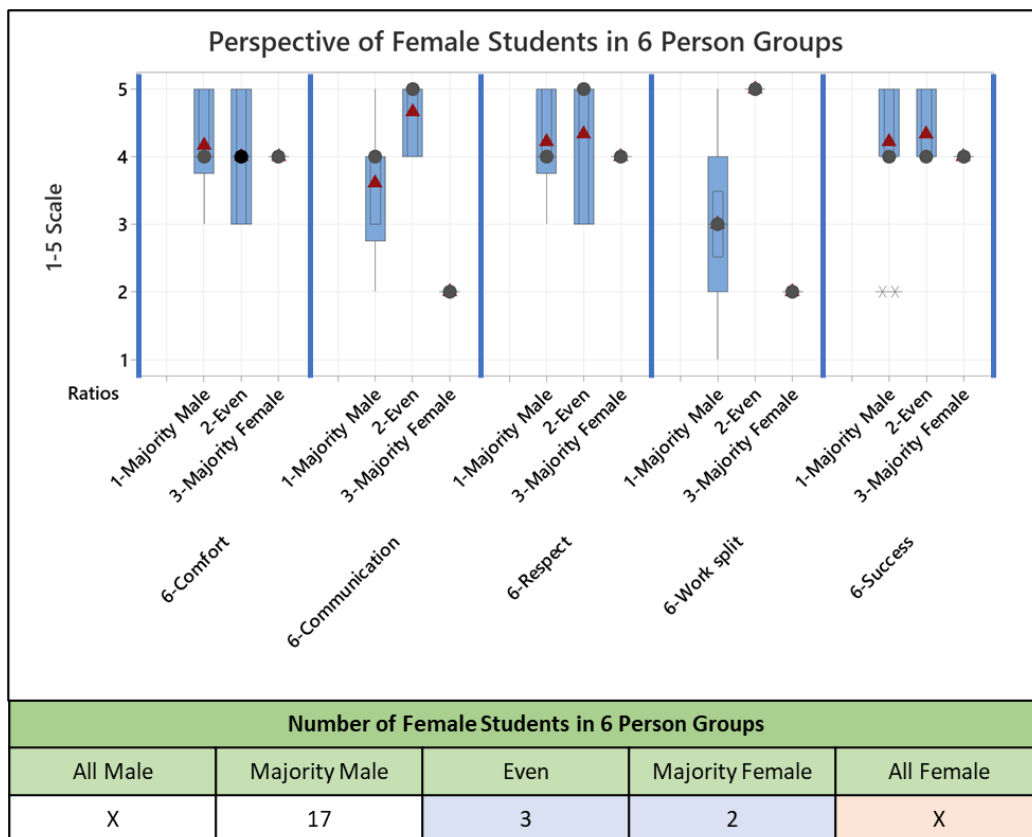


Figure 4. Perception of Female Students in Spring 2024 Semester in a 6 Person Group

Figure 5 presents a similar setup to the previous graph but reflects the perspectives of male-identifying students. It's notable that in these plots, only a single male participant reported being a part of an evenly ratioed group with the same thing occurring for the majority female group.

This results in those points representing a single student's viewpoint rather than that of a population. These points will still be included as a part of the discussions, however, the foundation for the comparisons is limited because of this. Starting on the left, male students reported feeling most comfortable in all-male groups. From the perspective of the male students, Communication, Respect, and the Division of work were all rated well and similarly across the groups except the evenly ratioed one. Interestingly, despite rating other aspects poorly, the male student in the evenly ratioed group rated the success of his project as perfect. The other male participants rated success highly as well, with the majority male group rating success slightly higher, (about 4.5 instead of 4.0).

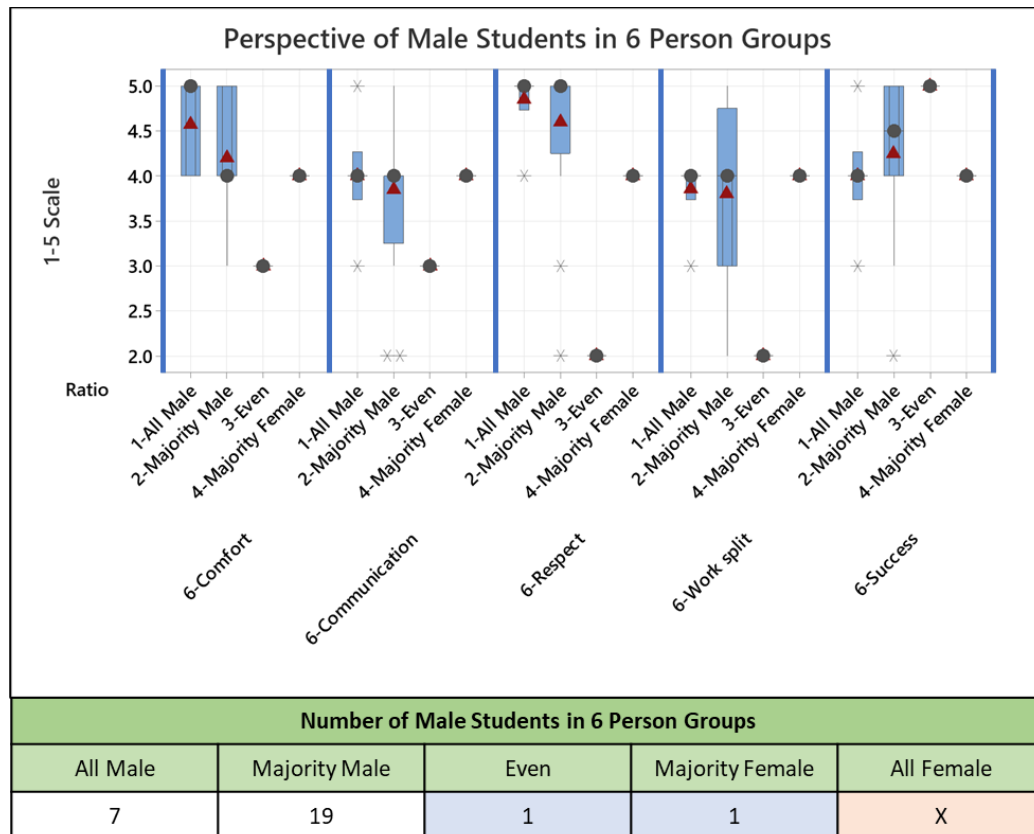


Figure 5. Perception of Male Students in Spring 2024 Semester in a 6 Person Group

4-Person Group:

Continuing with a focus on the 4-Person groups, Figure 6 and Figure 7 show the responses from the perspective of female and male students, respectively.

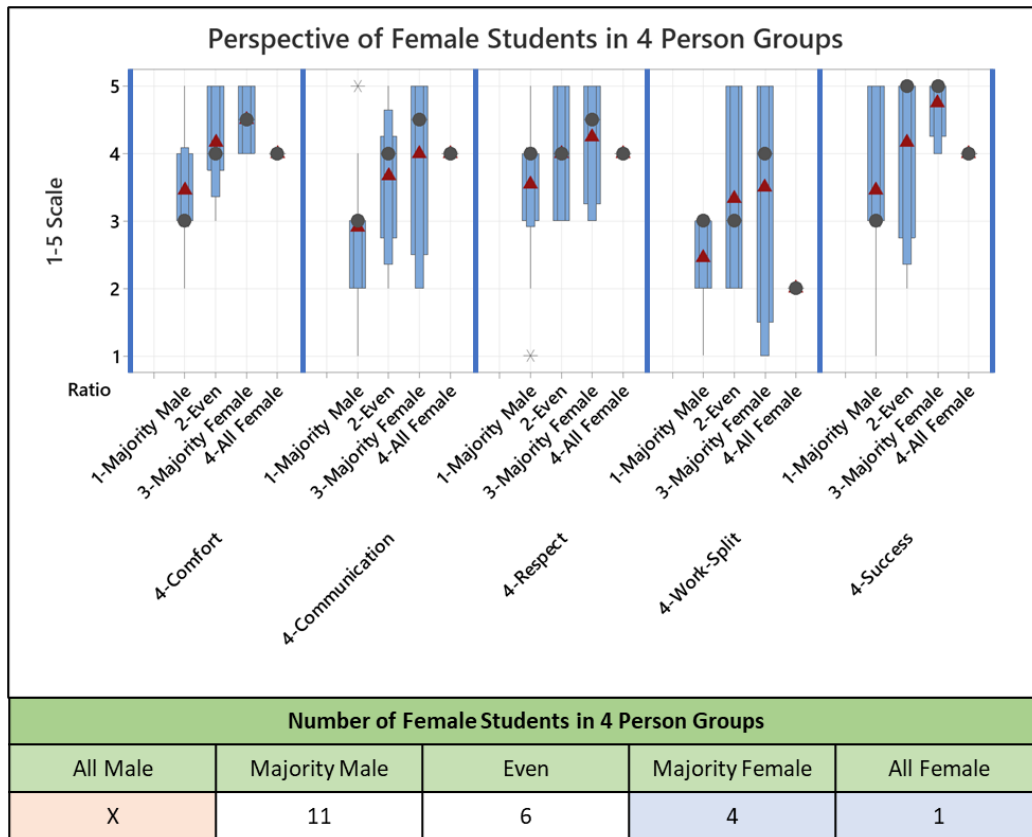


Figure 6. Perception of Female Students in Fall 2023 Semester in a 4 Person Group

Figure 6 displays female students' perceptions of their 4-person groups during the fall semester of 2023. As with the earlier data, only a single female student reported being a part of an all-female group, limiting the comparisons there with. Looking at the responses, female students reported feeling the most comfortable in majority female groups, with similar levels of comfort across all-female and even groups. Conversely, they felt least comfortable in majority male groups. This discomfort is consistent with their assessments of group communication and respect. Although female students reported feeling somewhat more respected in majority male groups compared to previous categories, there were still notable outliers with respect ratings as low as 1 out of 5. Work distribution was most balanced in even and majority female groups and least balanced in all female and majority male groups. Ultimately, female students rated their project as most successful in even and majority female groups, achieving perfect scores, while majority male groups we perceived as the least successful.

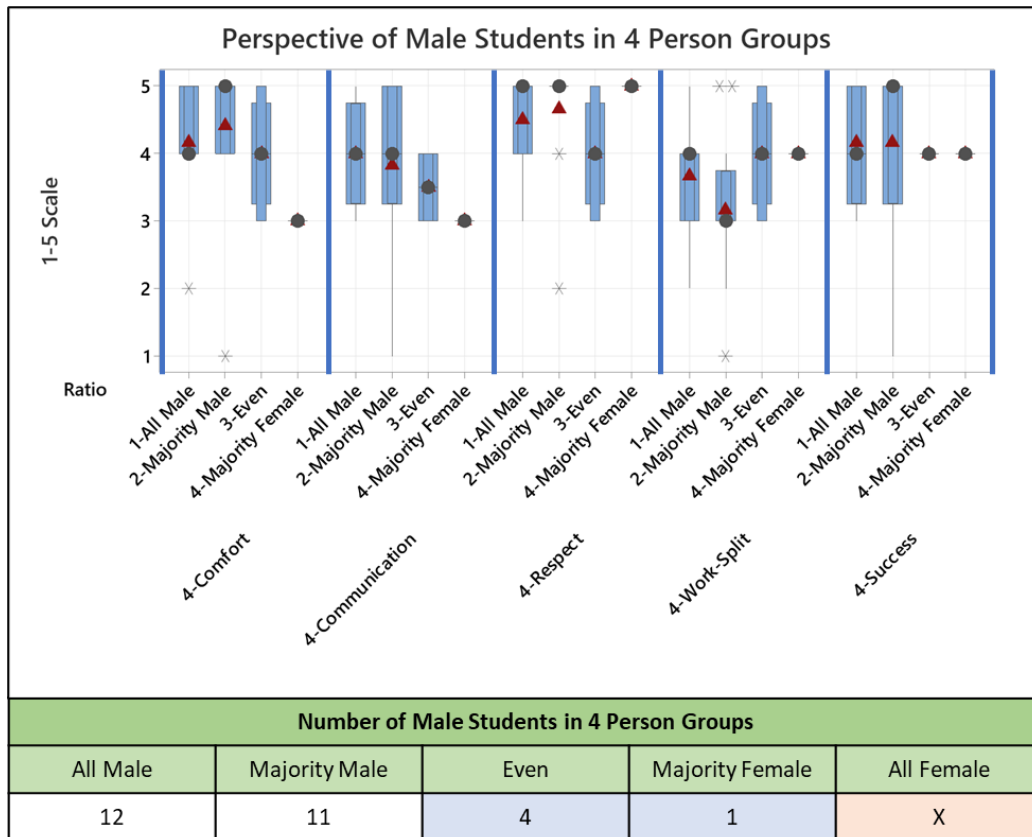


Figure 7. Perception of Male Students in Fall 2023 Semester in a 4 Person Group

Figure 7 presents the perspective of male students in 4-person groups from the fall semester of 2023. The data reveals comparable trends to those observed earlier. Starting from the left, we see that male students felt most comfortable in majority male groups, and reported high comfort levels in even and all male groups. The only male participant that reported being in a majority female group reported feeling neither uncomfortable nor comfortable resulting in a lower overall rating for that category.

Communication and work distribution followed similar patterns, with male students feeling well-respected across all group compositions. The perceived success of the project was highest in majority male groups. It is worth noting that most of the students surveyed were in majority male groups. This set also exhibited an increase in outliers within majority male groups, where students rated their groups very poorly in comfort, communication, respect, work distribution, and success.

2-Person Group:

Finally, looking at the responses related to the 2-Person groups, the female and male perspectives are shown in Figure 8 and Figure 9.

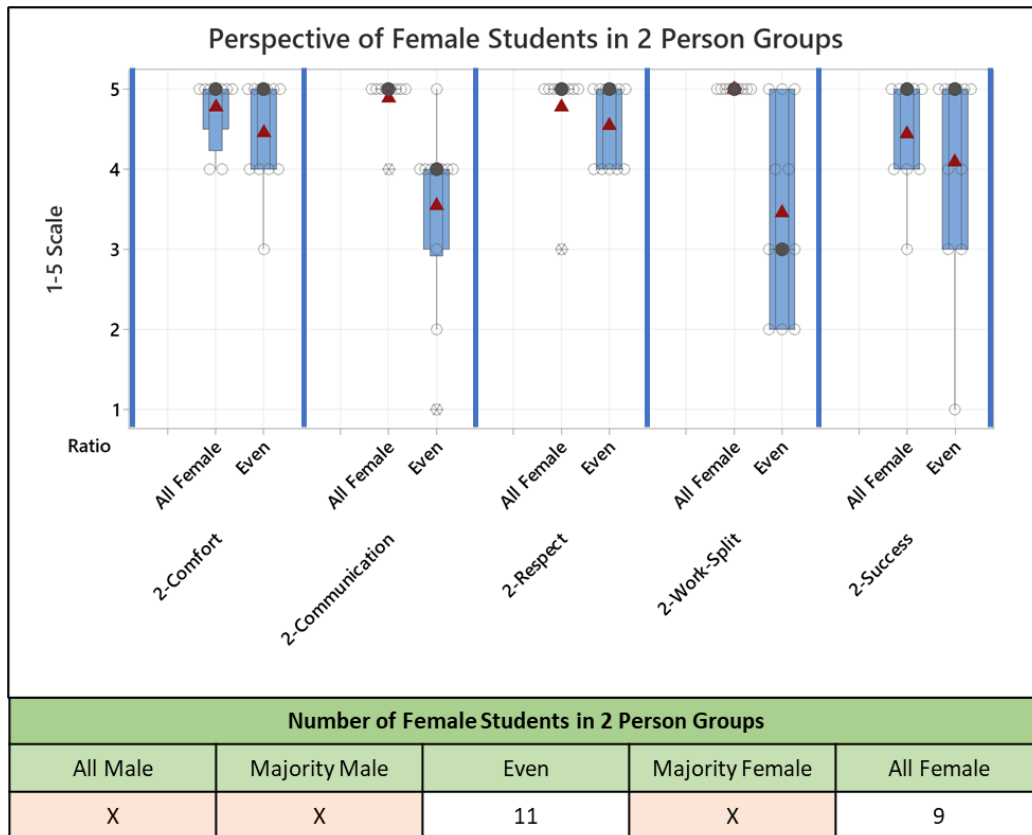


Figure 8. Perception of Female Students in Spring 2024 Semester in a 2 Person Group

Figure 8 presents the perspective of students in 2-person groups from the spring 2024 semester. Unlike the previous groups, these smaller groups were formed by the students themselves and only operated for a few weeks. The responses from this group lacked consistency and did not reveal clear trends. The data shows a wide range of responses, and the increased number of evenly sized groups further contributed to variability. Overall, all female student groups displayed a more positive perspective, particularly in work distribution and communication.

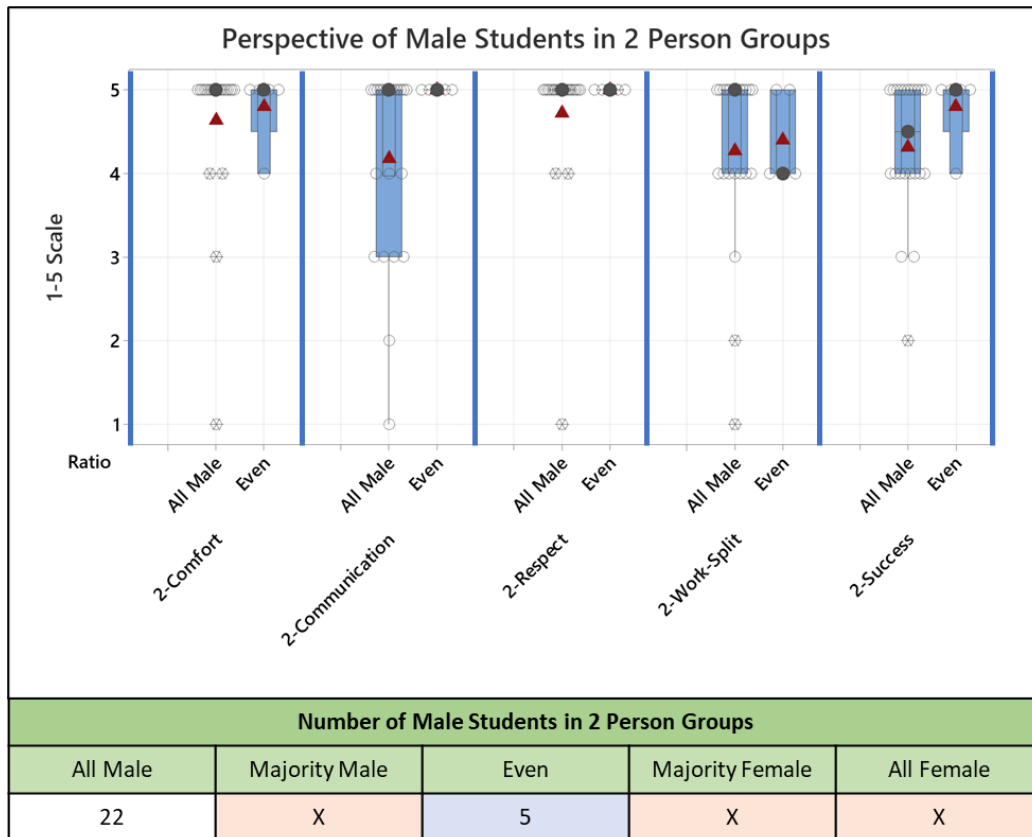


Figure 9. Perception of Male Students in Spring 2024 Semester in a 2 Person Group

Figure 9 displays the perspectives of male students in their 2-person groups from the same semester this graph mirrors the results of the previous one, with no recognizable trend. The data is characterized by individual responses with significant variability and numerous outliers. Both all-male and evenly sized groups show similar performance across categories, but responses ranged widely from 1 to 5.

Discussion:

In analyzing the responses of 50 students from various group sizes, including 6-person, 4-person, and 2-person groups from the Spring 2024 semester, several notable characteristics emerged. For the 2-person groups, no clear trend or correlation was observed between students' perceptions of their groups and gender composition. This lack of correlation could be attributed to the increased influence of individual personalities as group size decreases. The self-selection of their partners also could have had an impact on the ratings.

In contrast, some possible trends were observed in the 6-person and 4-person groups. Female students, in particular, reported higher satisfaction and success in groups with an even gender ratio. Male students displayed similar patterns, though with some notable exceptions. In multiple instances, a sub-population of the participants only had a single student reporting a specific group ratio. This makes strict comparisons of the data to be shaky at best and could represent a single viewpoint rather than that of the population. An example of this is that in an evenly ratioed 6-person group, a single male student rated his team significantly lower in all categories, which

deviated from the general data and our previous gender studies. Despite his negative perception, this student still awarded his group a perfect score for their project's success, indicating that while he felt his group performed poorly, they ultimately succeeded with a high grade.

The findings of this study suggest that ensuring gender balance in team composition could enhance communication, respect, and fairness in work distribution, particularly in medium-sized and large groups. By examining gender roles, this research highlights the influence of group dynamics on collaboration and success, underscoring the importance of addressing gender-based disparities in both academic and professional settings. Potential applications of these findings include the development of gender-aware group formation strategies in engineering education to foster inclusivity and improve group outcomes. Furthermore, industries reliant on team-based work structures could interpret these insights to enhance teamwork and inclusivity in the workplace.

With increased participant volume, the study would also have the statistical weight to support the conclusion that evenly mixed-gender groups promote better student comfort, collaboration, and project success, assuming the conclusion of the limited data set extrapolates to expanded data volumes. Larger sample sizes would allow for more robust statistical analysis, potentially uncovering nuanced impacts of gender balance on group effectiveness. These furthered conclusions, for example, could explore whether these benefits extend to other demographic factors, such as cultural diversity or varying levels of prior experience. Future research should aim to recruit a more representative and diverse participant pool to address the current limitations to both validate and expand upon these preliminary findings.

Overall, the study only suggests a correlation between group size, gender ratios, and students' perceptions of their group dynamics and success. Some correlations correspond to those in previous works, and other results do not yet have the sample size to provide any definitive trends.

Conclusion/Future Works:

While limited in applicability, this study provides insights into the influence of group size and gender composition on student experiences and performance within mixed-gendered engineering teams. Our findings indicate that as group size decreases, the impact of gender composition on students' perceptions and success diminishes. That is, in 4-person and 6-person groups, correlations emerged, particularly with even gendered groups often yielding the highest success rates for both male and female students. However, it is important to note the limitations of our study, including the small sample size of 50 students, with only 22 female participants, and the relatively few evenly gendered groups compared to majority-male or majority-female groups.

In the study, it was difficult to compare results when certain sub-groups only consisted of one participant. Although comparisons were still attempted, it was not likely an accurate representation of the group. A greater number of participants in each type of gender ratio is needed to accurately compare, but possible trends have begun to emerge which encourage future research in this subject.

For future research, it is crucial to expand the sample size and diversity of participants to provide more granularity and provide a more comprehensive understanding of these dynamics. Additionally, extending this research to other educational settings and different student demographics could offer valuable insights into how group gender composition effects students at all stages of their academic journeys.

Similarly, in trying to narrow down the cause for comfort or discomfort in a group, more than just the gender ratio should be investigated. It is likely that all facets of a student's intersectionality superimpose on one another in a group setting. Building upon this work and adding information related to a student's intersectionality could prove productive as it could be that one identity could foster connection with a team while another could present barriers.

By continuing to investigate these factors, we can contribute to the development of more effective educational practices that foster success and equity within engineering and other STEM fields.

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