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Key Observations of Enrollment Trends during the Pandemic in Early Programming Courses to Broaden Female Students' Participation in Computing

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Abstract

In an effort to increase the percentage of female students in the Computer Science (CS) Department at California State University, Los Angeles, we have conducted an in-depth data analysis of student enrollment, persistence, and performance in early programming courses (CS1 through CS3) during the pandemic period (Fall 2019 to Fall 2021). Currently, the department has a female enrollment of less than 12%, which is below the national average of 20%. Through this study, we aim to identify the most appropriate strategies for female students to broaden their participation in computing.

As a part of the study, we collected data on the introductory course sequence, CS1 Introduction to Programming I, CS2 Introduction to Programming II, and CS3 Programming with Data Structure. The data included quasi-cohort course outcomes, quasi-cohort persistence, retention graduation, day 1 to census day enrollment, completion by transfer status, outcomes by major, and student support. In addition, to understand in-depth the level of preparedness and the level of satisfaction of women and minority students in computing, we also collected additional data. This effort included collecting the results of midterm exams, quizzes, course projects, assignments, and the final exam from CS1, CS2, and CS3. Moreover, we conducted surveys with these students to find their satisfaction with peers' and instructors' interactions and their confidence level in the CS major[1].

Through the data analyses and discussion, we found that female students' academic performance is as good as, or even better than, their male classmates. However, compared to male students, female students tend to be less confident and satisfied with their academic performance. The withdrawal rate is higher among female students than male students. The discussion of these results contributes toward identifying possible practices that would broaden participation in computer science for women.

Introduction

California State University, Los Angeles has been historically committed to serving the educational needs of Los Angeles' well-diverse communities like many other institutions striving to improve the participation of minority students and female students [1] [2] [3] [4] [5] [6].

California State University, Los Angeles, Department of Computer Science (CS) offers a Bachelor of Science degree, where the degree program is accredited by the Computing Accreditation Commission of ABET, [7]. In addition, California State University, Los Angeles is a federally designated Title III institution, [8]. California State University, Los Angeles has a

[1]Definition of confidence level in CS – A student feels confident when the student believes that she/he is capable of getting a comprehensive and solid grasp of the materials/concept and can apply them to problem-solving and programming.

historic commitment and record of service in meeting the educational needs of Los Angeles's diverse communities. Aligned with the University's commitment, one of the goals that the College of Engineering, Computer Science, and Technology (ECST) at California State University, Los Angeles has set is increasing the percentage of women to 25% by 2025. The ECST currently has a female enrollment of only 15%, and the department of computer science has less than 12% of female students, which is below the national average of 20% [9]. To reach its goal, California State University Los Angeles has been making proactive efforts to broaden participation in Engineering and Computing.

These efforts include the LAunchPad Summer program [10], and the FYrE@ECST [11]. The LAunchPad Summer Program is a two-week summer program where female high school juniors and seniors experience a gender-inclusive learning environment, with scaffolded instruction, hands-on activities to reinforce the learning, and exposure to female role models. A study revealed that after participating in the LAunchPad, the student's interest in pursuing an engineering or computer science career increased by 29% [12]. The FYrE@ECST is a first-year experience program in the ECST where first-year students receive holistic academic support and go through a pathway to complete their Math and Science requirements during their first year. A study reveals that the FYrE@ECST intervention students maintained a higher GPA (Grade Point Average) than nonintervention students with statistical significance across all cohort years and students moved toward degree completion [12].

These programs have increased the participation of pre-college students and our current students in engineering and computing overall. However, as the focus of these programs is spread for multiple disciplines or different subjects than core computer science programming courses, the CS department recognizes the need to conduct in-depth data analysis on CS department data and created a more focused and customized model to broaden participation of the under-represented minorities, especially female students, in computing.

Hence, we partnered with Northeastern University Center for Inclusive Computing (CIC) through the Data Collection Grant to better understand and find the most right broadening participation strategies. We collected quasi-cohort course outcomes, quasi-cohort persistence, retention graduation, day 1 to census day enrollment, completion by transfer status, outcomes by major, and student support. In addition, to have an in-depth understanding of the level of preparedness and the level of satisfaction of women and minority students in computing, we also collected the results of midterm exams, quizzes, course projects, assignments, and the final exam scores from CS1, CS2, and CS3. Moreover, we conducted surveys with these students to find their satisfaction with peers' and instructors' interactions and their confidence level in the CS major.

Background

The data collection project started in the spring of 2021, the middle of the COVID-19 pandemic. We began the project by collecting past data from the spring of 2019 when the COVID-19 pandemic was not affected. During the spring of 2019 and fall of 2019, almost all courses were offered in in-person, in-classroom teaching mode.

Toward the end of the spring of 2020, most of the courses were converted to remote-teaching mode. In the fall of 2020, all courses from the CS department were converted to remote-teaching courses. The remote-teaching mode was continued until the spring of 2021. In the fall of 2021, the university started converting remote-teaching mode back to in-person, in-classroom teaching mode. In the spring of 2022, the CS department converted more remote-teaching courses back to in-classroom, in-person courses compared to the earlier term. In the fall of 2022, almost all courses were converted to in-person, in-classroom courses except a few courses.

While we continued to collect data from the spring of 2019 to the fall of 2021, we discovered noticeable enrollment trends throughout the COVID-19 pandemic period. Based on the data we collected, we observed that the COVID-19 pandemic crisis significantly affected female students' enrollment in early programming courses (CS1, CS2, and CS3). We suspect it could be because female students tend to spend more time doing household chores or taking care of their siblings than male students.

Previous research found that cultural and social gender roles significantly impact on the issues of gender inequity and inclusion in computing education. In [13], the panel suggested discussing the critical issues of gender inequity and inclusion in computing education. Also, the panel proposed to discuss the role of relationships, identity in cultural and social, and academic, political, and professional aspects to support gender equity and inclusion in computing education. In addition, in [14] [15], the authors discussed various challenges to female students in other engineering fields.

While collecting data, we also noticed a higher withdrawal rate among female students than male students although female students' academic performance was comparable with their male classmates or even better in some cases. From the survey, we found female students tend to be less confident and satisfied with their academic performance. These results are similar with the research results in [16]. We will further discuss them in the Discussion section.

Data Collection Methodologies

California State University Los Angeles, CS Department offers a three-semester introductory programming sequence: CS2011 Introduction to Programming I, equivalent to CS1, CS2012 Introduction to Programming II, equivalent to CS2, and CS2013 Programming with Data Structures, equivalent to CS3. A first-year student is required to take CS1010 Introduction to Higher Education for Computer Science Majors, equivalent to CS0. After passing CS1010, the student can enroll in CS2011. If a student completes CS2011 with a C or better, the student can enroll in CS2012. The same rules apply to CS2013 also.

We collected the results of midterm exams, quizzes, course projects, assignments, and final exams based on the subjects covered in the course as specified in Appendix A from spring 2021 to spring 2022 for CS2011 (CS1), CS2012 (CS2), and CS2013 (CS3).

Besides data collection, we also conducted a survey with these students to determine their satisfaction with interactions with peers and instructors. All participants took the survey voluntarily and the survey was conducted toward the end of the semester. The total number of

students who participated in the survey is summarized in the tables below. Also, the survey questions are listed in Appendix B.

Table 1. Number of participated in the survey

	CS 2011	CS 2012	CS 2013
Female	35	33	29
Male	69	98	75
Non-binary/third gender	0	0	8
Total	104	131	112

Results and Data Analysis

Pass Rate for CS2 (CS2012) and CS3 (CS2013) during the pandemic

In the fall of 2020, we observed a noticeable decrease in the passing rate for female students. For CS2012 and CS2013, the pass rate of female students dropped significantly in the spring of 2020 and the fall of 2020 as shown in Figure 1.

In the spring of 2020, 61.5% of female students (16 of 26) passed CS2012 and 27% of female students (7 out of 26) withdrew, which was twice higher than the previous term. Although 16 female students passed CS2012 in the spring of 2020, only 10 out of 16 female students continued with CS2013 in the fall of 2020. On the other hand, 79.2% of male students (84 out of 106) passed CS2012, and 1.9 % of male students (2 out of 106) withdrew, which was comparable to the previous terms. In addition, 87% of male students passed CS2012 in the spring of 2020 (92 out of 106) enrolled in CS2013 in the fall of 2020.

In the fall of 2020, the female students pass rate of CS2013 dropped to 30% (3 out of 10) from 86.7% in the spring of 2020 (13 out of 15) as shown in Table 2. Moreover, 40% of female students (4 out of 10) in CS2013 withdrew in the fall of 2020. Conversely, the male students pass rate of CS2013 was comparable with the previous terms (70% in the fall of 2019 and the spring of 2020, and 75% in the fall of 2020.) Moreover, the withdrawal rate was not noticeably changed during the pandemic period (within 9% - 14% ranges), as shown in Table 2.

Table 2. Quasi-Cohort Course Outcomes Summary for CS3 (CS2013)

Term	Female	Male
Spring 2019	0%	6%
Fall 2019	20%	15%
Spring 2020	7%	14%
Fall 2020	40%	9%

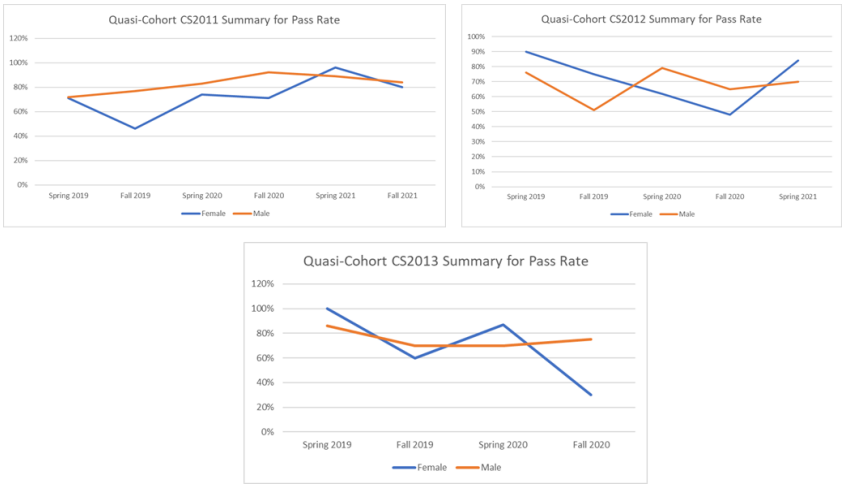

Figure 1. Pass rates of CS 2011, CS 2012, and CS 2013

CS2011

From spring 2019 to fall 2022, data from 100 students who enrolled in CS 2011 were collected: 18 of them were female, and 82 of them were male. The average final grades of the two genders are shown in Figure 2, as well as the average grades of the five modules in CS 2011. Female students' average final grade (81.72 out of 100) is higher than male students (78.28). Also, female students' average grade is higher than male students in each of the five sub-modules.

A Welch's t-test is conducted to test the significance of the differences between female and male students' grades in CS 2011. Welch's t-test, an adaptation of Student's t-test, is more reliable when the two samples have unequal variances and unequal sample sizes [17]. The test results are presented in Table 3. The differences are not statistically significant based on the results in all of the six Welch's t-tests. As shown in Table 3, all the p-values are larger than 0.05. Therefore, although female students' average final grade and average grades in all five modules are higher than male students, the differences are not statistically significant.

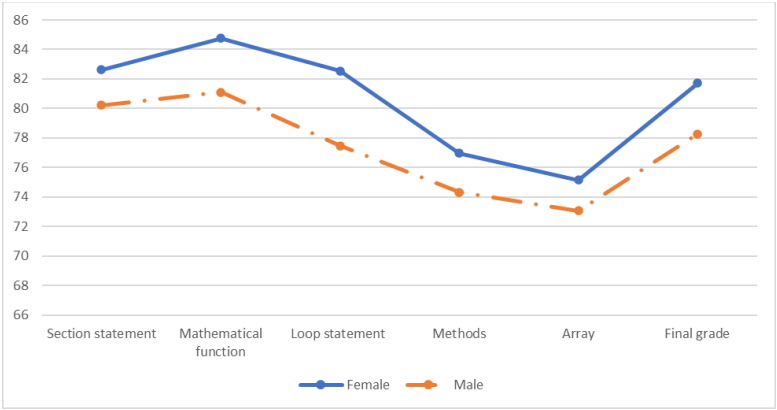

Figure 2. CS 2011 average grades

Table 3. Welch's t-test results for CS2011 grade grouped by gender

	t	df	P-value	95% Confidence Interval of the Difference	
				Lower	Upper
Average grade	1.107	23.153	0.280	-2.2417	9.1172
Section Statement	0.831	25.317	0.413	-3.5264	8.3063
Mathematical functions	1.390	25.686	0.176	-1.7462	9.0273
Loop Statement	1.404	26.001	0.172	-2.3558	12.5167
Methods	0.447	20.999	0.660	-9.6552	14.9351
Array	0.355	22.713	0.726	-10.0038	14.1485

Figure 3 shows the CS 2011 survey results. As mentioned before, student's attitude is measured using the 5-point Likert scale: 1-strongly disagree; 2-somewhat disagree; 3-neither agree nor disagree; 4- somewhat agree; 5- strongly agree. In general, male students' feedback is more positive than female students in all of the five questions. For example, male students agree more on the statement that "I'm confident that CS is the right major for me".

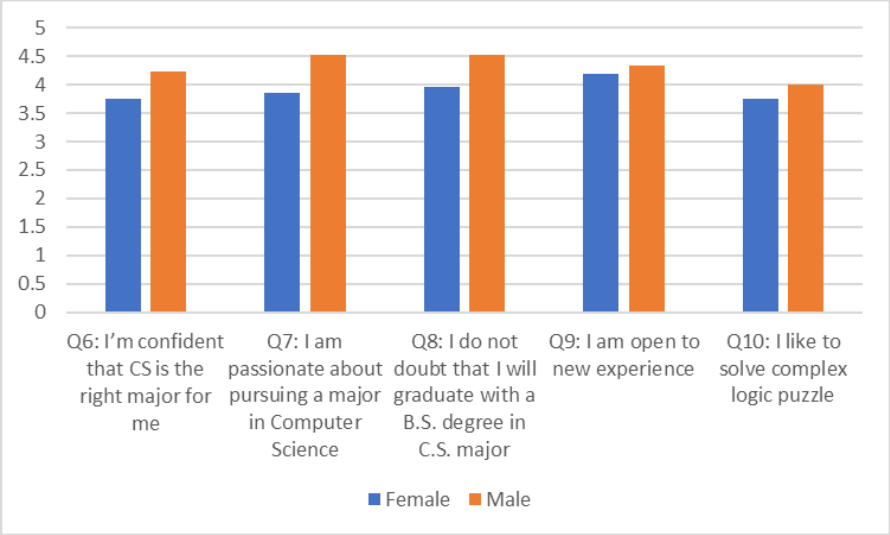

Figure 3. Average scores of CS2011 survey

Mann-Whitney test is conducted to test whether the differences are statistically significant. Based on the results of the Mann-Whitney test, as shown in Table 4, the differences between female and male students in Question 7 and Question 8 are statistically significant (p-value are 0.04 and 0.049 respectively). Male students feel more passionate about pursuing a major in Computer Science than female students. Compared to male students, female students are less confident that they would graduate with a B.S. degree in C.S. major even though their academic performances are as good as male students.

Table 4. Mann-Whitney results for CS2011 survey grouped by gender

	Q6 I am confident that CS is the right major for me.	Q7 I am passionate about pursuing a major in Computer Science.	Q8 I do not doubt that I will graduate with a B.S. degree in C.S. major.	Q9 I am open to new experiences.	Q10 I like to solve complex logic puzzles.
Mann-Whitney U	261.500	243.000	248.500	329.500	300.000
Wilcoxon W	492.500	474.000	479.500	560.500	531.000
Z	-1.607	-2.056	-1.948	-.330	-.871
P-value	.108	**.040**	**.049**	.741	.384

CS 2012

From spring 2019 to fall 2022, data of 230 students who enrolled in CS 2012 were collected: 44 of them were female, and 186 of them were male. The average final grades of the two genders are shown in Figure 4, as well as the average grades of the five modules in CS 2012. Female students' average final grade (77.95 out of 100) is higher than male students (71.18). Also, female students' average grades are higher than male students in four out of the five modules: define class, inheritance polymorphism, Java FXUI, and even-driven programming. Male students' average grade (72.19) is slightly higher than female students (70.19) in one module: exception handling.

Figure 4. CS 2012 average grades

Table 5 shows the results of Welch's t-test of the significance of the differences between female and male students' grades in CS 2012. Based on the test results, the difference between female and male students' average final grade is statistically significant (p-value is 0.022). Female students' average grade is also significantly higher than male students' grade in two modules: Java FX UI and event-driven programming (p-values are 0.018 and 0.022 respectively).

Table 5. Welch's t-test results for CS2012 grade grouped by gender

	t	df	P-value	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
Average grade	2.325	119.780	**0.022**	6.7729	1.004	12.5415
Define class	1.707	97.484	0.091	5.7319	-0.9334	12.3972
Inheritance Polymorphism	1.906	93.178	0.060	6.1586	-0.2583	12.5756
Exception Handing	-0.535	68.925	0.595	-2.3929	-11.3242	6.5384
Java FXUI	2.411	96.908	**0.018**	9.6686	1.7102	17.6269
Event-Driven Programming	2.299	101.277	**0.022**	6.7729	1.0004	12.5415

Figure 5 shows the CS 2012 survey results. Student's attitude is measured using the 5-point Likert scale: 1-strongly disagree; 2-somewhat disagree; 3-neither agree nor disagree; 4-somewhat agree; 5- strongly agree. In general, male students' feedback is more positive than female students in four out of the five questions. Female students agree more with the statement that "I am open to new experiences" than male students.

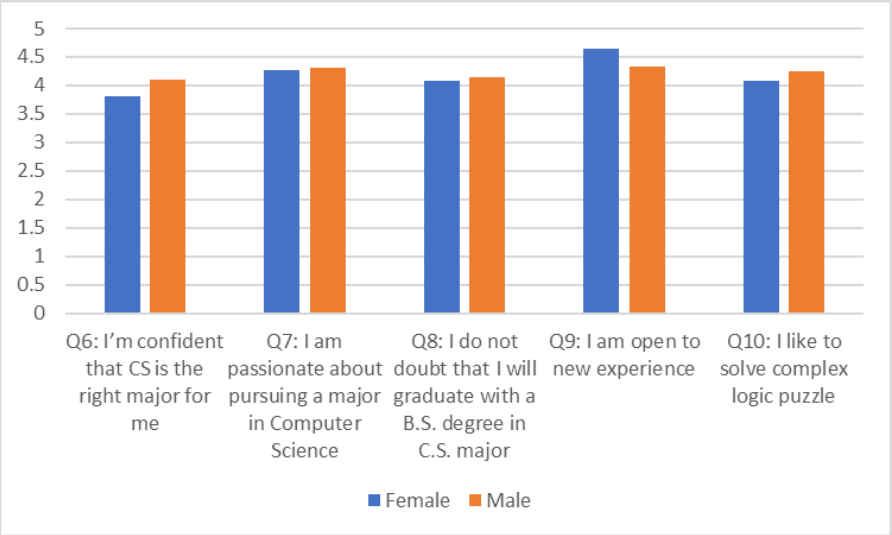

Figure 5. Average scores of CS2012 survey

Mann-Whitney test is conducted to test whether the differences are statistically significant. Based on the results of the Mann-Whitney test, as shown in Table 6, the difference between female and male students in Question 9 is statistically significant (p-value is 0.048). Female students feel more open to new experiences than male students. As for the other four questions, even though male students' feedback is more positive than female students, the differences are not statistically significant.

Table 6. Mann-Whitney results for CS2012 survey grouped by gender

	Q6 I am confident that CS is the right major for me.	Q7 I am passionate about pursuing a major in Computer Science.	Q8 I do not doubt that I will graduate with a B.S. degree in C.S. major.	Q9 I am open to new experiences.	Q10 I like to solve complex logic puzzles.
Mann-Whitney U	554.000	643.500	626.500	501.500	585.000
Wilcoxon W	905.000	1969.500	977.500	1827.500	936.000
Z	-1.246	-.232	-.425	-1.953	-.908
P-value	.213	.816	.671	**.048**	.364

CS2013

From spring 2019 to fall 2022, data of 237 students who enrolled in CS 2013 were collected: 45 of them were female, and 192 of them were male. The average final grades of the two genders are shown in Figure 6, as well as the average grades of the six modules in CS 2013. Female students' average final grade (90.12 out of 100) is higher than male students (82.96). Also, female students' average grades are higher than male students in all of six modules.

Table 7 shows the results of Welch's t-test of the significance of the differences between female and male students' grades in CS 2013. Based on the test results, the difference between female and male students' average final grades is statistically significant (p-value is 0.006). Female students' average grade is also significantly higher than male students' grade in three modules: Recursion, sorting, and Binary Search Tree (BST) (p-values are 0.011, 0.007, and 0.010 respectively)

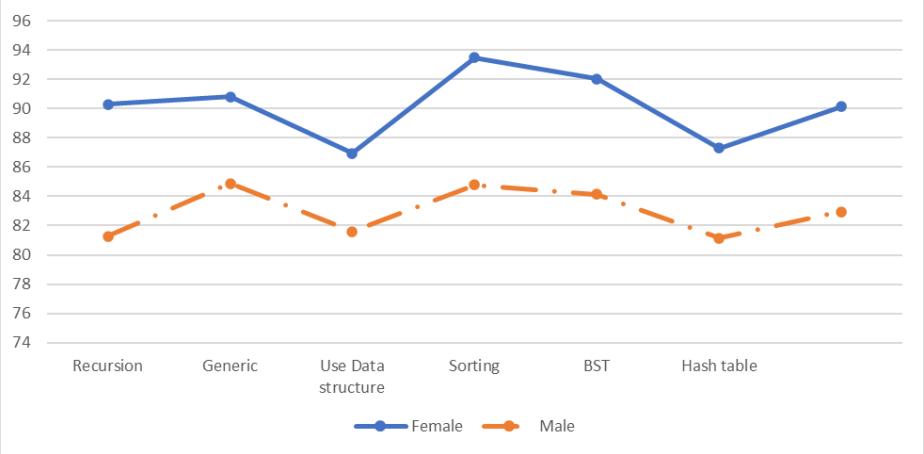

Figure 6. CS 2013 average grades

Table 7. Welch's t-test results for CS2013 grade grouped by gender

	T	df	Sig. (2-tailed)	Mean difference	95% Confidence Interval of the Difference	
					Lower	Upper
Average grade	2.815	85.116	**0.006**	7.1637	2.1033	12.2242
Recursion	2.592	89.786	**0.011**	9.0042	2.0982	15.9102
Generic	1.727	67.238	0.089	5.9292	-0.9219	12.7803
Use Data Structure	1.861	79.065	0.066	5.3417	-0.3712	11.0546
Sorting	2.724	112.583	**0.007**	8.6761	2.3662	14.9561
BST	2.637	109.065	**0.010**	7.8821	1.9589	13.8054
Hash Table	1.636	78.561	0.106	6.1490	-1.3326	13.6307

Figure 7 shows the descriptive statistics of the CS 2013 survey results. Student's attitude is measured using the 5-point Likert scale: 1-strongly disagree; 2-somewhat disagree; 3-neither agree nor disagree; 4- somewhat agree; 5- strongly agree. In general, male students' feedback is more positive than female students in four out of the five questions. Female students agree more with the statement that "I am open to new experiences" than male students.

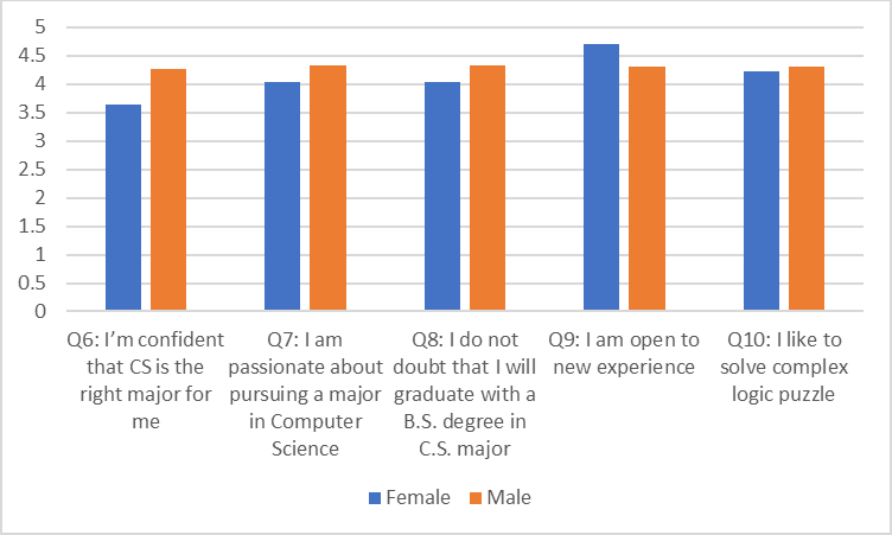

Figure 7. Average scores of CS2013 survey

Mann-Whitney test is conducted to test whether the differences are statistically significant. Based on the results of the Mann-Whitney test, as shown in Table 8, the differences between female and male students in Question 6 and Question 9 are statistically significant (p-values are 0.011 and 0.013 respectively). Female students feel more open to new experiences than male students, while male students feel more confident that CS is the right major. As for the other three questions, even though male students' feedback is more positive than female students, the differences are not statistically significant.

Table 8. Mann-Whitney results for CS2013 survey grouped by gender

	Q6I am confident that CS is the right major for me.	Q7I am passionate about pursuing a major in Computer Science.	Q8I do not doubt that I will graduate with a B.S. degree in C.S. major.	Q9I am open to new experiences.	Q10I like to solve complex logic puzzles.
Mann-Whitney U	324.000	480.000	459.000	339.500	479.000
Wilcoxon W	600.000	756.000	735.000	1329.500	755.000
Z	-2.555	-.379	-.710	-2.471	-.391
P-value	**.011**	.705	.478	**.013**	.696

Discussion

In this study, we observed the followings:

1. We found that female students were more affected by the COVID-19 pandemic than male students. Although female students' academic performance was comparable to male students before the pandemic, the pass rates for CS2 and CS3 were noticeably decreased, and the withdrawal rate doubled. Also, the persistence rate for female students significantly decreased in CS2 and CS3 in the fall of 2020.

2. The survey showed that female students were less confident about their academic performance. For example, the sixth question in the survey was to ask how students agree with the following statement "I'm confident that CS is the right major for me." The average score of male students remained stable from CS 2011 to CS 2013 (The average scores were 4.24 and 4.27, respectively). Female students, on the other hand, felt less confident as the content became increasingly challenging from CS 2011 to CS 2013 (The average scores were 3.76 and 3.65, respectively). However, the statistical analysis of the grades of female and male students revealed that the academic performance of female students was either equal to or superior to that of male students. Specifically, for CS 2013, the average grades of female students were significantly higher than those of male students in terms of the overall average grade in three modules: Recursion, Sorting, and BST data structure.

We believe that the impact on female students' enrolment rates during the COVID-19 pandemic and the lack of confidence in their academic performance may be due to the gender roles in student's daily life and social implications. Due to the gender roles and social implications, female students might have spent more time on household chores and taking care of younger siblings than male students. Thus, female students could have less time for schoolwork than male students.

To confirm our belief, we plan to conduct another survey to better understand the impact of gender roles and social implications on female students' confidence in their academic

performance. Also, we plan to continue to collect the data in early programming courses as we approach the end of the COVID-19 pandemic. Then, we will compare them with the current data. In addition, we plan to organize a female CS student support group to share their experiences.

Conclusion

Based on the data and the survey result, we believe that the academic performance of female students is comparable to that of male students' performance. However, we believe that gender roles and their social implications may have a negative impact on female students' participation in computing which is aligned with the previous studies [18] [19] [20] [21]. To increase the female population in the CS department, we may need to change gender-based cultural aspects.

Acknowledgment

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Appendix A – Categories based on the subjects in CS1, CS2, and CS3

CS1 (CS2011):

1. Constructing a selection statement,
2. Using library functions,
3. Constructing a loop statement,
4. Developing a function, and
5. Using an array.

CS2 (CS2012):

1. Constructing a class,
2. Using inheritance and polymorphism,
3. Constructing exception handling function,
4. Constructing UI using JavaFX, and
5. Using event driven programming techniques,

CS3 (CS2013):

1. Using Binary I/O functions,
2. Constructing a recursive statement,
3. Using generic functions,
4. Constructing various data structures,
5. Implementing various sorting algorithms,
6. Using binary tree data structures, and
7. Using a hash table and hash function.

Appendix B - Survey questions

1. What is your gender?
    a. Female
    b. Male
    c. Non-binary/third gender
2. What is your ethnicity?
    a. Hispanic/Latino
    b. American Indian or Alaska Native, not Hispanic
    c. Black or African American, not Hispanic
    d. Native Hawaiian or another Pacific Islander, not Hispanic
    e. Two or more races, not Hispanic
    f. Asian, not Hispanic
    g. White, not Hispanic
    h. Race/ethnicity unknown
3. What are the challenging topics? Please choose all that apply. (Subdivided categories from the Appendix B)
4. Whom do you ask when you need help with your schoolwork?
    a. Instructors
    b. Tutors
    c. Peers
    d. Online resources
    e. None
5. I am confident that CS is the right major for me.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree
6. I am passionate about pursuing a major in computer science.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree

    d. Somewhat disagree
    e. Strongly disagree
7. I do not doubt that I will graduate with a B.S. degree in computer science major.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree
8. I am open to new experiences.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree
9. I like to solve complex logic puzzles.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree