Gender Differences in Class Participation in Core CS Courses

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ABSTRACT

In terms of students enrolled, post-secondary computer science classes are typically male dominated, which can create a baseline perception of male dominance in class participation. This paper presents our analysis of participation scores received by male and female students in two core computer science classes across ten quarters at the University of California, Davis. We use this data to explore the question: Is there a difference in male and female participation scores, and does this disproportionately impact male and female students' final grades? We find a small gender gap in overall participation scores, but no significant difference between the rate at which male and female students' grades benefit from participation points. However, we do see a difference in behavior when it comes to different formats of participation: males score higher on average in more public formats, such as lecture and forum, while females score higher in more anonymous formats, such as survey completion. Therefore, instructors should diversify their definitions of participation to accommodate for gender correlated preferences in participation formats. Furthermore, we find that the top scorers in the most public forms of participation are disproportionately male. This explains the perception of a larger gender gap in participation than actually exists, which can enforce the stereotype that males have a greater aptitude for CS than females. Finally, although our data show differences in participation behaviors between genders, future research should be conducted to investigate what is driving these differences.

CCS CONCEPTS

• **Social and professional topics → Computer science education**.

KEYWORDS

Computer Science Education; Gender; Class participation

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1 INTRODUCTION

Since the all-time peak of the mid-1980s when females received almost 40% of the computer science (CS) bachelor's degrees awarded across the US, the gender gap in CS at post-secondary level has steadily increased; as of 2018, only around 20% of CS graduates were female [21]. The CS program at the University of California, Davis (UCD) is no exception. Of the undergraduate students who received a UCD CS degree during the 2018-2019 academic year, 69.77% were male and 30.23% were female [20]. This large imbalance can create a baseline perception that *participation in class* is disproportionately male, since there are so many more males than females enrolled in these CS courses.

The perception that male students participate more in the classroom than female students can reinforce the stereotype that males are more capable in CS than their female counterparts. The reinforcement of this stereotype likely perpetuates the gender imbalance we currently see in the UCD CS department. The perception that males perform better than females in CS can impact classroom climate, and therefore shape the experiences and attitudes of female students inside and outside the major. This perception can worsen imposter syndrome [17], and discourage female students from trying out CS [9], participating publicly in CS classes [1], and continuing in the CS major [13].

We want to determine whether class participation, when normalized for this imbalance of male and female students, is really disproportionately male. In other words, are male and female students earning participation points at the same rate? Is there a difference in male and female participation scores, and does this disproportionately impact male and female students' final grades?

To answer this, we compiled 1,860 student participation scores from ten in-person offerings of two core CS classes, as explained in section 3. In section 4, we quantify the impact of participation on students' final class grades, and compare how males and females scored on overall participation. In section 5, we consider the average male and female scores and distribution of scorers in lecture, forum, and survey to see if we observe gender differences in behavior when it comes to different formats of participation.

2 RELATED WORK

The imbalance of male and female students enrolled is not the only gender gap in post-secondary CS programs. Research by Beyer et al.found female students had significantly lower confidence with computers than males, even when quantitative ability was controlled for [7]. Alvarado et al.observed that, despite having no significant difference in course grades, female students were less likely to feel comfortable tutoring for a past CS class than males [1].

These confidence gaps are also reflected in student participation behaviors. In a study of online class forums, Sobel et al.found that female CS students were more likely to post questions than answers, and post anonymously more often than males [18]. Alvarado et al.found that female students were less comfortable asking questions in lecture than their male counterparts [1]. This is important, as how students participate in class can shape the idea of who belongs. For instance, students who speak during lecture are often seen as more knowledgeable by their peers [12].

Student participation is shaped by classroom climate, which has been studied to gain insight on the experience of male and female CS students. A study by Garvin-Doxas and Barker found that a defensive classroom climate can lead to lower confidence among female CS students [12]. Barker and Garvin-Doxas also observed that in a defensive classroom climate, students often conflate experience with intelligence, which is especially problematic for female students, who tend to have less programming experience than males [3]. In their work, Treu and Skinner suggest that lack of confidence in female CS students can also result from subtle signs of prejudice from instructors, a lack of female role models, and the widespread view that males are more cut out for CS than their female counterparts [19].

Conversely, in a supportive classroom climate, students are not afraid to make mistakes in front of their classmates. Barker et al.found that fostering a supportive classroom climate can encourage students to speak up in class, and ease the stress students feel from comparing themselves to their peers [5]. The way this encourages peer interaction has positive effects. Research by Barker et al.found that interaction between students was a strong predictor of student intent to continue in CS [4]. McDowell et al.observed that the incorporation of pair programming improved student retention, as well as their confidence in CS [14]. Similar findings on student retention were found by Werner et al.[22].

To combat the gender gap in post-secondary CS programs, efforts have been made to understand its origins, increase female enrollment in CS classes, and improve the retention of female students in the major [6, 8, 10, 11, 13, 19, 23]. Rich et al.describe efforts at the Georgia Institute of Technology to create an introductory CS course that defies the stereotypes thought to discourage females from studying computing [15]. Alvarado et al.and Roberts et al.describe changes made to the Harvey Mudd and Stanford CS programs, respectively, which aimed to emphasize research opportunities for female students, expose students to female role models, and make the content of the introductory CS sequence more accessible to a wider range of first year students [2, 16].

While these efforts mostly focus on the experience of female students at the introductory level, class participation can be used to study the experience of female students at all course levels.

3 METHODOLOGY

This study focuses on participation in class and final grades received in two core classes integral to the UCD CS curriculum: Data Structures and Algorithms (hereafter referred to as **CS3**) and Operating Systems (hereafter referred to as **CSOS**). Both of these quarter-long classes are concept-focused, programming-heavy, and required for all students majoring in CS. CS3 is the third and final course in the introductory sequence; students typically take it at the end of their freshman year or beginning of their sophomore year. For this course, 341 students' grades were compiled across two quarters. Of the students, 76.83% were male and 23.17% were female. As for CSOS, students typically take it at the end of their junior year or beginning of their senior year. For this course, 1,519 students' grades were compiled across eight quarters. Of the students, 75.84% were male and 24.16% were female. All data was collected by the same instructor over the last four years, and all classes took place in-person.

Official gender identity information was not available to us, so the instructor classified students as either male or female based on their names and photos on the class roster. We acknowledge that this is an oversimplified gender spectrum, but it is sufficient for the trends this research aimed to explore.

In CS3 and CSOS, a student's participation score could typically earn them up to 3% extra credit, and was determined by three categories: lecture, forum, and survey.

Lecture. A student earned points in lecture by asking questions about the material being presented, or by answering questions that the instructor posed during class. Students who participated in lecture did so in front of their classmates and the instructor, who kept track of approximately how often each student contributed.

Forum. For forum participation, a student earned points by posting on Piazza, an online class forum where students can help one another in real-time. Students could post their questions, answer other students' questions in the designated answer section for each post, or leave further comments or questions in the follow-up discussion below each post. These three metrics, which are tracked by Piazza, determined each student's forum score, with answers being awarded the most points, followed by questions, and then follow-ups. Students had the option to make their posts anonymous to classmates, but not to the instructor.

Survey. A student earned points for survey participation by completing class evaluations throughout the quarter. Each student's completion of these surveys was tracked by the instructor. Such evaluations included the official UCD course evaluation, as well as a mid-quarter and end of the quarter survey created by the instructor. These surveys were opportunities for students to evaluate and leave feedback on the course. Students' survey responses were seen only by the instructor.

4 SCORING SYSTEMS AND OVERALL PARTICIPATION

4.1 Borderline grades and letter bumps

The first thing we wanted to assess was how participation extra credit had impacted grades. To measure this, we identified letter bumps. A student received a letter bump if their grade went up by a letter solely due to the extra credit that they earned through participating. This is the only way participation extra credit has a concrete impact for a student, at least in terms of grades.

Interestingly enough, and as shown on figure 1, males only received a letter bump at a slightly higher rate than female students. For all statistical tests, we used an alpha level of .05. For CS3, there is no significant difference between the proportion of male and female students who received a letter bump, $z = -.56$, $p = .575$. For CSOS, there is also no significant difference between these proportions, $z = -1.86$, $p = .063$.

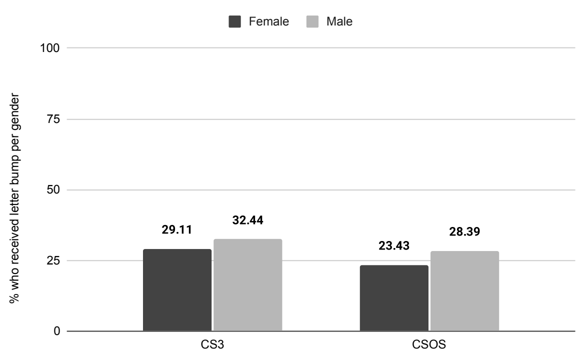

Figure 1: Letter bumps by gender

At UCD, a letter bump from an A to an A+ has no impact on a student's GPA. If you exclude the students who received this letter bump, the gap between the proportion of male and female students becomes even smaller. This incidentally tells us that the students who received letter bumps from an A to an A+ were disproportionately male.

This insignificant gap between the proportion of letter bumps received by male and female students contradicts what we were expecting. However, letter bumps are an interesting metric. When participation is quantified in this way, it is not a linear reward. A student whose core grade was closer to a threshold may receive a letter bump while another student who earned more participation points than them may not. In terms of letter bumps, males and females benefited from participation at the same rate. But we wanted to know whether the same held true for raw participation scores.

4.2 Overall participation

First, we considered the average overall participation score earned by male and female students, shown on figure 2.

For CS3 there is no significant difference between the average male overall participation score ($M = 28.47$, $SD = 25.13$) and average female overall participation score ($M = 25.33$, $SD = 16.25$), $t(339) = 1.31$, $p = .192$. For CSOS, the average male overall participation score ($M = 25.08$, $SD = 20.39$) is only 1.18 times the average female overall participation score ($M = 21.27$, $SD = 14.75$), $t(1517) = 3.90$, $p < .001$.

Our research was initially motivated by the feeling that class participation was male dominated, yet this insignificant gap in letter bump rates and small gap in overall participation scores suggests

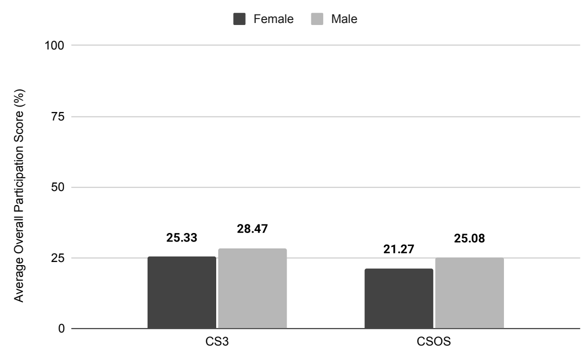

Figure 2: Average overall participation scores

that on average, male and female participation were much closer than we thought. In order to better understand how male and female participation were evening out, we considered the distribution of participation scorers.

The decile distribution of scorers helps us visualize how male and female students ranked in comparison to one another. When we combine the participation scores from all quarters of a class, and rank them from highest to lowest, the distribution shows what percentage of male and female students scored in the top 10% of scorers, the second decile of scorers, and so on down to the bottom 10% of scorers. If male and female students' scores were distributed evenly, each decile of scorers would contain 10% of the female students and 10% of the male students.

In the distribution of overall participation scorers, shown on figure 3, we find a disproportionately low percentage of females in the top and bottom 10% of scorers, and a disproportionately high percentage of them in the middle deciles.

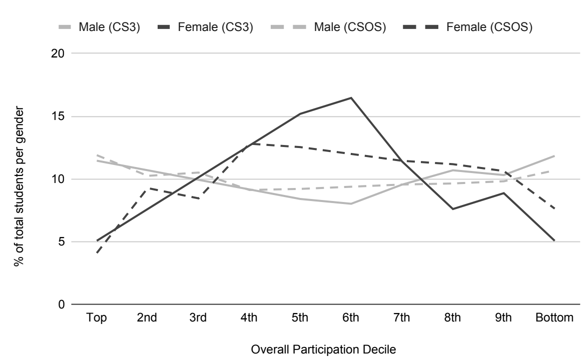

Figure 3: Decile distribution of overall participation scorers

This could explain where our initial perception of male dominance came from. Male students dominate the top deciles, indicating that the highest overall participation scores were primarily being earned by males. However, the middle deciles, and therefore middle range of scores, are female dominated, which could explain why overall, the letter bump rate and average overall participation scores for male and female students are closer than we expected.

In section 5, we analyze participation in lecture, forum, and survey to see if we observe the same patterns that we find in overall participation.

4.3 Rubric evolution

As a final note on overall participation scores, it is important to consider how the category weighting that determined a student's overall participation score shifted from quarter to quarter, particularly across the eight quarters of CSOS.

Lecture initially counted for as much as 50% of a student's participation score. However, it quickly became apparent that only a few students were actually participating and that accurately keeping track of who contributed during class was a challenge. Of the 341 students in CS3, only 5.57% participated in lecture. Of the 1,132 students in the first six quarters of CSOS, only 8.30% participated in lecture. It is also possible that who the instructor chose to call on in lecture was influenced by bias. As a result, the weighting of this category steadily decreased. By the final two quarters of CSOS in our dataset, lecture was no longer factored into a student's participation score.

In comparison, forum scores encompassed information from a much larger percentage of the class. Of the students in CS3 and CSOS, 75.07% and 62.48% participated on the forum, respectively. Forum weighting rose from 40% to 60% over time, as it became evident that this category was a much more reliable gauge of participation than lecture.

Survey weighting steadily increased from 5% to 40%, as additional instructor-created surveys were released in later quarters of CSOS and CS3.

Despite these changes to the rubric, there is no significant correlation between the weighting of a particular category and the difference between the average male and female overall participation scores in the CSOS classes. There is a nonsignificant correlation between lecture weighting and the difference between average male and female overall participation scores, $r(6) = .40$, $p = .329$. There also is a nonsignificant correlation between forum weighting and the difference between average male and female overall participation scores, $r(6) = -.44$, $p = .281$. Finally, there is a nonsignificant correlation between the survey weighting and the difference between average male and female overall participation scores, $r(6) = -.47$, $p = .237$.

Rubric weighting adjustments may not have been correlated with the gender gap between overall participation scores from quarter to quarter, because the lecture and forum trends for males and females were similar. As we will see in section 5, males dominated the highest scorers and scored higher on average in both lecture and forum.

5 PARTICIPATION PATTERNS

The next thing we wanted to assess were patterns of student behavior when it came to different types of participation.

5.1 Category averages

Breaking participation down further, we considered the different categories that determined a student's overall participation score, shown on figure 4. On average, male students outperformed females in lecture and on the forum, while female students outperformed males when it came to survey completion.

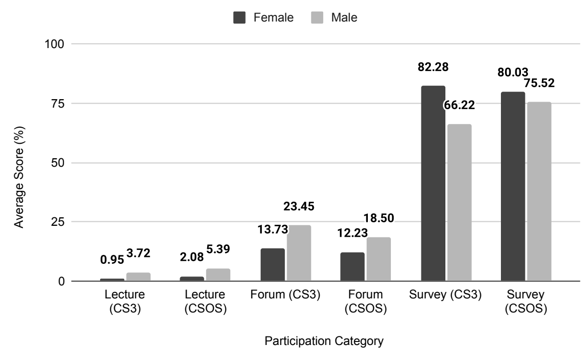

Figure 4: Category averages by gender

For CS3, the average male lecture score ($M = 3.72$, $SD = 16.46$) is 3.92 times the average female lecture score ($M = .95$, $SD = 6.26$), $t(339) = 2.24$, $p = .026$. The average male forum score ($M = 23.45$, $SD = 32.51$) is 1.71 times the average female forum score ($M = 13.73$, $SD = 20.56$), $t(339) = 3.17$, $p = .002$. The average female survey score ($M = 82.28$, $SD = 32.06$) is 1.24 times the average male survey score ($M = 66.22$, $SD = 37.83$), $t(339) = -3.74$, $p < .001$.

For CSOS, the average male lecture score ($M = 5.39$, $SD = 18.80$) is 2.59 times the average female lecture score ($M = 2.08$, $SD = 11.24$), $t(1130) = 3.57$, $p < .001$. The average male forum score ($M = 18.50$, $SD = 26.77$) is 1.51 times the average female forum score ($M = 12.23$, $SD = 19.13$), $t(1517) = 4.92$, $p < .001$. The average female survey score ($M = 80.03$, $SD = 30.40$) is 1.06 times the average male survey score ($M = 75.52$, $SD = 34.01$), $t(1517) = -2.41$, $p = .016$.

Here, we can abstract away from the average raw scores, which are arbitrary when looking for behavioral differences between the genders. Instead, the ratios between the average male and average female scores in each category tell us that lecture and forum participation were male dominated while survey completion was female dominated. **It seems the more anonymous the setting, the more female students participated.** Although it does not necessarily imply causation, there exists a correlation between participation setting and the gender gap in participation. Lecture participation, which was completely public, had the biggest gap between the rate of male and female participation. Participation on the forum, which was less public, and could even be anonymous to classmates, had a smaller gap between male and female participation rates. However, it was only in survey completion, where participation was completely anonymous to classmates, that females actually participated at a higher rate than male students.

5.2 Lecture

Revisiting the distributions, we considered the decile distribution of lecture participation scorers, shown on figure 5. A majority of students received a zero in lecture participation, which explains the even distribution of students from the second to the bottom decile.

What we can see is that a disproportionately low percentage of female students scored in the top 10% of scorers. In other words,

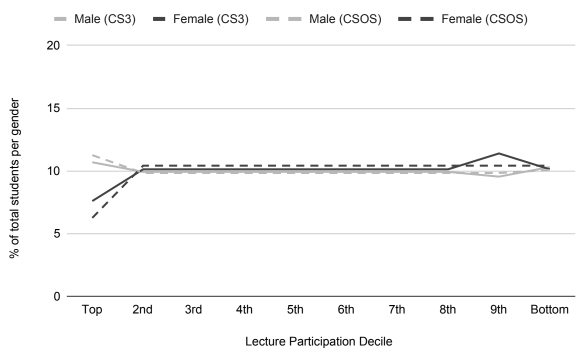

Figure 5: Decile distribution of lecture participation scorers

looking at the small group of students who actually participated in class, this group was disproportionately male. This is consistent with research done by Alvarado et al., who found that female students were less comfortable asking questions in lecture than males [1].

5.3 Forum

In the distribution of forum participation scorers, shown on figure 6, we find a disproportionately low percentage of female students in the top deciles of scorers, but a disproportionately high percentage of them along the mid to low deciles.

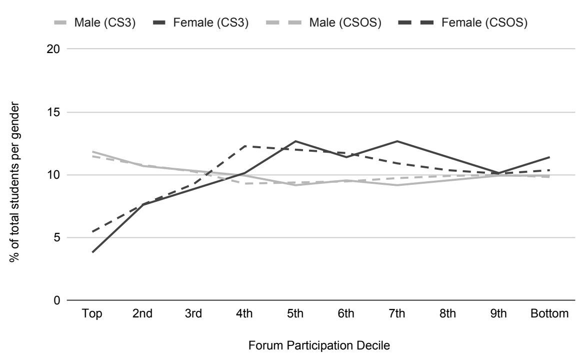

Figure 6: Decile distribution of forum participation scorers

As mentioned in section 3, a student's forum score was determined by three metrics: answers, questions, and follow-ups. Answers were awarded the most points, followed by questions, and then follow-ups. It is important to note the qualitative differences in making these contributions to the forum. The question and answer sections are pinned at the top of each post, where everyone on the forum can easily see. On the other hand, the follow-up discussion section sits at the bottom of each post, where it is relatively hidden and sometimes obscured unless you scroll down. In this way, it can be more public for a student to post an answer, where many of their classmates will see, than to leave their input as a follow-up, which is less visible.

Like lecture, the top decile of forum scorers indicates that the handful of students who earned the most points on the forum were disproportionately male. In the distribution, females dominate the tail. This is likely because a majority of female students participated just a bit on the forum, or because they were mostly posting questions or in the follow-up discussions, which were rewarded significantly fewer points than answers. This would echo findings from Sobel et al., who observed that female students were more likely to post questions than answers [18].

5.4 Survey

In the distribution of male and female survey scorers, shown on figure 7, we find a disproportionately high percentage of female students in the top 50% of scorers, and a disproportionately low percentage of them in the bottom deciles.

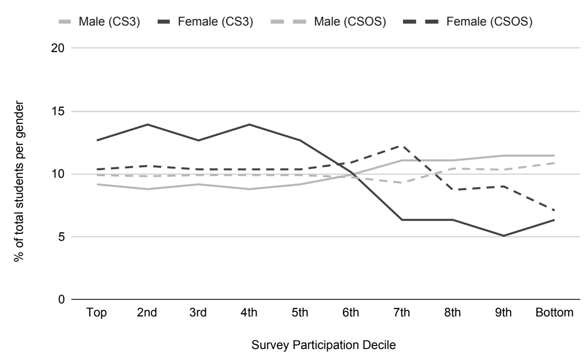

Figure 7: Decile distribution of survey participation scorers

This tells us that, on average, female students were more likely to complete the surveys than their male counterparts. In comparison to lecture and the forum, surveys are a much more private way to earn participation points. This could have made them more approachable for female students, who may have been hesitant to participate in the higher pressure environments in front of their peers.

6 LIMITATIONS

Official gender identification information was not available to us, so students were identified based off of their names and photos on the class roster. The gender spectrum was also simplified to just male or female. If possible in future studies, it would be ideal to have students self report the gender that they identify with.

All data came from classes taught under the same male instructor. To gauge the consistency of the trends we identified, it would be beneficial to analyze similar classes taught under a diverse range of instructors. Additionally, it would be interesting to investigate whether we see similar patterns in different kinds of CS classes, for instance, specialized CS electives (e.g., Machine Learning, Computer Vision), more algorithm and theory focused courses (e.g., Algorithm Design and Analysis, Theory of Computation), or classes where the proportion of male and female students is more balanced (e.g., Introduction to Programming for non-majors).

7 CONCLUSION

Contrary to our initial perception, we did not find a large gender gap between average overall participation scores. In fact, the insignificant difference in letter bump rates tells us that male and female students were benefiting from participation, as defined by previous scoring systems, at approximately the same rate. We observe similar trends in participation patterns across the lower-division and upper-division course, suggesting these participation behaviors remain consistent throughout the CS major track. This aligns with existing research, which found similar lecture and forum trends in both lower-division and upper-division courses [1, 18].

Our perception of participation being male dominated likely formed because the top participants in the most public forms of participation, lecture and forum, were disproportionately male. In this way, overall participation scores are not necessarily the most informative measure when assessing classroom climate. Instead, it is important to consider levels of student participation in different formats, as the visibility of certain forms of participation can shape how students and instructors view the class.

The data suggests female students are more likely to participate in less public settings. Therefore, instructors should vary their measures of participation to be more inclusive. If the participation grade had omitted less traditional measures of participation, like survey completion, and only accounted for more common ideas of participation, like speaking in lecture, female students would have been at a disadvantage. It is important that instructors account for gender correlated preferences in participation when defining what it means to participate in their class.

8 FUTURE WORK

The data shows behavioral differences between male and female students when it comes to different forms of participation. Further research should be done to understand what might be driving some of these differences.

The next step of our research aims to accomplish this. We want to investigate which student traits are a predictor of class participation habits, and why these students behave this way. We are currently developing a student survey to assess whether certain gender identities, ethnicities, personalities, or confidence levels are correlated with certain behaviors or attitudes towards participation in CS classes. Additionally, we want to explore what students believe should count as participation in CS classes.

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