Confidence, Connection, and Comfort: Reports from an All-Women's CS1 Class

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ABSTRACT

The computer science education community has long strived to create more equitable opportunities for students, such as initiatives to foster inclusion of women and other people from historically marginalized groups in CS. Despite these efforts, the gender gap has persisted, with less than a quarter of CS Bachelor's degrees awarded to women in the United States in 2019. As a community, we must strive to improve women's experiences in CS. This paper describes work conducted at a large research university which has traditionally offered CS1 through lecture sections ranging in size from 400-650 students. In Fall 2019, we offered an alternative small all-women's class (35 students) in addition to the traditional lecture class (601 students; 149 women). Both classes covered the same CS concepts but were led by different instructors. Students reported on their experience through a survey administered at the end of the semester. Students in the all-women's class reported significantly greater social connections and comfort collaborating with their peers compared to women in the traditional class. They also reported significantly greater feelings of support within their class, more confidence in their CS knowledge, and a more welcoming classroom environment compared to women in the traditional class. Additionally, the drop rate for students in the all-women's class was significantly lower (5.7%) than the drop rate for women in the traditional class (24.8%). In light of these positive results, we provide actionable insights for CS educators and discuss how to better support women in their CS endeavors.

CCS CONCEPTS

• **Social and professional topics → Women**; **CS1**.

KEYWORDS

Gender; CS1; Women; Undergraduate Education

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1 INTRODUCTION

The advancement of computer science depends on a rich and diverse community of people working together. However, certain populations, such as women, are marginalized in computer science education and computing careers [20, 31]. Specifically, just 24.4% of computer science bachelor's degrees were awarded to women at U.S. non-doctoral institutions in 2019 [31]. Previous work has attempted to broaden the field's diversity by improving women's experiences in computer science education. The creation of welcoming environments specifically for women and girls in CS has resulted in their increased participation in CS majors and classes [1], and increased interest and confidence in computing [21, 23]. Another promising approach to improving the experiences of women in CS is the implementation of women-only education initiatives. Previous girls-only initiatives in the context of K-12 math and science classrooms resulted in improved academic achievements [7, 25], increased enrollments in higher-level courses [25], and mitigated academic stereotypes [7].

Despite these successful interventions, a majority of computer science classes are offered in traditional coeducational settings, with students of different gender identities, in which women tend to report vastly different experiences than men. In these classrooms, women may be subject to unflattering gendered stereotypes [13, 15, 18] and lack role models with whom they identify [10, 17, 28]. Women also tend to report feeling a lack of support or feeling like an outsider [2, 13]. These obstacles and negative experiences in introductory computer science classrooms may influence women's decisions to remain in the computing field of study [18], thus widening the gender gap and furthering a lack of diversity.

This experience report describes a study conducted in Fall 2019, in which we offered an alternative CS1 class for women, capped at 49 students. Traditionally, CS1 at this institution is administered as a coeducational class, ranging in size from 400-650 students. Actual enrollment numbers for the all-women's class and the traditional class were 35 and 601, respectively. We aimed to investigate women's experiences in the all-women's CS1 class and we used the traditional class as a benchmark, comparing the experiences reported by the students in the all-women's class to the experiences reported by women in the traditional class. This study is based on survey responses from 116 participants, with 27 from the small all-women's class and 89 from the traditional class. We expected that the small all-women's class would improve women's experiences by facilitating a more welcoming classroom climate and building a greater sense of community.

The findings from this study suggest that students in the all-women's class had a more positive and supportive CS1 experience than the women in the traditional CS1 class. The survey results revealed significant differences between women's experiences from the two classes. Students from the all-women's class reported a more enjoyable and welcoming classroom climate, felt more confident in the course material, and felt more strongly that the women in the class were supported. Students in the all-women's class were more comfortable collaborating with their peers and were more likely to meet up with their classmates outside of class.

Given the gender gap in computer science and the different experiences of women in CS1, it is important to find methods to support women in this context. Improving women's experiences in computer science could promote their interest in the field and lower drop rates. The findings from this experience report suggest that women-only educational interventions can benefit and support women in computer science. For cases in which women-only classes are not feasible, we suggest flexible alternatives for CS educators, such as offering women-only lab sections and promoting women-centric student organizations. These alternatives serve to welcome and celebrate women both inside and outside the CS classroom and can complement women-only classes.

2 BACKGROUND AND RELATED WORK

A large body of research has been conducted to understand the gender gap in computer science and women's continual marginalization in the field, with many of these studies resulting in women reporting vastly different experiences in the CS1 classroom. The many negative stereotypes associated with the field have been cited as possible influences for women's lack of participation in computer science, including the notion that people in the computer science field are antisocial or obsessed with machinery [13, 15]. Previous work has found that these stereotypes can cause adversity in women's computer science experiences [2, 13, 15, 23] and play a role in women's decisions to leave the CS major [18]. Moreover, other research has revealed that many women lack a sense of belonging in computer science [13] and tend to report less confidence in their computer science abilities [6, 13, 15], regardless of their level of experience with computers or academic abilities [6]. Women tend to enter CS majors with less computing experience [12, 19] and receive lower grades in engineering-specific introductory computer science classes [4]. Some women also experience familial or societal discouragement in their efforts to study computer science [2, 13]. Therefore, the creation of an all-women's CS1 class may facilitate feelings of community and comfort among women entering the major that could help ease the impacts of stereotypes associated with the field and improve women's CS1 experiences.

Additionally, women's attrition in computer science contributes greatly to the gender gap [22], with women computer science majors being twice as likely to switch majors when compared to men [18] and men being more likely to persist in the computer science major [3]. The gender gap in computer science pervades throughout the workforce as well; according to the U.S. Bureau of Labor Statistics, women represent just 25.8% of the workforce in computer and mathematical occupations [20]. Several studies have suggested reasons for women's higher attrition rate compared to men, including receiving low or failing CS1 course grades [4], women's lower confidence in their computing skills [6], or women reporting feelings of not belonging in the major due to a sense of not fitting CS stereotypes [18]. Research has shown that most women who decide to leave the computer science major do so after taking CS1 [3], suggesting that CS1 is a critical point in education to attract and retain women in the field. This experience report is based on the idea that an all-women's class may improve women's confidence and mitigate the misconceptions of the CS major by promoting a more comfortable social climate.

Other interventions have been conducted to create a welcoming environment for women majoring in CS, such as Living Learning Communities [29] and breadth-first curricula with exposure to interdisciplinary applications and societal contributions [1]. In Fall 2016, Rutgers University initiated a resident-hall Living Learning Community for first-year women CS majors [29]. In its second deployment, this Living Learning Community achieved mixed results, including a decrease in women's self-efficacy and higher interest in non-computing majors, but a stronger sense of mentor support, higher rates of persistence in the major, and increased involvement in computing-related activities. Harvey Mudd College increased women's participation in computing through a combination of curriculum restructuring, summer research experiences for women entering their sophomore year, and encouraging women to attend the Grace Hopper Celebration [1]. Another intervention occurred at the high-school level in the form of a girls' summer program, which increased girls' interest in CS and their confidence in their CS skills. Creating separate learning experiences for girls, such as girls-only classrooms or educational programs, has improved their academic achievements in elementary school [7] and high school [25], increased comfort in computing concepts for middle school girls [9], and mitigated academic stereotypes for both instructors and students in elementary school [7]. Specifically in the context of computer science, women-only interventions have also resulted in increased participation in CS majors and courses [1].

3 METHODS

This study was conducted in Fall 2019 at a large public university in the Southeastern United States and was part of a larger study on students' experiences in CS1. This experience report focuses specifically on women's experiences in the traditional CS1 class and in the newly-offered all-women's CS1 class. Students were notified about the all-women's class offering through direct email to the CS department's undergraduate listserv, direct email from the first year college advising office to their listserv of first-year students, and from the CS department advising office to advising offices with relevant programs. The traditional class had 601 students, 149 of which identified as women, and the all-women's class had 35 students, although it had the capacity for 49 students. The consenting students completed a survey (discussed in section 3.3) and a reflection essay (not included in this analysis). As compensation for participation, they received extra credit toward their CS1 class grade. All students were offered an alternative extra-credit assignment if they chose not to participate in this study. All consenting students who identified as women (n=116) were enrolled in one of the two CS1 classes, either the all-women's class (n=27) or the traditional class (n=89).

3.1 Class Context

Both classes had the same course number, covered the same CS concepts, and included 150 minutes of lecture and two hours of lab each week. Both classes featured the same lab assignments, quizzes, and projects, with different policies for which project could be dropped. Exams covered the same concepts but were not identical. Both class instructors who led the lectures were women; the traditional class was taught by a lecturer and the all-women's class was taught by an industry partner from a local software company. The lab sections, each led by a teaching assistant, ranged in size from 19 to 23 students for the traditional class. The all-women's class had one lab section of 14 students and one lab section of 21 students. The teaching assistants for the all-women's lab sections were also women, while the teaching assistants for the traditional lab sections were a combination of men and women.

3.2 Participants

Of the 27 participants[1] in the all-women's class, 23 were freshmen (85%), two were sophomores (7%), one was a junior (4%), and one was a transfer student (4%). Of the 89 participants in the traditional class, there were 58 freshmen (65%), 20 sophomores (22%), nine juniors (10%), one post-baccalaureatte student (1%), and one graduate student (1%). The difference in class standing distribution for the two CS1 classes may be due to the recruitment efforts of the all-women's class being targeted more toward incoming freshman, with one of the recruiting outlets being an email to the first-year student listserv.

Participants had a range of majors, the most common being CS-related majors (computer science, computer engineering, etc.), representing 25 women (93%) from the all-women's class, and 59 women (66%) from the traditional class. Some participants had majors in other engineering disciplines: two women (7%) in the all-women's class and 13 women (15%) in the traditional class. The remaining 17 participants in the traditional class had other majors from a variety of disciplines.

The racial/ethnic identities of participants from the all-women's class were 12 White/Caucasian (44%), seven Asian/Pacific Islander (26%), five multiracial (19%), and three Hispanic/Latino (11%) women. From the traditional class, there were 35 White/Caucasian (39%), 25 Asian/Pacific Islander (28%), 14 multiracial (16%), 10 Hispanic/Latino (11%), and five Black /African-American (6%) women. Participants from the all-women's class ranged in age from 18 to 24, with an average age of 18.5, and participants from the traditional class ranged in age from 18 to 28, with an average age of 18.9.

3.3 Survey Questions

Toward the end of the semester, students from both CS1 classes were recruited to complete a survey, which asked about their experience in the class. This survey was administered as part of a larger study, and also asked questions about future career plans, previous computing experience, and demographic information. For this paper, we focus on a subset of survey items covering career choice, social connections, classroom climate, and confidence. We use the responses from the women in the traditional class as a benchmark to compare the responses from the all-women's class.

3.3.1 Career Choice. We included a question asking about the respondent's choice of a career in technology. Specifically, we asked *Are you pleased with your choice of a career in technology?* Respondents could pick from a range of options indicating what level of doubt, if any, they had in their career choice.

3.3.2 Social Connections. We included two questions to gauge social connections among the class. The first was a simple "yes" or "no" question asking the respondent whether they met new people. The second question asked if the respondent met up with people outside of class and included a set of select-all-that-apply options: "Yes, to study," "Yes, to socialize," and "No."

3.3.3 Classroom Climate. We included four Likert-scale questions regarding the classroom climate:

(1) **Enjoyment**. I enjoy the class environment.
(2) **Inclusion**. The instructor facilitates an inclusive and welcoming environment.
(3) **Comfort**. I feel comfortable collaborating with my peers.
(4) **Support**. I feel that women in my computer science course are supported.

Respondents answered on a five-point scale from *Strongly Disagree* (1) to *Strongly Agree* (5).

3.3.4 Confidence. Lastly, there was one Likert-scale question about confidence: *I feel confident in my knowledge of the concepts taught in class.* Respondents answered on the same five-point scale.

4 RESULTS

Table 1 shows the students' responses to the three categorical questions: *Are you pleased with your choice of a career in tech?* (tech career question), *Did you meet new people?* (network question), and *Did you meet up with people outside of class?* (friendship question). Figure 1 shows the distribution for students' responses to these questions after merging some of the response choices, which we explain in detail below.

For the tech career question (Figure 1a), we removed students from nontechnical majors (those who chose "Not applicable"), leaving 25 students from the all-women's class and 67 students from the traditional class. Due to the lower frequency, we collapsed both "No" responses, leaving three responses for further analysis: "Yes," "Yes, but I have some doubts," and "No." The networking question did not undergo any collapse in response and the distribution in responses is shown in Figure 1b. For the friendship question (Figure 1c), which had a select-all-that-apply format, we combined the "Yes, to study" and "Yes, to socialize" options into a single "Yes" response if the respondent selected either or both of those options. In other words, we counted how many students reported "Yes" and how many reported "No."

To determine any significant differences in students' responses between the classes, we compared the frequencies of the responses chosen for each question by class using likelihood ratio Chi-square

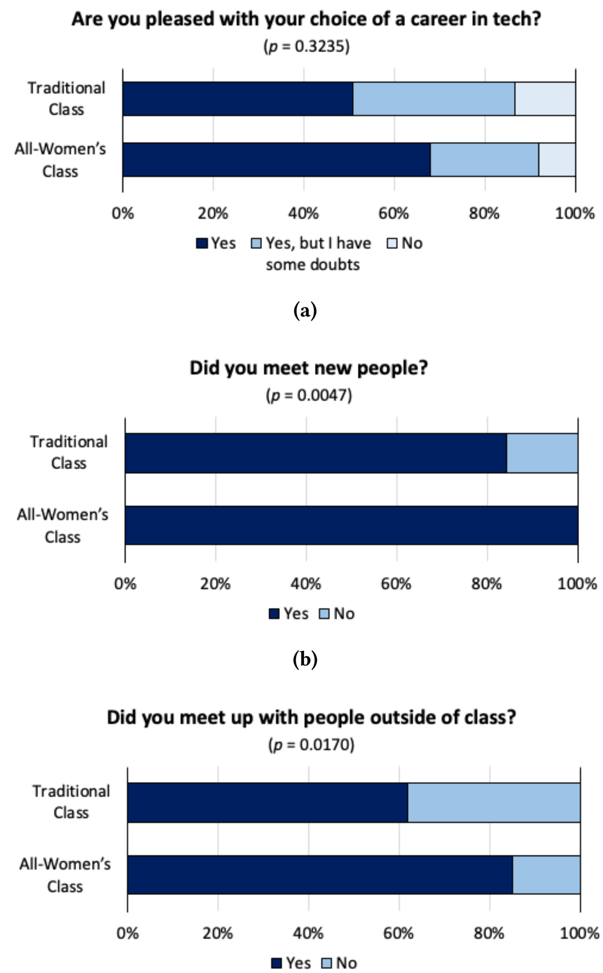
[1]Throughout this paper, we use the term "participant" to refer to a consenting, enrolled student who identifies as a woman.

Table 1: Responses to the categorical survey items by frequency and percentage of each option. The first two questions include multiple-choice options and the last question is a select-all-that-apply question, which is why the totals are larger than the participant populations.

Survey Response	All-Women's Class (n=27)	Traditional Class (n=89)
Are you pleased with your choice of a career in tech?		
Yes	17 (63.0%)	34 (38.2%)
Yes, but I have some doubts	6 (22.2%)	24 (27.0%)
No, and I'm *considering* switching majors / leaving the field	2 (7.4%)	2 (2.2%)
No, and I'm *definitely* switching majors / leaving the field	0 (0%)	7 (7.9%)
Not applicable	2 (7.4%)	22 (24.7%)
Did you meet new people?		
Yes	27 (100%)	75 (84.3%)
No	0 (0%)	14 (15.7%)
Did you meet up with people outside of class?		
Yes, to study	20 (74.1%)	49 (55.1%)
Yes, to socialize	6 (22.2%)	33 (37.1%)
No	4 (14.8%)	34 (38.2%)

tests. Treating the threshold for statistical significance as $p < 0.05$, there was no statistically significant difference in the responses to the question about their choice of a career in tech ($p = 0.3819$). There were, however, statistically significant differences in the remaining two questions: students in the all-women's class were more likely to meet new people ($p = 0.0047$) and were more likely to meet up with people outside of class ($p = 0.0170$) than women from the traditional class. These results remain significant after correcting for multiple comparisons by performing a Benjamini-Hochberg correction ($p < 0.033$).

Figure 2 compares the Likert scale responses of students from the all-women's class and women from the traditional class. To determine statistically significant differences in these responses, we compared the distributions of the responses from both classes using Wilcoxon rank sum tests. We found significant differences in all five questions, even after performing Benjamini-Hochberg correction for multiple comparisons ($p < 0.05$). Students from the all-women's class had higher average responses to these questions than women from the traditional class. They reported higher enjoyment of the class environment, felt more confident in their knowledge of the course concepts, felt more strongly that the instructor facilitated a welcoming environment, felt more comfortable collaborating with their peers, and felt more strongly that women in the class were supported.



(a)

(b)

(c)

Figure 1: Responses to categorical questions by class

Lastly, in addition to analyzing survey responses, we analyzed aggregate drop data for both CS1 classes. Out of the total 35 students enrolled in the all-women's class, two students dropped the course after drop/add week, a retention rate of 94.3%. Out of the total 149 women in the traditional course, 37 women dropped after drop/add week, a retention rate of 75.2% for women. This difference is statistically significant according to a likelihood ratio Chi-square test ($p = 0.0128$).

5 DISCUSSION

We found that the students from the all-women's class reported a more welcoming and inclusive class climate and appeared to form stronger social ties with their peers than the women enrolled in the traditional class. Moreover, students in the all-women's class expressed more confidence in the course concepts, dropped the class at a significantly lower rate, and reported feeling more supported by the class than the women from the traditional class. Below, we

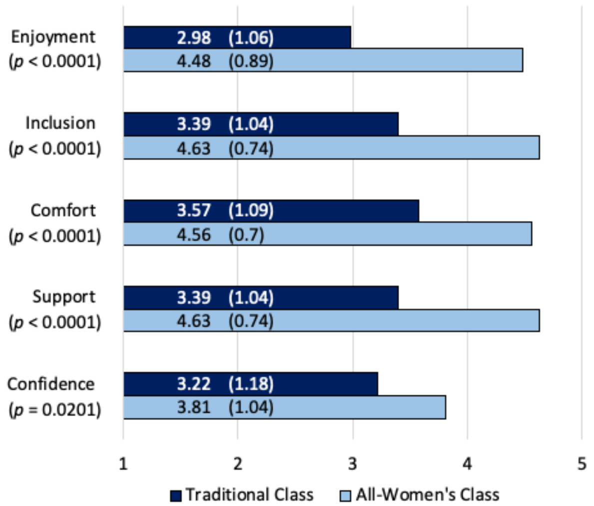


Figure 2: Average responses and standard deviations to Likert scale items by class

discuss these main points and suggest potential reasons for these findings based on previous literature.

5.1 Improved Class Climate and Stronger Social Connections

The reports of higher enjoyment and a more inclusive and welcoming environment from the students in the smaller all-women's class suggest that this classroom climate was preferable to that of the traditional class. Women in the traditional class may feel pressures of competition with men, who are generally more confident in their computing abilities [6, 13] and enter the CS major with more computing experience [12, 19]. There are also common misconceptions surrounding the computer science field, such as it being an antisocial, obsessive, and geeky workplace [13, 15]. However, students in the all-women's class reported feeling more comfortable collaborating with their classmates than the women in the traditional class, which could have resulted in a stronger sense of belonging and community. The all-women's class may have facilitated a more enjoyable environment for the women, as the women from the traditional class reported less enjoyment. These findings may have resulted from the smaller class size, which previous research has shown to be beneficial for learning in CS1 [8]. Additionally, the women-only student population could have mitigated the competitive nature of the CS1 classroom environment, which has previously been reported by women as intimidating [23].

Furthermore, the students in the all-women's class were more socially connected to their classmates than the women in the traditional class, as noted by their survey responses: they were more likely to report meeting new people, meeting up with people outside of class, and feeling comfortable collaborating with their peers. Prior research on collaborative learning in CS revealed that women value the positive atmosphere and connection with peers that it facilitates [30]. Women in a traditional introductory CS class may be less likely to form social connections in their class [22], which may be due to inherent gender biases in the classroom [15, 18] or the fewer number of women in the class. However, the students in the all-women's class from the study reported in this paper may have felt more comfortable with the smaller class size and may have been less likely to feel socially isolated due to their gender. Thus, the students in the all-women's class may have had more fruitful opportunities to connect with their peers compared to the women in the traditional class.

5.2 Increased Confidence and Retention

Survey results from the all-women's class suggest that students felt significantly more confident in their knowledge of course material than the women in the traditional class. Prior research has continually revealed that women tend to report lower confidence in their computing abilities than men [6, 12, 13, 15]; in fact, women majoring in CS have reported lower confidence in their computing abilities than men who are not CS majors [6]. Confidence is critical for women in CS, as academic self-efficacy has been shown to be a predictor of academic achievement [14]. Our findings suggest that an all-women's class may help improve women's confidence in the course material, which may lead to better experiences in the field and increase their academic achievements [14].

Additionally, compared to the women in the traditional CS1 class, the students in the all-women's class had significantly lower drop rates. Previous research has shown that smaller classes already benefit from lower drop rates [8]; however, this finding is especially notable, given the higher likelihood of women to drop out of the CS major in traditional coeducational CS1 classes [3, 18]. Lower drop rates for the students in the all-women's class may have been linked to their higher reports of confidence, since a lack of confidence in computing abilities has been found to be a reason for women leaving the computer science major [22]. Prior work has also demonstrated that women are more likely to persist in CS majors or minors who have supportive communities at home or in school [11]. Regardless, the significantly lower drop rate in the all-women's class is a promising finding that aligns with prior research revealing improved attrition in higher level math and science courses through enrollment in all-girls' classes [25].

5.3 Improved Support for Women

Finally, the survey results suggest that students from the all-women's class felt more strongly that women in the class were supported. Women in other studies have reported feeling unsupported by their families and society [2, 13], which can have a notable impact on their interest in a career in CS and persistence in a CS major [15, 24]. The all-women's class may have mitigated feelings of competition and intimidation from the class climate, which could have resulted in a stronger sense of support. Moreover, the smaller class size and the women-only student population may have led to feelings of community, leading these women to feel a sense of belonging and encouragement from their peers or instructors. This study suggests that an all-women's class may facilitate an enhanced support system for women in CS1, which has the potential to increase women's interest in the field, improve retention rates in CS majors, and make CS a more diverse and inclusive field.

5.4 Actionable Insights

Computer science educators should be aware of the many obstacles that women face in their traditional CS1 classrooms, including feeling less experienced compared to their classmates [15], lack of belonging [2, 13], and lower confidence compared to men [6, 12, 13, 15]. Creating an accepting and inclusive environment in computer science classrooms could promote women's interest in the major, improve their experiences in CS1, and decrease attrition [21, 25]. Such an environment provides women with safe spaces that may facilitate connections among women in a large coeducational classroom, which can lead to feeling a sense of community and the formation of stronger social ties.

Our findings suggest that all-women's classes may generate a welcoming and supportive environment for women to build confidence in their computing abilities and connections with their classmates. While CS departments at some institutions may not have the resources or capabilities to create all-women's classes, smaller-scale alternatives may have the same effect, including women teaching assistants and women-only lab sections. Women teaching assistants in a traditional CS1 class may act as role models who can help mitigate the isolation and the negative stereotypes that surround women in computer science. While findings are inconsistent, some studies have revealed that women faculty can improve retention in STEM majors [5, 10, 16].

Additionally, further research is needed to determine how we might facilitate these social connections and feelings of belonging even within the traditional large lecture class. Perhaps a similar effect could be created within the larger class by assigning students to smaller semester-long cohorts, encouraging collaboration, and reserving in-class time for students to connect and complete team-building activities. Previous research has shown that undergraduate classes that involved group work were positively correlated with students' feelings of classroom community, which was significantly greater compared to classes without collaborative work [26]. They also found these results to be true regardless of class size and that women especially benefited from these group interactions, perceiving significantly more classroom community than men within the same class.

Encouraging women to find computer science communities outside of classes could promote a similar sense of camaraderie. Such communities include local chapters of national clubs or programs that support women in CS, like Women in Computer Science Education (WiCSE) or Association for Women in Computing (AWC). Other initiatives that foster women's participation in CS include the Grace Hopper Celebration and similar events that celebrate women in computing [27].

5.5 Limitations

The differences in women's experiences from these two classes cannot solely be attributed to the single-gender class or the smaller class size, as there were many other differences between the two classes, such as different instructors or student demographic distributions. A more controlled study is necessary to pinpoint which factors result in the most positive influences. The differences in instructors may have created a different learning environment, influenced by the instructor's personality or teaching style. Moreover, the student populations in each class were different, not only in terms of class size but in terms of demographics as well. This could cause implicit differences between each student population, solely based on their class composition.

Additionally, not all women enrolled in the traditional class were aware of the alternative all-women's class, which could have resulted in an uneven sample distribution. The women who were aware of this opportunity were given a choice whether to take the all-women's class or the traditional class. Thus, the students who enrolled in the all-women's class did so voluntarily, which results in a self-selection bias.

Lastly, it is necessary to consider what long-term implications this separation by gender might entail. We are hopeful that these women would have found a community during their CS1 course that might persist throughout their undergraduate career, but it is also possible that they might feel more isolated once they do experience the reality of the CS gender gap. Future studies should investigate how an all-women CS1 class may impact women's experiences in later (mixed-gender) classes.

6 CONCLUSION AND FUTURE WORK

This experience report describes a study that investigated the differences in experiences between women enrolled in a small all-women's CS1 class and women enrolled in a larger traditional CS1 class. To explore the women's experiences in each class, we compared survey responses from students in the all-women's class to those from the women in the traditional coeducational class. The survey results indicated that the all-women's class provided an improved CS1 experience for women compared to the traditional class. Specifically, the students in the all-women's class reported significantly stronger social connections and ease of collaborating with their classmates. They also reported significantly greater confidence in the course content, stronger feelings of support within their class, and a more welcoming and inclusive classroom environment. Finally, the students in the small all-women's class had significantly lower drop rates than the women in the traditional class. These results suggest that the creation of all-women's labs, course sections, or clubs may facilitate a sense of community, improving women's computer science experiences. Women-only interventions could function as another way for the CS education community to support and celebrate women in computer science.

Future work should focus on conducting a controlled study, where influences of class size, instructors, and other internal factors are controlled. This work could include surveys, interviews, or reflection prompts that ask students in all-women's classes to report on the reasons why they chose to enroll in the alternative class option. It is also important to understand how intersectional interventions based on race and ethnicity may impact CS1 experiences for other marginalized groups in the field. Future work should aim to better understand the impact of all-women's classes and other interventions for marginalized groups in computer science, such as Black or Hispanic/Latinx people to better inform methods of promoting diversity in the computer science field. This work suggests a variety of methods to improve women's experiences in CS1, aligning with the current goals of the CS community in their endeavors to better support women in computer science.

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