



Experience and Representation of Gender Minorities in Undergraduate Computer Science

Rhody Kaner and Eitan Frachtenberg

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Rhody D. Kaner and Eitan Frachtenberg*

Abstract

Computer science (CS) has a well-known gender diversity problem. Gender minorities (GeM) continue to be significantly underrepresented in professional and academic CS careers. This underrepresentation can be traced back to undergraduate programs and even to high school, where gender bias and stereotypes persist to drive GeM students away from the field.

To better understand the causes of the lack of diversity and poor GeM retention through undergraduate programs, this study reports on a survey of undergraduate students (n=84) in the nascent CS department at Reed College. Since Reed only began offering the CS major in 2018, it does not have an entrenched culture, which can help in isolating the larger cultural context and stereotypes that are affecting its students. Thus, the results of our survey may be generalized to other CS programs, despite its modest size.

We found that on the one hand, GeM students feel similarly passionate about CS and are as content with the department as their male counterparts. On the other hand, they rank their own CS ability and confidence as lower than male students and feel less encouraged to major in CS overall, especially students in early CS classes. Female students are not satisfied with the information and resources related to CS careers provided at Reed, and seem to value social connection within the department more than other students. Specifically for male students, there appears to be a strong correlation between being passionate about CS and feeling liked by CS faculty.

1 Introduction

Historically, CS had significantly better gender diversity than one might assume given the field's current state (Thompson, 2019). During World War II, women were often employed as 'Computers', the title given to those whose job was to solve calculations for use on the battlefield. As early digital computers were developed, it made sense to teach those already experienced with math and logical reasoning to become programmers, and women were viewed as good

*Department of Computer Science, Reed College, Oregon

candidates, so some women were taught to program (ETHW, 2017; Thompson, 2019). Women continued to be undervalued and underpaid for their work, and computer programming had yet to earn the prestigious reputation it holds today (Little, 2018).

But soon after, women began to lose their role in the field (Devlin and Hern, 2017). As Clive Thompson explains, “the advent of personal computers in the late ’70s and early ’80s remade the pool of students who pursued computer-science degrees. Before then, pretty much every student who showed up at college had never touched a computer or even been in the room with one” (Thompson, 2019). Therefore, this disparity may have started at home, but extended and expanded into the college years (Beyer and DeKeuster, 2008).

A later study on the gender representation and experiences of undergraduate CS students at Carnegie Mellon University found that “first-year students arriving at Carnegie Mellon with substantial experience were almost all male and also traced this disparity to factors in childhood” (Margolis and Fisher, 2002b). The opportunities available and encouragement for boys to learn programming as children provided them with ample preparation for their college CS courses. Girls were not given these opportunities, and would most often begin their college CS education with little to no CS experience. The majority of male students with prior coding experience led to “a sense in the classroom that if you hadn’t already been coding obsessively for years, you didn’t belong” (Thompson, 2019).

The view that myopic obsession was the expected way to engage with CS played a large factor in the gendered culture of CS education (Margolis and Fisher, 2002a). Boys growing up around computers and developing their skills and passion for programming from a young age led to a culture where obsession with computers was the norm. Feeling simultaneously unprepared and alienated from the culture of CS, women felt unsure of their place in CS programs. “By the second year, many of these women, besieged by doubts, began dropping out of the program. (The same was true for the few black and Latino students who also arrived on campus without teenage programming experience)” (Thompson, 2019).

The stereotype of a computer scientist as a computer-obsessed (and white (Guynn, 2017)) man was further entrenched through media portrayals, and found its way into present academic and corporate culture as well (Thompson, 2019). On average, 25% of computing jobs are held by women (Ashcraft et al., 2016). And representation of women appears to be even lower in academia. Among the five institutions¹ that grant the most undergraduate degrees in CS, an average of 21% went to women in 2016 (Department of Labor, 2018). Only 18.3% of PhD graduates in CS in 2017 were women (Zweben and Bizot, 2018). The field also exhibits excessive homogeneity in race and socioeconomic status (Gallup, 2019; Parker et al., 2018; Myers, 2018), but these aspects remain outside the scope of our survey because of its modest size. Although schools such as Carnegie Mellon (Frieze, 2018; CMU, 2016; McBride, 2015) and Stan-

¹UCM, USC, UI at Urbana Champaign, UCSD, and UI at Springfield

ford (Roberts et al., 2002) are actively working on increasing diversity, the large gap in undergraduate CS gender representation persists in most colleges.

Our main research question for this study was, in what ways do these entrenched cultural stereotypes affect CS students in a small liberal-arts college with little internal history of CS? In addition, we wanted to better understand the factors affecting the experience of GeM CS students, and how they evolve over time. To accomplish this, we deployed a survey, the design of which is described in the next section. Then, the results section presents the distribution of responses to each question, along with their interpretation. The discussion section further considers these results in context. We conclude and present future work ideas in the final section.

2 Materials and Methods

Our survey’s questions were inspired in part by similar studies of undergraduate CS experiences and in part by personal and anecdotal experiences. We therefore wrote all of the survey questions in terms of subjective personal impressions and experiences and phrased them in positive terms to avoid negatively biasing students’ answers. In consulting with a survey statistician, we decided on the following questions to be ordered randomly so as to limit bias (priming) in student responses.

- “I feel that my innate ability in CS matters to the CS Faculty” and “I feel that the time and effort that I put into my CS classwork matters to the CS Faculty”
- “I have generally had positive experiences with CS drop-in tutoring”, “I have generally had positive experiences with CS individual tutoring”, and “I have generally had positive experiences in office hours with CS Faculty”
- “I feel that CS Faculty care about my academic success” and “I feel that CS Faculty care about my personal well-being”

Randomizing these sets of questions resulted in 24 uniquely ordered versions of the survey, which were shuffled and handed out to students.

We asked students for their gender on the last page of the survey, after they had answered all of the multiple-choice questions, again to avoid priming their responses (Steele and Ambady, 2005). We considered several alternatives for which gender choices to list on the survey. While a write-in box would be the least prescriptivist or presumptuous way to ask for gender, we were concerned that this would deter students from answering it. After considering issues ranging from syntax to adequately respecting survey participants, and consulting a few non-binary students for input, we selected four gender options: ‘Male’, ‘Female’, ‘Non-Binary’, and ‘Other’. We avoided any other questions that hint at identifying information in order to protect their anonymity. Since only one respondent marked their gender as ‘Other’, we chose to combine the

categories of ‘Other’ and ‘Non-Binary’ to create one superset of students whose gender identity is outside of the gender binary.

The survey was given in paper form during the lecture section of all five CS courses offered at Reed in the Fall semester of 2018: CS Fundamentals I, CS Fundamentals II, Computability and Complexity, Artificial Intelligence, and Systems. This distribution timing and method were chosen to maintain anonymity and encourage students to participate by giving them time to complete the survey that would otherwise be spent in class. We received 84 responses to the survey. This study was approved by the Reed College IRB (#2018-F39).

3 Survey Responses

A primary goal in this survey was to understand better the factors and experiences that can benefit or detriment GeM students’ decisions to pursue degrees in CS. To this end, we surveyed Reed students enrolled in any of five CS courses to analyze the subjective experiences of a sampling of undergraduate CS students. Reed is a small school with a small CS department, so these analyses are based on only 84 survey responses (not all of whom indicated their gender). While this was sufficient data to suggest some interesting trends, some of our research questions remained inconclusive.

3.1 Experience and Ability

The first few questions in our survey concentrated on the overall experience of students in the CS department, as well as their overall self-assessed CS abilities.

3.1.1 Overall Experience

We found that Reed students are relatively happy with the CS department. When asked to rate how positive their overall experience within the Reed CS department has been, the vast majority of students indicated relatively positive experiences, with median scores at or above 7 (out of 10) for all gender groupings (Fig. 1). GeM students indicated slightly less positive experiences than male students, with median scores of 7 for women and for Non-Binary/Other gendered students, while male students had a median score of 8. There does not appear to be a statistically significant difference between these scores for any gender groupings ($p > 0.075$).

3.1.2 Faculty Encouragement

Students’ responses to the question asking them to rate how much they agree with the statement “I feel encouraged to major in Computer Science by CS Faculty” showed that the median response for all gender groups was “neither agree nor disagree” (Fig. 2). The vast majority of responses for GeM students fell between “neither agree nor disagree” and “disagree” while most responses from male students fell between “agree” and “neither agree nor disagree”. When

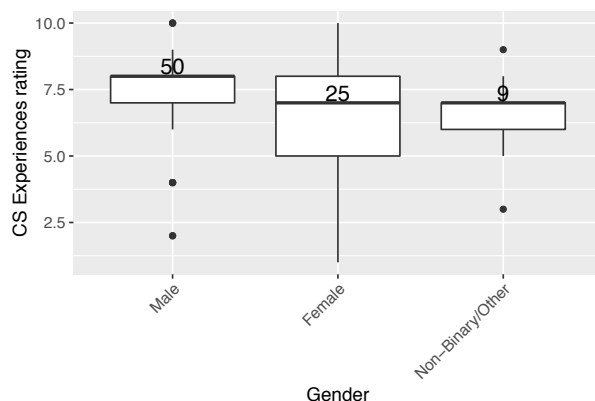


Figure 1: Students’ self-ranking of overall positivity of their experience with the Reed CS department. In this and all other distribution plots (boxplots), the middle bar represents the median value. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 x inter-quantile range from the hinge. Dots represent outliers to this range, and numbers represent sample size for the category.

assigning numeric values to these responses (with 1 referring to “strongly disagree” and 5 referring to “strongly agree”), the mean value for GeM students was 2.91 and the mean value for male students was 3.44, with a difference of 0.53 ($p = 0.017$).

3.1.3 Career Exposure

Another question asked students how much they agree with the statement “I feel that the CS department provides sufficient exposure to a variety of CS-related careers and encourages exploration of different career paths” (Fig. 3). All students have access to the same career resources at Reed, yet 92% of female students said that they disagree with this statement, while only 33% of male students disagreed with it. The majority of male students said either that they “neither agree nor disagree” or “agree” with this statement. This finding is consistent with the results of another study analyzing the experiences of undergraduate CS students led by Linda Sax at UCLA’s Graduate School of Education and Information Studies (Sax, 2019).

A possible explanation for this disparity may relate to the singular reason for choosing CS that was cited more often by women than by men in Sax’s study, which was “I am interested in helping people or society” (Sax, 2019). If women are generally more interested in using their CS education to help people or contribute positively to society, they are more likely to be focused on their career plans and how they will use CS to achieve those goals. It follows that women are more dissatisfied by the lack of information about various CS careers,

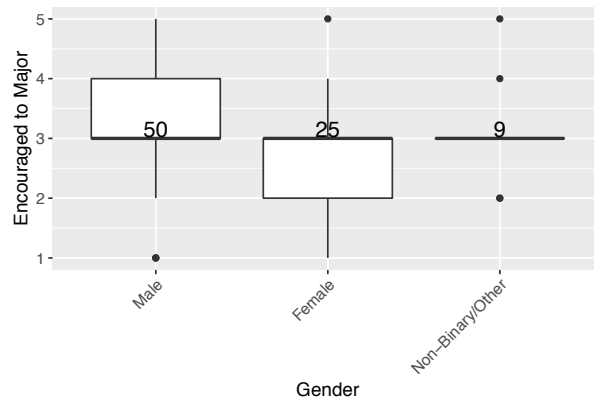


Figure 2: Students' self-ranking of perceived encouragement to major in CS

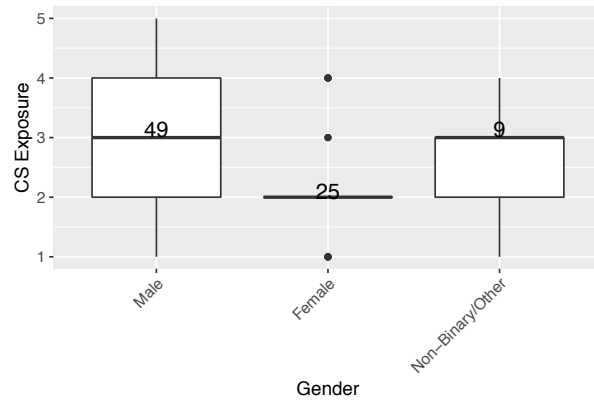


Figure 3: Students' ranking of the department's exposure to CS careers and opportunities

while men are more likely to be studying CS because they enjoy it. Subsequently, male students likely either do not care as much about career exploration or are satisfied by the limited and academia-focused CS career information that Reed does provide.

3.1.4 Passion for CS

Despite feeling less encouraged to major in CS and underexposed to career resources, GeM CS students maintain approximately the same level of passion for CS as male students (Fig. 4). Although the median male CS student at Reed views their own passion for CS as “above average”, while the median GeM student views their own passion as “average”, there does not appear to be a statistically significant difference between the distributions of CS passion

across gender ($p = 0.26$). Perhaps there would be more differences in gendered responses to this question if it were more specific or addressed sources of passion for CS individually. Sax’s results indicate that for male students, agreement with the statements “I like to program computers” and “I am interested in solving problems with computing” were more often reasons for choosing to major in CS than for female students. This could imply that in larger samples, male students tend to exhibit higher passion for CS. However, in the context of the smaller Reed college, we think it is more likely that passion for CS can arise from different sources for students, and the sources are somewhat correlated by gender.

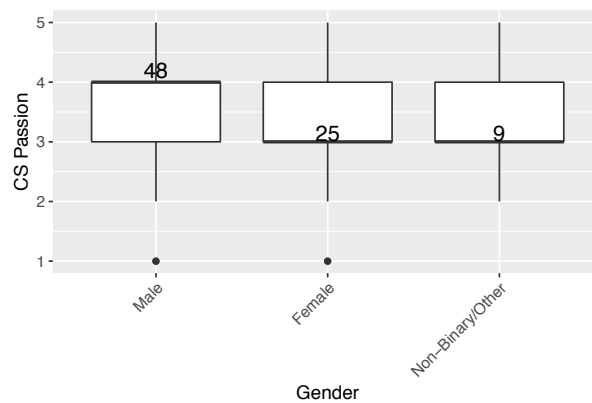


Figure 4: Students’ self-ranking of passion for CS

3.1.5 CS Ability

The largest disparities across genders arose in self-assessed ability and confidence in solving CS problems, as found in another study (Beyer et al., 2003). Overall, 66% of men responded that their CS ability is above average, compared to 29% of women and only one of the 9 students in the Non-Binary gender group. The median response for male students was that their CS ability is “above average” while the median response for both groupings of GeM students was that their ability was “average”. The mean ranking for GeM students was 3.0 (which corresponds to “average”) while the mean for male students was 3.66, with a difference of 0.66 ($p = 0.005$).

3.1.6 Problem Solving Confidence

There was also a significant difference in students’ asserted confidence to solve a typical CS problem in a Reed course (Fig. 6). The median response for male students was that they were “often” confident they could solve a problem, while Non-Binary/Other students were “sometimes” confident, and female students were only “occasionally” confident. The mean responses (on a corresponding

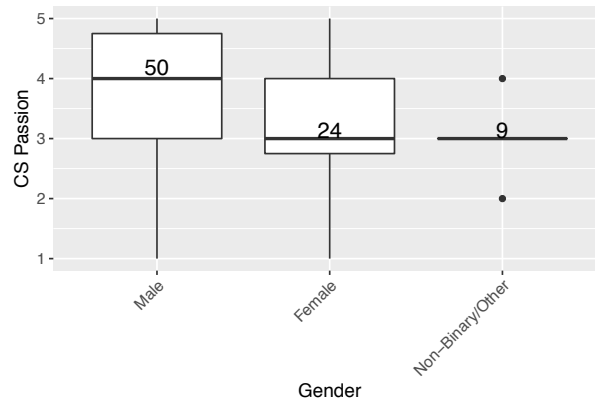


Figure 5: Students' self-ranking of CS ability

5-point scale) were 4.18 for male students, 4 for Non-Binary/Other students, and 3.12 for female students. No significant difference exist between confidence of male students and Non-Binary/Other students, but a clear difference exists between the means of men and women. The difference between means of male and female confidence to solve a CS problem is 1.06 ($p = 0.0006$). Sax found a similar result in her study: “A paradoxical finding is that even when men’s and women’s achievements are similar, women typically have lower confidence in their programming abilities than men” (Vu, 2017).

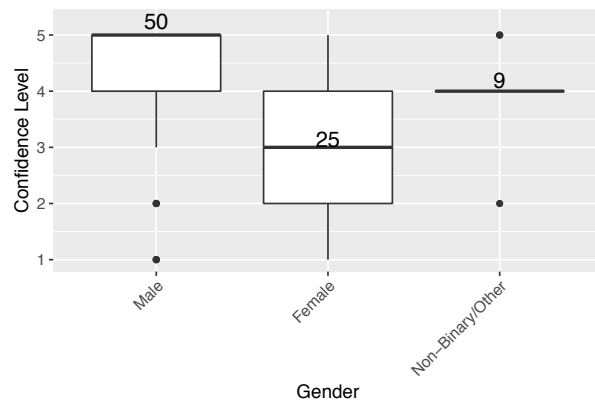


Figure 6: Students' self-ranking of confidence to solve a CS problem

3.2 Differences by Course

To better understand these differences, we compared some factors individually by class. Unfortunately, when divided up by students' current CS course, the

sample sizes for each gender grouping become far too small to produce conclusive results, but this data suggests some trends that are worth consideration. We chose not to focus on the gender category of Non-Binary/Other for this analysis, because no single class had more than three students who fell into this category, which is not a large enough sample size to demonstrate useful results. Instead, we focused only on the differences between male and female students' responses.

3.2.1 Ability by Course

The gendered differences in self-assessed CS ability are more pronounced in introductory CS courses and grow less distinct in advanced classes (Fig. 7). We considered two possible explanations: either less-confident women drop out before reaching advanced classes, or women improve their perception of their own abilities over time. We found no support in the literature for the latter, but a study of undergraduate CS students at Carnegie Mellon offers evidence for the former explanation (Margolis et al., 2001). This study found that “as [female CS students] continue into their second and third semesters, a number of female students experience a crisis in confidence, an internal struggle over whether they are suited for CS, followed by a loss of interest in the field” (Margolis et al., 2001).

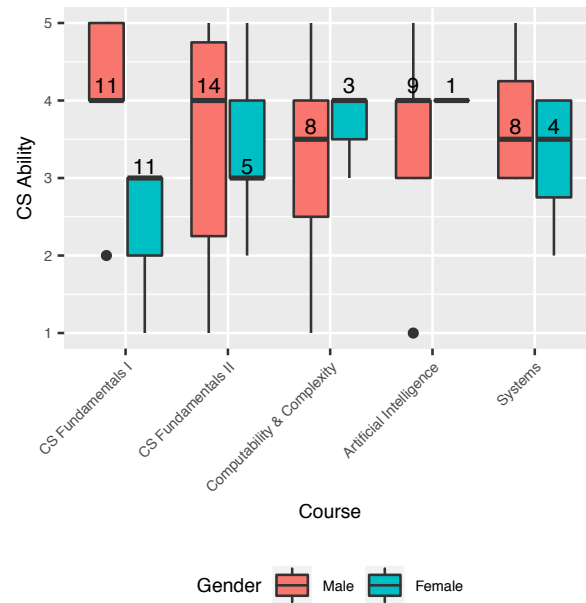


Figure 7: Students' self-ranking of CS ability by course and gender

3.2.2 Confidence by Course

We compared the responses of women and men in the four classes that had more than one female student (Fig. 8). Female students’ confidence in problem-solving for CS Fundamentals I and Computability and Complexity are significantly lower than their confidence in CS Fundamentals II and Systems. A possible explanation for this comes from Carol Dweck’s psychological research on fifth-grade students (Dweck, 2016). Dweck found that “bright girls, when given something to learn that was particularly foreign or complex, were quick to give up” (Halvorson, 2011). Both CS Fundamentals I and Computability and Complexity emphasize new and unfamiliar material and particularly complex problems that often involve figuring out the ‘trick’ to a problem. Perhaps women feel less confident when faced with this sort of material and more confident in courses that instead require hard work and consistent effort to complete assignments.

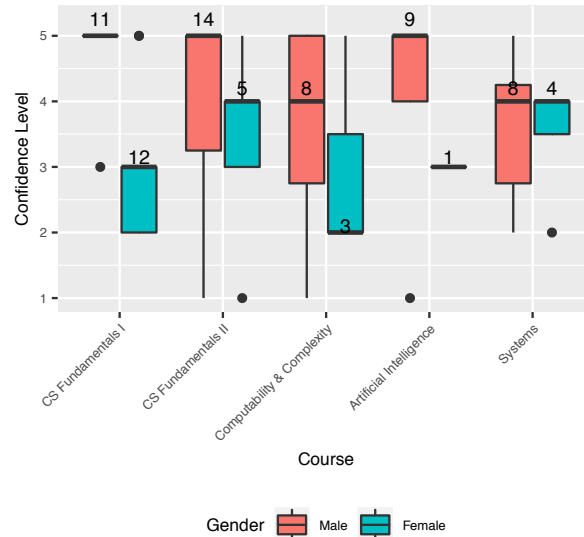


Figure 8: Students’ self-ranking of confidence to solve a CS problem by course and gender

3.2.3 Passion by Course

Passion for CS does not appear to have any correlation with course (Fig. 9). While female students in CS Fundamentals I have decidedly lower confidence and self-assessed CS ability, their passion for CS is on average either higher than or equal to women in every other CS course.

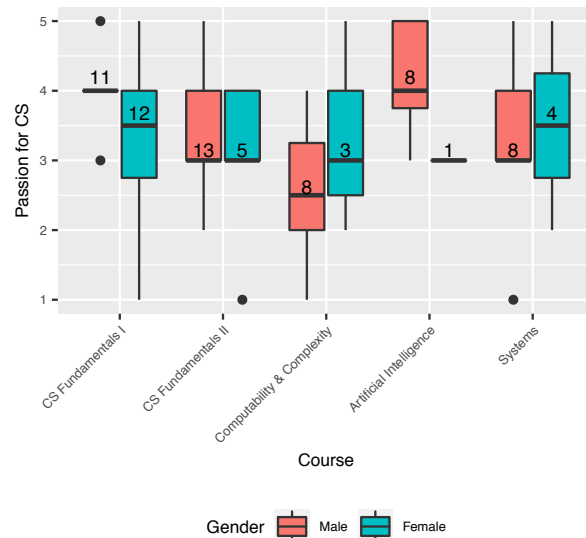


Figure 9: Students’ self-ranking of passion for CS by course and gender

3.3 Qualitative Questions

We asked students two write-in questions: “What do you like about the CS department?”; and “What would you like to see improved about the CS department?”. Analyzing the responses and looking at word frequencies by gender, we were unable to discern any gendered differences to these questions.

For the first question, the word “professors” occurred most frequently (Fig. 10). CS students generally seem to view the faculty as friendly and caring, and appreciate their passion for CS and dedication to helping students. Students also frequently used the word “assignments” in their praise of the department, noting that they were often “fun”, “interesting”, and “useful”. The word “math” appears because several people mentioned how much more they like CS than math. Several students also had praise for the “help” available from both professors and “drop”-in “tutoring”.

For the second question, the word “professors” also appears quite large in this cloud, but in the context of very different sentences (Fig. 11). A few students have had negative experiences with CS professors, particularly surrounding mental health and missing work due to illness. However, most of the times the word “professors” appears in these responses, it is in sentiments expressing a desire for more CS faculty and more diverse CS faculty. Other responses requested more support for students. One student expressed that they would like the department to provide “support for more students who have no experience with programming” and another would like the department to “improve support of struggling students”. Another type of sentiment that often includes the word “students” are ones expressing dissatisfaction with interactions with



Figure 10: Word cloud for responses to the question: "What do you like about the CS department?"

other CS students. One female student explained that "I experience the most discrimination (e.g. mansplaining and underestimating my abilities) when interacting with students. I'd like to have a better dialogue about diversity among students" and another female student felt that she needed to "find a way to befriend STEM bros" to better fit in within the CS department. Students of all genders expressed much interest in having more CS courses and more varied topics of CS available to study at the college.

3.4 Correlation Analysis

To explore any correlations between surveyed factors, we looked at correlation matrices for male and non-male students. We avoided separate correlation matrices for female and Non-Binary/Other students because the low number of responses in the latter category caused strong correlations to appear for many factors based on just a few responses, which likely means the sample size is too small to determine any meaningful correlations. Instead, we combined the female and Non-Binary/Other categories into one data set to produce the two matrices in Figure 12 for comparison.

Given our previous results, it is not surprising that these correlation matrices demonstrate a stronger correlation between self-assessed ability and confidence to solve a CS problem for male students than for GeMs. We were unable to find other research with a similar finding, as self-assessed ability and confidence seem to rarely be evaluated separately. As our previous findings suggest, there appear to be more complicated reasons that GeM students may have lower confidence to solve a CS problem in certain courses, such as lack of experience before college (Cohoon, 2010), perfectionism (Sax, 2019), or a tendency to be dissuaded by complex and tricky problems.



Figure 11: Word cloud for responses to the question: "What would you like to see improved about the CS department?"

We also found that for female students only, having positive individual tutoring experiences is strongly correlated with feeling encouraged to major. This gender difference can perhaps be explained by another finding of Sax’s study; “collaboration also is a determining factor” for women choosing to major in CS. Sax explains that for women, “If someone stays in the major, it’s usually because they have strong peer connections” (Vu, 2017), which matches our anecdotal evidence.

Another intriguing result was the appearance of a positive correlation between passion for CS and feeling liked by CS professors for male students, while no correlation exists between these two factors for GeM students.

There is no significant difference across genders in either how liked by professors students feel or in passion for CS (Fig. 4), but a clear correlation between these factors exists exclusively for male students. No single likely explanation for this result emerged, so we asked several CS students to look at a linear regression graph between the two (Fig. 14) and suggest their own explanations. One student hypothesized that men who are passionate about CS are likely to have a higher ego relating to the field, which may lead them to assume professors like them. Another student suggested that GeM students may build resilience due to the inherent discouragement of being a minority in the field of CS, which would help them maintain a drive to continue studying CS even when they feel disliked by professors, whereas male students may be more discouraged by being disliked and drop out. However, this hypothesis fails to account for the few male students who both have low passion for CS and feel disliked by professors. A third student suggested that male students who are passionate about CS may

be more likely to participate in class and talk with CS professors, leading to them feeling more liked, whereas a lack of confidence might prevent equally as passionate GeM students from similarly engaging with professors. According to a survey by Piazza, “Female CS students answer 37% fewer questions on average compared to their male peers” (Parekh, 2015). Piazza attributes this gap to women’s general lack of confidence in CS, which is also apparent in our survey. This explanation does not account for the data points showing women with low passion who feel highly liked by professors. It is possible that the pressure for perfectionism that women often feel (Sax, 2019) leads some female students to interact frequently with professors (providing more opportunities to develop a positive relationship), despite a lack of passion for the specific material.

4 Discussion

The survey responses from Reed CS students demonstrate some of the gendered differences in experiences of undergraduate students studying CS as well as anecdotes and suggestions for ways to improve the educational climate. Some GeM students described feeling out of place or unsupported. One student described her experience in the CS department as follows: “I know there is a lot in the department that pushes to have more diversity and encourage it, but I still feel like I’m not as important as male students here. This is my first CS class ever and maybe other people have way more experience than me but I sort of feel like I can’t make a career in CS. When I go to CS talks, I see 90% men and 10% women and it doesn’t seem like me having an interest in CS is encouraged”. Despite efforts to encourage diversity, a critical mass of a minority group is often necessary to make members of that group feel comfortable (Lathrop, 2015). A research team at University of Amherst led by Dasgupta, found “that women, particularly first-year students, participate more actively and feel less anxious when they are able to work in small groups or ‘microenvironments’ that are mostly female or that have equal numbers of men and women compared to mostly male groups.” (Lathrop, 2015).

Students provided a variety of ideas and suggestions for improving the climate of the Reed CS department. Some students expressed a desire for more diverse CS faculty, perhaps to serve as role models for students whose identities are not represented among the current faculty. Research at Stanford University demonstrated that providing female role models in undergraduate CS courses can improve women’s experience and increase the number of women majoring in CS (Roberts et al., 2002). These role models do not necessarily have to be faculty, but can also be slightly older students. The study’s conclusion is that the ideal setup involves “stepping-stone role models” in which students have role models at many different points of achievement along their potential educational and/or career path.

Many students also wished to spend more time with faculty and get to know them better. One student described their experience interacting with Professors: “Most of the conversations I have had have been limited to course material

only - I've found it difficult to connect with CS professors personally". Many students also indicated that they felt the community of the department could be improved. One student explained that "there's many people I don't talk to, and it just doesn't feel like a supportive/friendly department". Students have expressed informally that the few organized CS department events that have occurred at Reed helped to build community, and one idea for a fair and sustainable way to continue the practice would be to have a paid student position (or multiple positions) as department social coordinator.

Students (and particularly GeM students) indicated that they would like the CS department to provide more support for programming novices. Some students felt that more lab time in introductory CS courses would be helpful for inexperienced students. Another suggestion was to offer multiple courses corresponding to students' level of experience, as has been successfully employed, for example, at Harvey Mudd College (Harvey Mudd College, 2019). Furthermore, several students indicated that they appreciated and benefited from the opportunity to express their experiences as minorities in CS. Anecdotal student feedback suggests that discussions about the CS department climate and issues facing GeM students fostered an increased sense of community among GeM students in itself.

5 Conclusion

This paper examined the subjective differences in experience between gender minority students and men in a new undergraduate CS department. In a natural experiment at Reed College, we identify differences between GeM students and male students, and because of the history of Reed College we know that these are not the result of institutional social history.

Our main findings from the survey responses are that while GeM students feel just as passionate about CS and generally happy with the department as their male counterparts, they also feel less encouraged to major in CS and rank their own CS ability and confidence as lower than male students. These findings are corroborated by past studies. These feelings do appear to improve in upper-level CS students, suggesting that a renewed focus on diversity and GeM experience in the introductory classes is warranted.

We also found that female students are dissatisfied with the information and resources related to CS careers provided at Reed, and appear to value social connection within the department more than students of other genders. There also appears to be a strong correlation between being passionate about CS and feeling liked by CS professors, but only for male students. The implication here may be that strengthening the social bonds among students and with faculty may improve the GeM student experience.

There are many more potential areas of inquiry pertaining to gender disparities in undergraduate computer science education. To validate our data, we hope to conduct a more comprehensive version of this survey in the same classes across multiple semesters. This would help to mitigate effects of variabil-

ity caused by courses being taught by different professors and personal student circumstances. It would also increase the sample size to yield more statistically meaningful results. Another area of study that may be illuminating would be to study gender representation and experiences of students who choose to drop out of CS courses or switch out of the CS major. Understanding why students, and particularly those who are under-represented, choose to leave CS courses could provide the Reed CS department with valuable information about how to better serve students and promote inclusivity.

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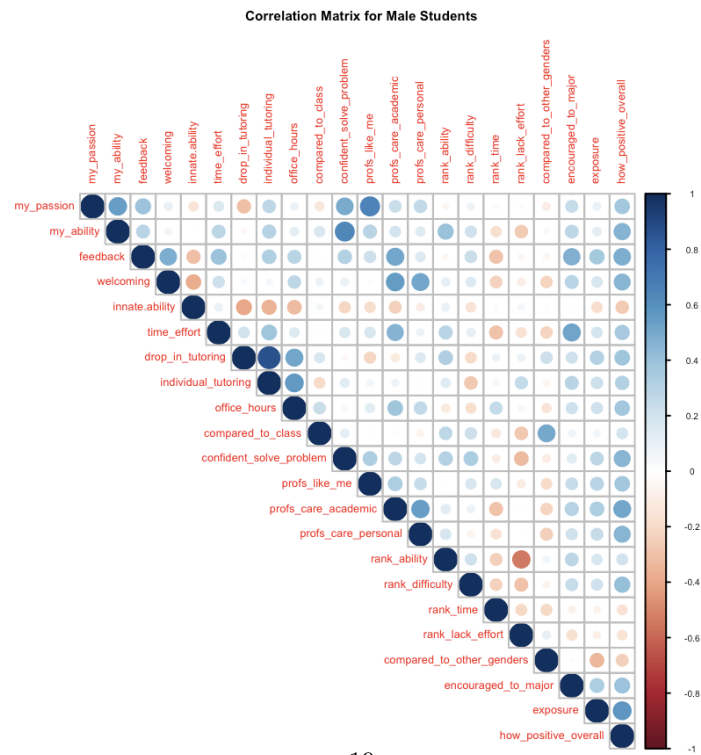
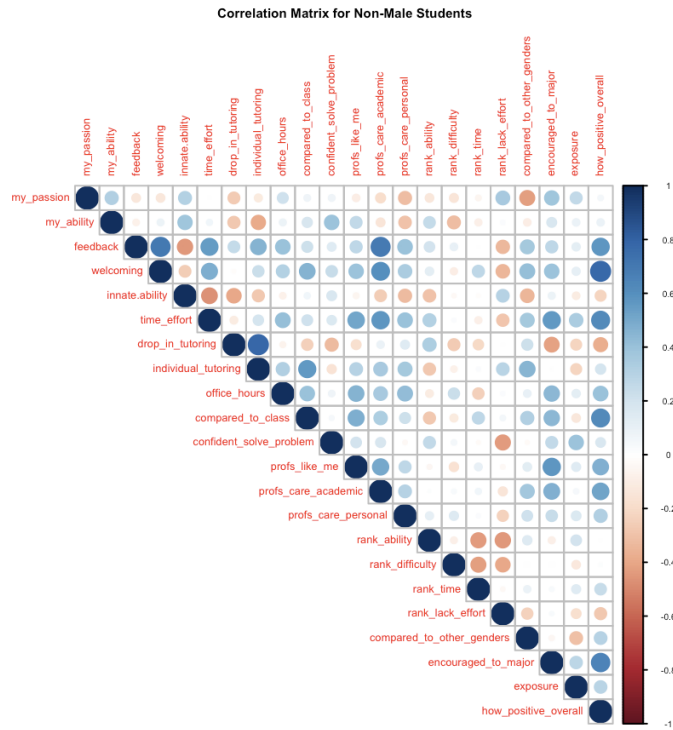


Figure 12: Correlation matrix of survey responses for GeM (top) and male students

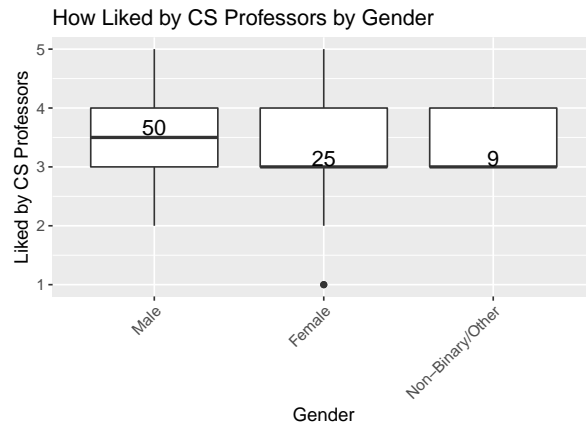


Figure 13: Students' self-ranking of feeling liked by CS professors. Higher numbers represent students who feel more liked by their professors.

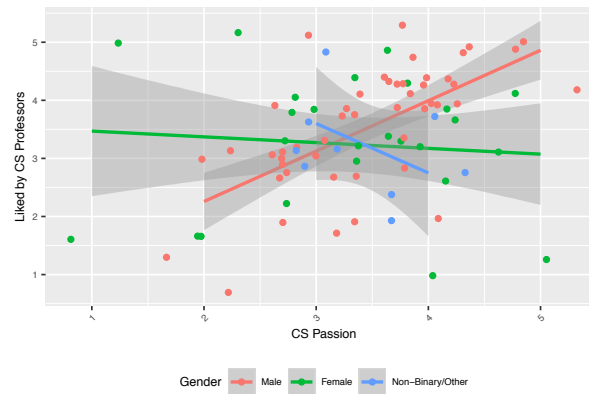


Figure 14: Linear regression graph of correlation between passion for CS and feeling liked by CS Professors for each gender group. Shaded regions represent 95% confidence interval for each linear model