Gender Diversity in Computer Science at a Large Public R1 Research University: Reporting on a Self-Study

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With the number of jobs in computer occupations on the rise, there is a greater need for computer science (CS) graduates than ever. At the same time, most CS departments across the country are only seeing 25-30% of women students in their classes, meaning that we are failing to draw interest from a large portion of the population. In this work, we explore the gender gap in CS at Rutgers University–New Brunswick, a large public R1 research university, using three data sets that span thousands of students across six academic years. Specifically, we combine these data sets to study the gender gaps in four core CS courses and explore the correlation of several factors with retention and the impact of these factors on changes to the gender gap as students proceed through the CS courses toward completing the CS major. For example, we find that a significant percentage of women students taking the introductory CS1 course for majors do not intend to major in CS, which may be a contributing factor to a large increase in the gender gap immediately after CS1. This finding implies that part of the retention task is attracting these women students to further explore the major. Results from our study include both novel findings and findings that are consistent with known challenges for increasing gender diversity in CS. In both cases, we provide extensive quantitative data in support of the findings.

CCS Concepts: • **Social and professional topics** → **Computer science education**; **Women**; **Men**.

Additional Key Words and Phrases: Gender diversity, CS1, CS2, Student retention.

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1 INTRODUCTION

The need for computing professionals in the workforce is greater than ever. The U.S. Department of Labor estimates that by 2029 there will be nearly 5.2 million jobs in computer occupations, representing a 11.5% growth from 2019 (compared to an 8% growth projection for STEM occupations and a 3.7% growth for all occupations) [52]. Enrollment in computer science (CS) classes and in

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the CS major has increased rapidly in the past decade in response to this need. Yet, progress in reducing the gender gap in CS programs has been slow. For example, the percentage of women earning a bachelor's degree in computer and information sciences (CIS) has only increased from about 17% in 2011/2012 to 21% in 2018/19 [14]. (The number of women earning degrees in CIS has increased significantly, but only at a slightly higher rate than the number of men earning degrees in CIS.) Further increasing the number of women with degrees in computing is critical in providing the needed workforce, and, at the same time, increasing diversity, which is crucial in the creation of technology [31]. Environments that are diverse perform better, have more innovation and productivity, and have a more supportive infrastructure [5].

The gender gaps in many college STEM majors have been extensively studied [39]. Sax has pointed out that it is important to study each discipline separately [40], rather than looking at all STEM disciplines together as in previous work [39], since root causes of gender gaps can be different in various disciplines. Multiple studies have looked at the gender gap in CS [2, 31, 48]. In this work, we add to this body of knowledge using extensive data sets from a large public R1 research university.

Specifically, in this paper, we analyze student data from a set of four core courses, CS1 through CS4, that all majors in our undergraduate CS program are required to take. Our data comprises three different data sets: one data set contains demographic data, course information, and grades; the second one comes from an introductory survey our CS1 students take and contains information about each student's computing background and how likely they are to pursue the CS major (among other information); the third data set comes from an exit survey, asking CS1 students, among other information, what is their level of agreement with three statements revealing their attitudes toward CS. We describe these data sets in more detail in Section 3.

Using the above data sets, in Section 4, we first explore questions such as whether or not there is a gender gap in CS at our university, how the gender gap has changed over the last several years, how it changes from introductory courses to advanced courses in the major, and whether there are differences between the two main categories of students, those entering the university as freshmen students and those entering as transfer students. Then, in Section 5, we explore the correlation between student retention and four factors: intent to major, prior experience, students' attitudes and confidence, and grades. As we present quantitative data, we carefully reflect on implications for efforts targeted at increasing gender diversity in CS.

A main contribution of our work is the combining of three complementary data sets with extensive amounts of longitudinal data to answer a number of questions about our CS student body that, as far as we know, have not been answered before. For example, we give concrete data on where along a path of four required courses women decide to leave the CS major, and show the retention rates for women and men students who take the CS1 course intending to major in CS compared to those not intending to major in CS. Some results match current knowledge and accepted wisdom, but we provide concrete numbers from a large CS program.

We believe that this data and the accompanying analyses are valuable because large departments at institutions similar to ours generate a considerable percentage of the computing workforce in the country. Further, this paper presents a self-study and assessment that stretches over a number of years. The results are partially informing a comprehensive initiative to increase diversity, equity and inclusion (DEI) in the CS major. We summarize our findings and their implications in Section 6, briefly discuss a lesson learned, and briefly describe some of the efforts in our initiative. We hope that the data reported in this paper, our findings, and our approach to the self-study are useful to peers at institutions pursuing the same goal of increasing DEI in CS.

2 BACKGROUND AND RELATED WORK

A number of studies have looked at enrollment data on computing students and some analyzed gender differences in enrollment numbers and pass and fail rates in CS classes [2, 46, 48, 53]. Our work integrates data on enrollments, grades, and surveys to answer questions about intent to major, prior experience, attitudes, and grades, and their correlations with actual retention rates. Other related papers report on survey data [11, 17, 41] or on data from interviews [16, 21, 31] and assess the students' sense of belonging, students' attitudes, motivations, and confidence in computing. We use both surveys and enrollment data to correlate our observations on gender differences with grades and retention.

One paper analyzed the students' grades on seven projects in an introductory programming course [38] and fitted these grades to a mixture model with two Gaussian distributions. While this work also analyzed student data, it was mainly focused on students' grades and the analysis did not include any other student information.

A few other papers have analyzed student data with the goal of understanding phenomena such as gender gaps in college courses. The Freshman Survey [22] provided one of the largest such databases. This data has been extensively analyzed and used to answer questions on how men and women attending college are different in terms of background, achievement, perceptions of their environment, etc [39]. Our work focuses on gender differences in computer science specifically.

Previous work has also addressed the issue of low female representation in STEM disciplines [41, 45], looking at educational factors that influence this phenomenon and making suggestions on how to change this trend. In computer science specifically, many have asked the question why are there so few women majors [6, 9, 11, 16, 21, 31] and strategies to close the gender gap have been proposed [2, 10, 17, 18, 23, 27, 33, 35, 42, 43], including addressing the attitudes of students toward computer science [1, 7, 30, 37, 41, 49]. Our work does not directly address the reasons behind low female representation in CS, but rather uses extensive student data to explore the gender gap and correlations between several factors and student retention.

Our work explores differences in gender diversity and retention between students entering our university as freshmen and transfer students. Previous work has described the experiences of transfer students transitioning to 4-year institutions, including their academic and social adjustment [28]. The experiences and unique challenges of women of color in STEM transferring from a community college to a 4-year institution were also discussed [34]. Another study [24] examines community college pathways to computer science degrees earned at 4-year institutions and explains the challenges, especially for women and underrepresented minorities, of transferring from the supportive environment in community colleges to the competitive setting that characterizes 4-year institutions. Such competition can trigger stereotype threat and lower the students' confidence in their ability to succeed in the field. They also show that only 12% of CS bachelor's recipients are female compared to 50% of other STEM graduates. The lower representation of women can contribute to a decrease in the women's feelings of belonging to CS. Our work complements these previous studies by providing quantitative data and correlation between several factors and retention.

Research in the retention of women students in the computer science major lacks a consistent theoretical framework [32]. While a few theoretical models exist, they either are not widely used or they do not account for differences in the experiences of men and women students [32, 47].

Stephenson et al. [46] have reported retention rates in some CS undergraduate programs in the US. They note that "... retention ... is difficult to define and isn't used consistently across institutions or conversations." Indeed, differences between the data sets that they studied and ours lead to differences in our abilities to quantify retention, making it difficult to compare findings. Nevertheless,

we discuss some high-level similarities and differences in findings in Section 4.3. Stephenson et al. also wrote, "additional research is needed to provide a more nuanced understanding of the dynamics of attrition and retention, to identify the factors that decrease retention ...". Our work adds to this needed body of knowledge.

A number of computing departments at North American universities have made it their goal to increase the percentage of women in their classrooms. Some of their initiatives included changing their CS1 classes to contain more real-life applications [20, 26], offering learning opportunities to students who did not have prior experience [13, 26], providing research projects for undergraduate female students [13, 26], building a solid community of women in computing [26, 31], engaging faculty in recruitment [13] and training them on how to design engaging classes [20], increasing the diversity of the faculty [13], and reaching out to middle schools and high-schools [13, 20]. Our data and analyses may aid these and other universities and colleges in their efforts to narrow the gender gap in CS.

3 RESEARCH CONTEXT, DATA SETS, AND METHODOLOGY

This research was conducted at Rutgers University–New Brunswick, a large public R1 research university, located in New Jersey, United States. Our student body comprises over 50,000 students from all 50 states and more than 100 countries, is approximately equally divided between women and men students, and is highly diverse with respect to race, ethnicity, and socioeconomic background.

Rutgers–New Brunswick offers at least several computing-related majors, including Computer Science (CS), Electrical and Computer Engineering, Information Technology and Informatics, Business Analytics and Information Technology, and Management Information Systems. In this study, we explore the gender gap in four CS courses offered by the CS Department in the School of Arts and Sciences (SAS). Undergraduate students are admitted into schools within the university. Admitted students enter SAS without declaring a major, although they may indicate specific interests. Then, students generally declare a major as soon as they have met admission requirements for majors, usually by the end of their second year. Students may adjust their declared major or majors at any time until their final semester. Students in our school can also earn minors. The CS department offers programs leading to bachelor degrees (B.S. and B.A.) and a CS minor. Students entering schools other than SAS may also take courses in SAS and graduate with majors and minors from our school in addition to majors and minors from their enrolling schools.

The four courses we study broadly cover foundational CS concepts, including Introduction to Computer Science (CS1), Data Structures (CS2), Computer Architecture (CS3), and Algorithms (CS4). All four are required for the undergraduate CS major, and only CS1 and CS2 are required for a CS minor (although CS3 is needed for a significant fraction of the pathways toward earning a CS minor).

The first three courses, CS1, CS2, and CS3, form a direct sequence, with CS3 requiring CS2 as a prerequisite, and CS2 requiring CS1. The fourth course, CS4, requires CS2 as a prerequisite but not CS3, and so may not always be taken after CS3. However, it is the highest level course required for the major and the majority of our students delay taking CS4 until after CS3 (often by several semesters). Thus, the students' progression through this sequence of courses is very indicative of their progression through the major. Most students taking and passing CS4 end up earning a bachelor's degree in CS. In this study, we equate students' taking CS4 with their declaration of a CS major. This approach more accurately captures students working toward CS bachelor's degrees than counting declared majors since a fraction of students do not formally declare their major until they are ready to graduate.

Our CS department values diversity and has been intentionally working to promote diversity, equity, and inclusion (DEI) in our undergraduate student body for several years with strong

support from the school and university. Our expanding and ongoing effort includes outreach to middle schools, high schools, and community colleges,[1] curricular reforms [12], and co-curricular programming [51], all guided by data-informed reflections on student experiences and outcomes [4] (and this work). Our DEI efforts involve collaborations with partners throughout Rutgers–New Brunswick and a range of statewide and nationwide partners (for example, BRAID at AnitaB.org). We refer the interested reader to the departmental Broadening Participation in Computing (BPC) Plan verified and available on BPCnet.org.[2]

We use the terms "women students" and "men students" to denote categories of self-identified gender (female and male) in our data sets. Students can also decline to provide gender information or self-identify as "other" (than male or female), but the fraction of such students is very small and, therefore, we do not include them in our analyses.

Our study uses three data sets. All data sets are anonymized, but entries are linked between data sets by anonymized student ids.

The first data set contains all students who have enrolled in CS classes from Summer 2014 through Spring 2020, with student demographics (for example, gender), admission categories (for example, entering the university as a freshman or as a transfer student), and grades. We call this data set the Registrar data. It allows us to longitudinally observe students taking the sequence of four courses as they make their way through the CS major.

The second data set, the Introductory Survey, contains responses to optional surveys taken at the beginning of CS1 for the following semesters: Fall 2015, Spring and Fall 2016, and Spring and Fall 2017. As we explain below, for consistency within the data set[3] and across several analyses, we limit the use of this data set to survey answers gathered during four semesters: Fall 2015, Spring 2016, Fall 2016, and Spring 2017. Among other information, each survey asks students about their tentative or declared major and what kind of prior experience in CS they have. The set of students taking these surveys is a strict subset of the students in the Registrar data.

The third data set, the Exit Survey, comes from an optional survey taken at the end of CS1 during every Fall and Spring semester between Fall 2015 and Fall 2017. Again, as we explain below, we only use survey answers from Fall 2016 and Spring 2017. Among other information, each survey asks students about their attitude toward CS, the frequency with which they used available resources such as tutoring, and how helpful they found these resources to be. Many of these survey questions were designed to collect information that is outside the scope of this study. The set of students taking these surveys is also a strict subset of the students in the Registrar data.

The above data sets complement each other to give a more comprehensive picture of who our students are, what are their backgrounds, what are their interests in the CS major, what classes they take, and the grades they earn. When analyzing our data, we typically group pairs of Fall and Spring semesters into academic years (AYs) as the characteristics of the populations of students differ somewhat between Fall and Spring. For example, enrollment in CS1 is always significantly higher in the Fall, and typically a greater fraction of the students in the Fall intends to pursue the CS major than in the Spring. An AY contains the Fall semester from the previous calendar year and the Spring semester of that year. For example, AY 2015 contains Fall 2014 and Spring 2015.

We typically do not consider Summer course offerings because the vast majority of our students take classes during the Fall and Spring semesters, and the Summer offerings are substantially different than the normal Fall and Spring offerings.

[1]Some examples: https://www.rutgerscshub.com/ and https://cesp.rutgers.edu/extending-computer-science-pipeline-enhancing-rigor-and-relevance-middle-school-computer-science.

[2]URL for PDF: https://drive.google.com/file/d/1rNJwfP5j2o11Yk8oaQ_k-DR3_pZ5g9I-/view.

[3]The introductory survey evolved over time.

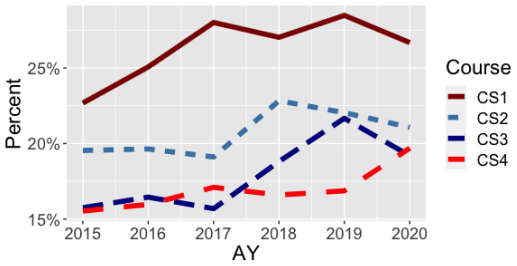

Fig. 1. Percent of women students in CS1 through CS4 over time.

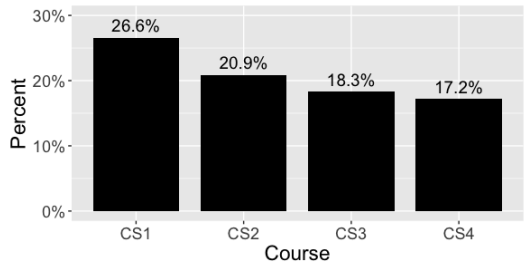

Fig. 2. Percent of women students in CS1 through CS4 for cumulative enrollment across AYs 2015-2020.

We use the χ^2 (chi-square) test with a significance level (α) of 0.05 to determine the statistical significance of differences between groups in a number of analyses in the paper. When discussing the statistical significance of changes in percentages, for example, the percentages of women students enrolled in a course over time, we are using the χ^2 test on the actual counts behind the percentages. We explicitly mention when differences are statistically significant or not statistically significant. When the numbers in a group are too low for χ^2, we use Fisher's exact test instead.

4 GENDER GAPS AND RETENTION

4.1 Overall Gender Gaps

We begin our study by assessing the gender gaps in CS1 through CS4. Using the Registrar data, Figure 1 shows the percentages of women students in the four courses for AYs 2015 through 2020, and Figure 2 shows the percentages of women students in the four courses when enrollment is accumulated over all 6 AYs. The total number of students enrolled in the courses over all AYs are: 9,193 in CS1, 6,620 in CS2, 3,968 in CS3, and 3,375 in CS4. Since we are only studying students who identify as women and men, the percent of women students and the percent of men students add up to 100%.

Clearly, there are significant gender gaps that are similar to national averages [14]. The differences in the percentages of women students taking CS1 over the six AYs are statistically significant. We observe, however, that the percent of women students in CS1 increased from 2015 to 2017, but then essentially "flattened" out from 2017 through 2020. We can see the increase in the percentage of women students in CS1 reflected later in time in all three of CS2, CS3, and CS4, although the differences across the six AYs are statistically significant only for CS1 and CS3. We also see the flattening or a slight decrease reflected in CS2 and CS3, and expect to see the same trend in the near future in CS4.

The gender gap increases steadily as our students progress toward completing the CS major. In particular, the percentage of women students starts at 26.6% in CS1 and decreases to 17.2% in CS4, with the largest decrease occurring between CS1 and CS2 (a drop of 5.7% from 26.6% to 20.9%). The differences in percentages of women students for cumulative enrollment in the four courses (Figure 2) are statistically significant.

Consistent with previous research [14], the number of women students studying CS has increased significantly from AY 2015 to AY 2020. However, the number of men studying CS has also increased significantly, so that the overall gender gap has decreased slowly; in fact, in our case, the narrowing of the gender gap seems to have stalled between AY 2017 and AY 2020.

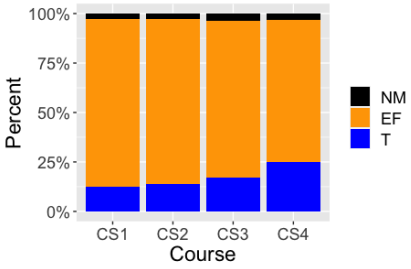

Fig. 3. Percentages of students from three categories in CS1 - CS4. NM = non-matriculated, EF = entering as freshmen, T = transfer.

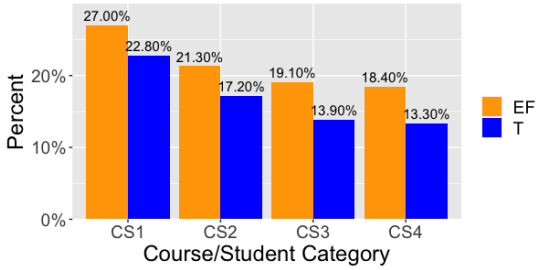

Fig. 4. Percent of women entering as freshmen (EF) and transfer (T) students in CS1 - CS4.

4.2 Gender Gaps for Students Entering as Freshmen and for Transfer Students

Our courses enroll three main categories of students: students entering the university as freshmen ("entering as freshmen (EF)"), students transferring to the university with at least 12 college credits ("transfer (T)"), and non-matriculated (NM) students. In the remainder of the paper, the term *entering as freshmen* refers to the *entering* status of the students, rather than their current year in the program when they enroll in a specific class. For example, an entering as freshman student interested in the CS major will typically take CS3 in their sophomore year and CS4 in their junior or senior year.

Figure 3 shows the breakdown of the cumulative enrollments (AYs 2015 through 2020) for CS1 through CS4 for the three categories of students. Figure 4 shows the percentages of women students in CS1 through CS4 for students entering as freshmen and for transfer students.[4] These figures show that the percentage of transfer students increases from CS1 to CS4, rising above 25% for CS4, and that *the gender gaps are larger for transfer students than for students entering as freshmen in all four courses.* In addition, the difference between the percentages of women transfer students and students entering as freshmen is *increasing* from CS1 to CS4, and the differences are statistically significant. Our findings for CS1 and CS2 are consistent with data reported for first-year and transfer students in a case study from the University of California, San Diego [46]. Overall, the findings indicate the importance of working with institutions that our transfer students are transferring from to recruit more women students to explore the CS major, and to ensure well aligned pathways that support and allow transfer students to successfully complete the CS major at our university.

4.3 Retention

We now explore how the retention of our students affects the gender gaps shown above. In particular, we look at retention rates for the three two-course sequences CS1 to CS2, CS2 to CS3, and CS3 to CS4, where *retention rate* is defined as *the percent of students enrolling in the first course that go on to take the second course.* In each case, we look at the students enrolling in the first course during AY 2016 and AY 2017 and compute the fraction that go on to take the second course in any semester from Fall 2016 through Spring 2020, including summer. We limit the time period for students taking the first course to AY 2016 and AY 2017 because (i) it gives the students time to take the second course, and (ii) the time period coincides with the survey data we use below to explore the correlation between some factors and student retention. We consider pairs of courses

[4]We do not show percentages for non-matriculated students because they comprise only small percentages of the overall enrollments.

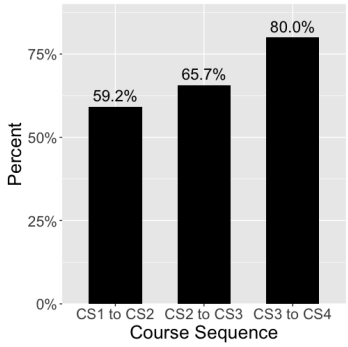

Fig. 5. Retention rates.

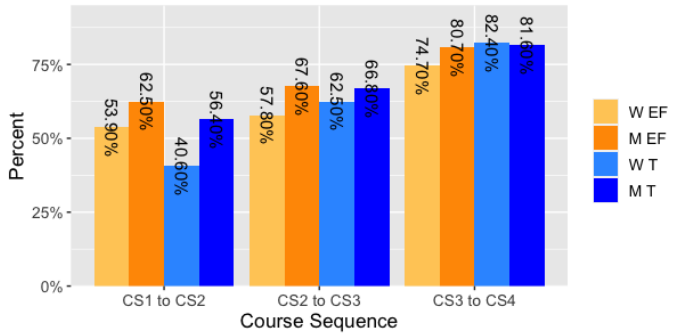

Fig. 6. Retention rates for women entering as freshmen (W EF), men entering as freshmen (M EF), women transfer (W T), and men transfer (M T) students.

as opposed to the entire sequence from CS1 through CS4 because the latter approach would ignore students starting later in the sequence, for example, a transfer student who has taken CS1 elsewhere and enters our course sequence by taking CS2. Finally, we only consider students entering as freshmen and transfer students since non-matriculated students are typically not working toward a CS degree.

Figure 5 shows the retention rates for the three two-course sequences, and Figure 6 shows the retention rates broken up by categories of students and gender. During AYs 2016 and 2017, 2,591 unique students took CS1, with 26.4% women students; 1,783 students took CS2, with 19.3% women students; and 1,030 students took CS3, with 15.8% women students.

Our data shows that significant fractions of students stop exploring or pursuing the CS major after CS1 and CS2. (Students not going on to take CS2 have also stopped exploring or pursuing a CS minor.) On the other hand, a large fraction (80%) of the students who take CS3 go on to take CS4 (and, as discussed above in Section 3, most will complete the CS major). The differences in the retention rates between the groups shown in Figure 6 for the three sequences are statistically significant.

The retention rates for women students are lower than those for men students with the exception of the retention of transfer students from CS3 to CS4. Retention is especially poor from CS1 to CS2 for women transfer students, with a statistically significant difference between the retention rates of women entering as freshmen and of women transfer students. Interestingly, the retention rates for women transfer students rise above those for women students entering as freshmen for CS2 to CS3 and CS3 to CS4. The retention rate for men transfer students is also below that for men students entering as freshmen for CS1 to CS2, although the difference is not statistically significant, and is comparable for CS2 to CS3 and CS3 to CS4. These findings point to the possible challenges that transfer students face when they must start with CS1 on arrival to our university. In the near future, we will seek to understand why so many transfer students need to take CS1, and why such large fractions of these students, especially of women students, do not continue on to CS2.

While the retention rates from CS2 to CS3 and CS3 to CS4 are slightly higher for women transfer students than for women students entering as freshmen, combining these data with the results shown in Figure 4 tells us that proportionally more men transfer students are arriving to CS3 and CS4, so that the overall percentages of women transfer students in these courses are dropping faster than those for students entering as freshmen.

As mentioned above, Stephenson et al. [46] reported statistics on student retention using a data set from the National Center for Women & Information Technology (NCWIT). They reported retention rates for declared majors (whereas our data includes all students taking CS courses) that start at around 70% for freshmen (which is higher than the retention rates we observe for CS1-CS2 and CS2-CS3) and peak at around a 90% for seniors (which is comparable with our observation from CS3-CS4 and the fact that most students taking CS4 go on to earn a bachelor degree in CS). Interestingly, they do not find significant differences in retention rates between men and women students, whereas we observe significant differences between these two groups, especially early on in the four-course sequence.

5 CORRELATION OF VARIOUS FACTORS WITH RETENTION

We now consider the correlation between several factors and student retention in CS courses and the CS major. More specifically, we look at the correlation of four factors: intent to major, prior experience, student attitudes and confidence, and grades, with the retention rates for pairs of courses as well as retention rates from CS1 through CS4. We explore intent to major because students enter our school without declaring their major. Thus, quantifying intent to major and correlating it with retention can help us assess whether there are differences in the level of interest from different groups of students, and whether these differences may be leading to differences in retention rates. Previous work has shown correlations between retention and prior experience, attitudes, and confidence [6, 25]. We seek to quantitatively understand these factors for our student body and complement the previous results with data from a large public university. Finally, grades are undoubtedly important to most of our students, motivating us to study whether there are differences among various groups of students. Differences and correlation with retention rates can point to challenges for students that we need to explore and address in our efforts to promote DEI.

5.1 Intent to Major

The observation that the highest drop in the percentage of women students is after CS1 raises an important but unexpected question: is there a difference in the level of interest in majoring in CS between the women and men students taking CS1? We did not expect this question to be a factor when we began this study because CS1 is intended for CS majors and has a reputation for being challenging and we have several introductory computing courses with very large enrollments for students who are not exploring a CS major. However, we did ask our students about their intended major in our Introductory Survey for completeness.

The survey had slight variations between semesters but, generally, included two questions, with the first one asking what was the students' intended or declared major and the second one asking students to estimate how likely they were to choose to major in CS. A student was considered as intending to major in CS if they had either answered "Computer Science" to the first question or "likely" or "highly likely" to the second question or both. This criterion offered the broadest interpretation for intention to major in CS.

For consistency with our other results, we use the Introductory Survey from AY 2016 and AY 2017 to explore differences in intent to major between men and women students who take CS1. Overall, we have a high response rate (69.9%) for the surveys, and there is evidence that the respondents are representative of the overall student population with respect to gender composition and retention rates. As mentioned above, during these two AYs, 2,591 students took CS1, with 26.4% women students. 1,812 of these students responded to our survey, with 27.3% women respondents. 63.3% of the survey respondents subsequently took CS2 compared to 59.2% of all students (Figure 5). 56.0% and 66.1% of the women and men survey respondents, respectively, continued to CS2 compared to 52.6% and 61.6% of all women and men students, respectively.

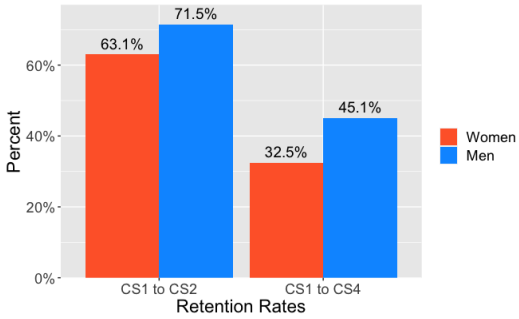

Fig. 7. Retention of students taking CS1 intending to major in CS.

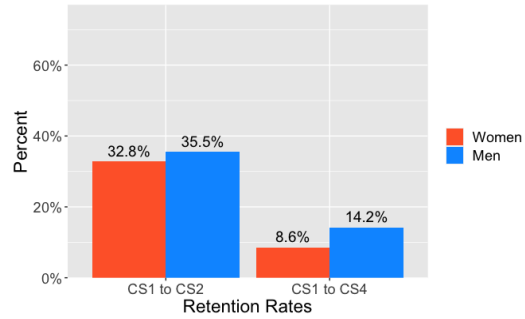

Fig. 8. Retention of students taking CS1 not intending to major in CS.

Survey results show that 76.6% of the women students intended to major in CS before taking CS1 compared to 85.0% of the men students, and the difference is statistically significant. While the (relatively low) numbers were initially surprising to us, in retrospect, they make sense given that CS1 can be used to meet parts of the "core" requirements for all students regardless of major in our school. Many students seem to be taking the more rigorous CS1 course rather than the courses for non-majors for this purpose. CS1 can also be substituted for introductory programming courses in other majors.

Combining the Introductory Survey and Registrar data sets, Figures 7 and 8 show the retention rates for women and men students taking CS1 and then continuing on to take CS2 and ultimately, CS4, broken up by students intending to major and not intending to major in CS.

Clearly, in terms of progressing from CS1 to CS2, the retention rates for both genders are higher for students who intend to major in CS than for students who do not intend to major in CS, and the differences are statistically significant. When this fact is coupled with the higher percentage of women students taking CS1 but not intending to major in CS, we find a possible major factor that contributes to the proportionally higher loss of women students from CS1 to CS2. *The gender gap between men and women students taking CS1 with the intention to major in CS is larger than the gap between all men and women students taking CS1.* That is, proportionally more women students choose to take CS1 despite the fact that they do not intend to major in CS, and we do not successfully attract them to the major. This matches the known fact that women students often lose interest in CS before they enter college. Yet, it also points to an opportunity: if we can (re)kindle interest for the CS major in the women students who choose to take CS1 without intending to major in CS, we have a chance to reduce the current loss of women students after CS1. This finding also reinforces the need to work with K-12 schools to attract more women students to explore CS, but the large overall gender gap in CS1 already stipulates such work.

Figure 8 shows that almost a third of the women students who do not intend to major in CS go on to take CS2. This implies that, while we still need to consider how to improve CS1 to encourage more women (in fact, to encourage more students of both genders) to further explore the CS major, at least some of the women not intending to major in CS continue taking classes toward the major after CS1. We currently do not know whether the students are taking CS2 because they became interested in the CS major, they were pursuing a CS minor, or for other reasons. We plan to survey CS2 students in the near future. Unfortunately, Figure 8 shows that by CS4, most of the women (and similarly most of the men) students who did not intend to major in CS at the beginning of CS1

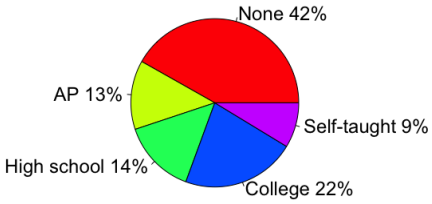

Fig. 9. Prior experience for women students in CS1.

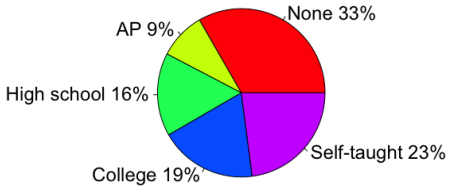

Fig. 10. Prior experience for men students in CS1.

have chosen to leave the major. Perhaps this is because many of the students were pursuing a CS minor. Anecdotally, while CS4 can be taken toward fulfilling a minor in CS, it is rarely done.

Interestingly, we find that a larger percentage (83.0%) of women transfer students taking CS1 intend to major in CS compared to women students entering as freshmen (75.9%). This finding implies that intent to major is *not* a factor behind the comparatively low retention rate from CS1 to CS2 for women transfer students (Figure 6).

In terms of progressing from CS1 to CS4, Figures 7 and 8 show that the percentage of students intending to major in CS persisting to CS4 is about 3-4 times that of students not intending to major in CS.

5.2 Prior Experience

Do women and men students who take CS1 have different prior experience in CS? Does prior experience correlate with retention? We use the Introductory Survey and Registrar data to answer these questions. Specifically, we use survey answers from the Spring 2016 and Spring 2017 semesters, when students were asked about their prior experience in computing. The possible answers were: AP CS, some high school classes, college, self-learned, and none. It would have been preferable to have data for AY 2016 and AY 2017 rather than just the two Spring semesters, since enrollments are higher during Fall semesters than during Spring semesters and characteristics of the student body may differ between Fall and Spring (as discussed in Section 3). Unfortunately, the surveys during Fall 2015 and Fall 2016 had incompatible forms of the question.

During Spring 2016 and Spring 2017, a total of 982 students took CS1, with 29.9% women students. Of these, 628 students (64.0%) took the survey, with 20.0% women survey respondents. 58.1% of the survey respondents subsequently took CS2 compared to 59.2% of all students (Figure 5). 49.5% and 62% of the women and men survey respondents, respectively, continued to CS2 compared to 52.6% and 61.6% of all women and men students, respectively.

Figures 9 and 10 show the proportions of women and men students taking CS1 with different types of prior experience. The difference in the proportions of women and men with various types of prior experience is statistically significant. We observe that higher percentages of women students took an AP CS course in high school and did not have prior experience in CS compared to men students. A higher percentage of men students previously taught themselves compared to women students.

Combining data from the Introductory Survey and Registrar data sets, Figure 11 shows the retention rates for women and men students for the CS1 to CS2 sequence, broken up by prior experience. Differences in the retention rates for women and men students are statistically significant. We

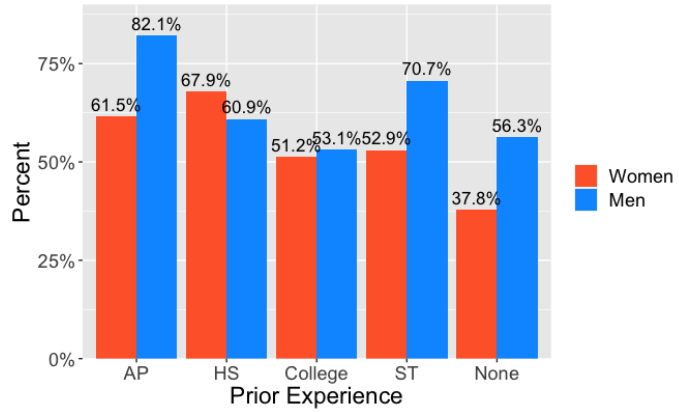

Fig. 11. Retention rates for CS1 to CS2 for women and men students by prior experience. HS = high school, ST = self-taught.

do not look at retention rates into CS3 and CS4 because the numbers of students for some of the categories of prior experience become quite small.

We observe that the retention rates for women students with any type of prior experience are significantly higher than the retention rate for women students without prior experience. This finding is consistent with previous results showing that experience with an AP CS course in high school increases the chance of attracting women students to the CS major [15]. Further, we observe that, for students without prior experience, the retention rate is significantly higher for men students than for women students.

The above findings point to a second possible factor leading to the gender gap increasing as students advance in the CS course sequence: *a higher proportion of women students taking CS1 have no prior experience in CS compared to men students, and the retention rate for these women students is much lower than the retention rate for men students.* This implication points to the importance of partnering with K-12 schools to attract women students to explore CS before entering college. This implication is well known, but our work adds concrete quantitative data to this knowledge.

Interestingly, most of the transfer students have either prior college experience or no prior experience (although the sample of students is small): 44% of the women transfer students (n = 8) and 46% of the men transfer students (n = 24) have prior college experience; 44% of the women transfer students and 21% of the men transfer students have no prior experience. Retention rates are the lowest for students with these two categories of prior experience, which may partially account for the overall low retention rates from CS1 to CS2 for transfer students shown earlier in Figure 6. While we must be careful to avoid generalizing from such a small sample, this finding does point to the need to understand our body of transfer students better and reemphasizes the need to partner with institutions such as community colleges to ensure pathways that lead to success for transfer students.

Considering a possible correlation between intent to major and prior experience, Figure 12 shows the distribution of prior experience types for women students who intend to major in CS (Women IM), women students who do not intend to major (Women NOT IM), men students who intend to major (Men IM), and men students who do not intend to major (Men NOT IM). It is interesting to observe that there seems to be no correlation between the two factors other than for students with AP experience. We again need to be careful in drawing insights from this analysis since the

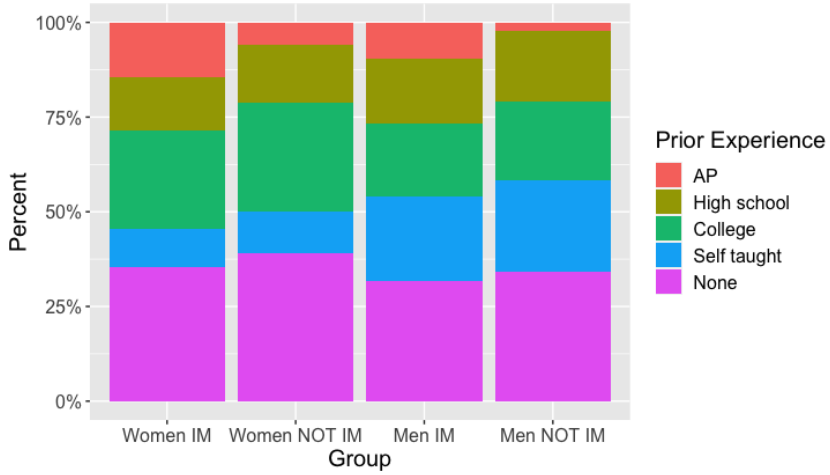

Fig. 12. Prior experience by intent to major for women and men students. IM = intend to major; NOT IM = not intending to major.

partitioning of the student sample among the two dimensions leads to small numbers in some of the categories. However, the finding that students with AP experience are more likely to be interested in the CS major is consistent with previous work [15]. Further, it perhaps adds a small piece of evidence for encouraging women students to explore AP CS courses in high school, both to gain a rigorous background in CS in preparation for college and to increase interest in the CS major.

5.3 Student Attitudes and Confidence

Next, we look at differences in attitudes toward CS between women and men students. We use the Exit Survey data set, with surveys during Fall 2016 and Spring 2017 (corresponding to AY 2017) asking students how much they agree or disagree with the following statements: I can be successful in CS; I believe that if I study hard, I can be successful in CS; and, I feel comfortable raising my hand and asking a question in my classes. Again, it would have been preferable to have data for both AY 2016 and AY 2017. However, the Exit survey of Fall 2015 did not include the above questions.

During AY 2017, a total of 1,331 students took CS1, with 27.9% women students. Of these, 988 students (74.23%) took the survey, with 28.8% women survey respondents. 64.6% of the survey respondents subsequently took CS2 compared to 59.2% of all students (Figure 5). 55.4% and 68.2% of the women and men survey respondents, respectively, continued to CS2 compared to 52.6% and 61.6% of all women and men students, respectively.

We show the scores corresponding to students' responses on CS attitudes questions in Figure 13. For each statement, we test the statistical significance of the difference in the proportions of men and women with various levels of agreement with the statements on attitudes toward CS. We find that the difference between the answers of men and women are statistically significant for all statements.

We see that, overall, women feel less confident that they can be successful in CS and less comfortable raising their hands to ask questions in class, similar to the findings of other studies [36, 44]. Do these differences correlate with retention?

Figures 14 and 15 show the retention rates for CS1 to CS2 and CS1 to CS4, respectively, broken up by positive and negative attitudes toward CS. Attitudes are considered positive for answers

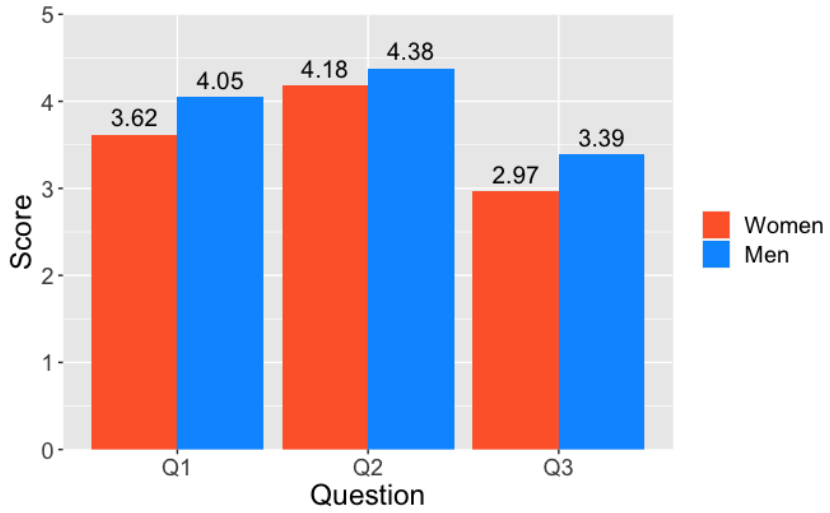

Fig. 13. Average scores for women and men students taking CS1 indicating their level of agreement (1-5) with the following statements: Q1: I can be successful in CS courses; Q2: I believe that if I study hard, I can be successful in CS; and, Q3: I feel comfortable raising my hand and asking a question in my classes.

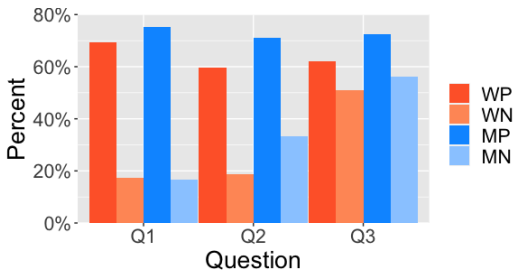

Fig. 14. Retention rates for CS1 to CS2 for women (W) and men (M) with positive (P) and negative (N) attitudes.

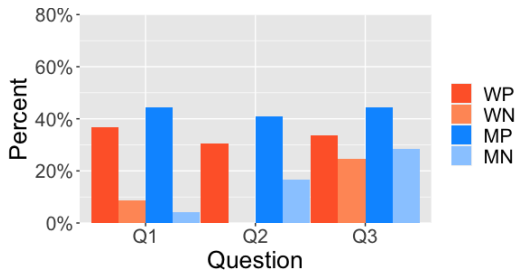

Fig. 15. Retention rates for CS1 to CS4 for women (W) and men (M) with positive (P) and negative (N) attitudes.

"Strongly agree" and "Agree," and negative for answers "Disagree" and "Strongly disagree." For Q3, the differences in retention rates from CS1 to CS2 and from CS1 to CS4 for women students with positive and negative attitudes are not statistically significant, whereas for men, they are. For Q1 and Q2, for both men and women, the differences in the continuation rates to CS2 and CS4 are statistically significant. Here, because of the low number of women who continue to CS4, we used Fisher's exact test to determine the statistical significance of differences between men and women students in retention to CS4.

Clearly, students' confidence in their success in CS correlates highly with retention, with much higher retention rates for students with positive attitudes than for students with negative attitudes. This finding points to a third possible reason for the widening of the gender gap as students progress toward completing the CS major: *confidence is highly correlated with retention, and, overall, women students are less confident than men.* This finding is consistent with a number of previous studies

suggesting that women feel less confident in CS and therefore, feel that they do not belong [9, 10, 31]; our results add concrete data to this body of knowledge.

5.4 Grades

In this section, we study the correlation between grades and the students' decisions to continue in the CS major. First, we compare grades for women and men students taking CS1 through CS4 for AY 2015 through AY 2019. We do not consider grades from AY 2020 because grades for Spring 2020 were affected by the COVID-19 pandemic. For each of the four classes, the grade distributions were very similar for women and men, with non statistically significant differences. When combined with results from the last section on students' confidence, an important (known) implication is immediately derived: *women students are less confident than men students despite comparable performance, defined by earned grades*. Thus, we must build supporting structures to help increase the confidence of women students taking CS courses.

5.4.1 Retention. Next, we examine retention rates for women and men students earning various grades. Figures 16 and 17 show the retention rates for women and men students for the sequences CS1 to CS2 and CS2 to CS3, broken up by grades earned in the first course. Similar to our analysis in Section 4.3, we use the Registrar data set and look at the retention of students taking the first course in a sequence during AY 2016 and AY 2017.

As expected, the retention rates are higher for students earning higher grades. These results are consistent with a previously reported correlation between retention and self-efficacy [6], and grades are significant contributors to the students' self-efficacy [50]. However, the retention rates seem to be more strongly impacted by grades for CS1 to CS2 than for CS2 to CS3. In particular, retention rates consistently decrease from the best grade (A) to the worst grades (D/F/W) for CS1 to CS2, whereas retention rates are similar (and relatively high) for grades A through C, and then drop significantly for D/F/W for CS2 to CS3. Unfortunately, of the four courses, CS2 has the highest percentage of D/F/W.

We also looked at retention rates for the sequence CS3 to CS4. They are similar to, but uniformly higher than those for CS2 to CS3: about 74 - 89% for grades A-C, and about 58% for D/F/W.

The retention rates are lower for women than for men students in every category shown in Figures 16 and 17, and, in most categories, substantially so. Furthermore, the differences between the retention rates of women and those of men earning the same grade widens from A to C for the CS1 to CS2 sequence. The latter finding has an important implication: the commonly used grading scheme based on a bell-shape curve leading to certain percentages of students earning each grade will, at least partially, contribute to a widening of the gender gap after CS1. The increasing difference between the retention rates of women and those of men students earning lower (but passing) grades, the fact that the grade distributions are similar between genders, and the fact that certain percentages of students will be assigned each grade, combine to mean that proportionally fewer women students will continue to CS2 than men students. We believe that "mastery-based" grading [8, 29] is a pedagogically better alternative and our findings imply that it might also be important for reducing the gender gap in student retention.

Finally, we compare the grade distributions in CS1 for students entering as freshmen and transfer students to see whether there might be a correlation between grades and the low retention rates of transfer students immediately after CS1, which we observed in Section 4.3. Figure 18 shows the grade distributions for women and men students, respectively. We can see a clear (and statistically significant) difference in grade distributions between the two categories of women students. For men, the difference in grade distributions between the two categories of students is not statistically significant. Given that a higher percentage of women transfer students intend to major in CS

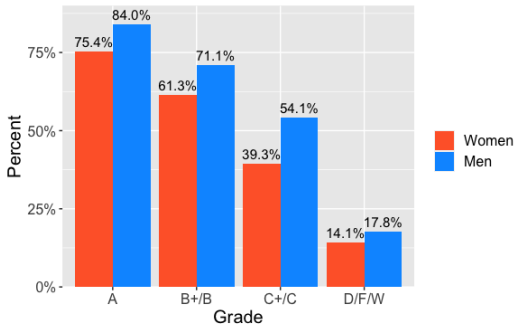

Fig. 16. Retention rates for CS1-CS2 vs. grades in CS1.

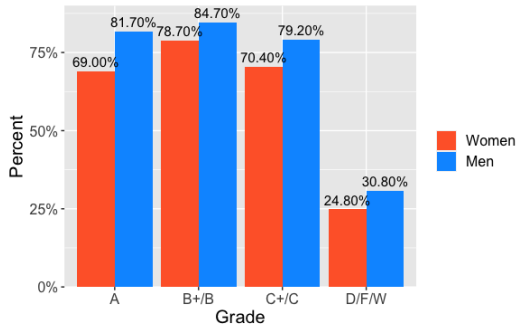

Fig. 17. Retention rates for CS2-CS3 vs. grades in CS2.

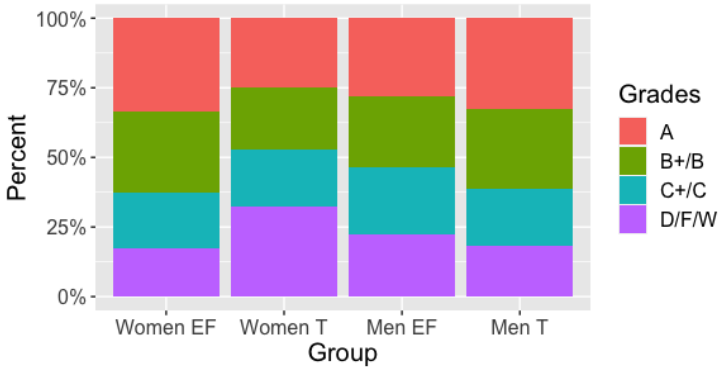

Fig. 18. CS1 grades for women and men entering as freshmen (EF) and transfer (T) students.

compared to women students entering as freshmen, this data shows that grades may be a factor behind the low retention rates immediately after CS1 for women transfer students. This finding reemphasizes the need to provide transfer pathways that can help students to succeed in the CS major at our university.

5.4.2 Correlation between Early Grades and Later Grades. To determine whether grades in courses taken earlier in the CS major correlate with grades in courses taken later in the CS major, we used the Registrar Data set, more specifically, information about the grades that students received in CS1, CS2, CS3, and CS4 and the students' gender for AY 2015 through AY 2019. Since the Registrar data contains letter grades, we used the Goodman and Kruskal's G test [19] to assess the strength of the association between grades in every pair of courses. We find that there is a *significant moderate positive association between every pair of courses*, with values ranging from 0.344 to 0.44.

In Figures 19 through 24, we show the Sankey diagrams[5] for the distributions of grades between the sequences CS1 to CS2, CS2 to CS3, and CS3 to CS4. This data maps the grade earned the first time a unique student takes the first course to the grade earned the first time the same student takes the second course. Note that grade B includes B+ and B and grade C includes C+ and C in the diagrams. The number of students taking both CS1 and CS2 is 3,401 (776 women students and

[5]http://sankeymatic.com/build/

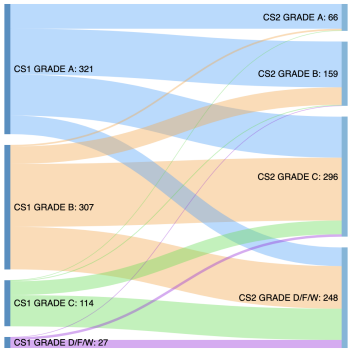

Fig. 19. CS1 and CS2 (Women).

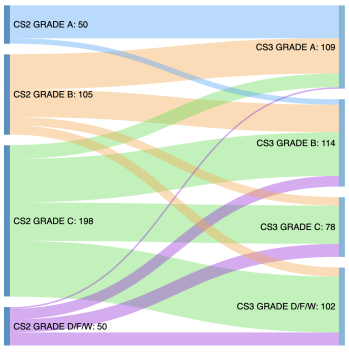

Fig. 20. CS2 and CS3 (Women).

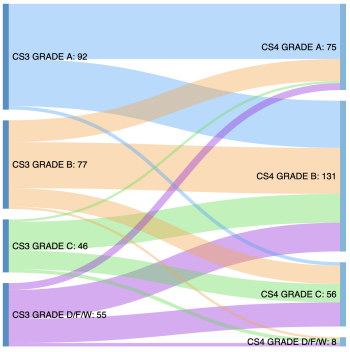

Fig. 21. CS3 and CS4 (Women).

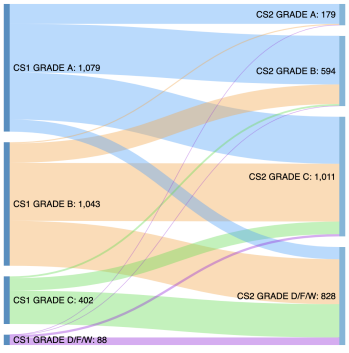

Fig. 22. CS1 and CS2 (Men).

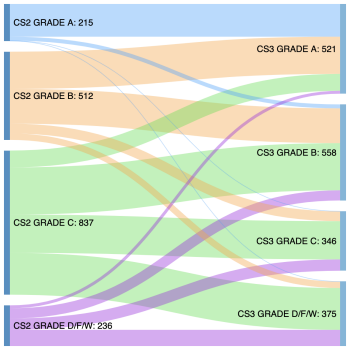

Fig. 23. CS2 and CS3 (Men).

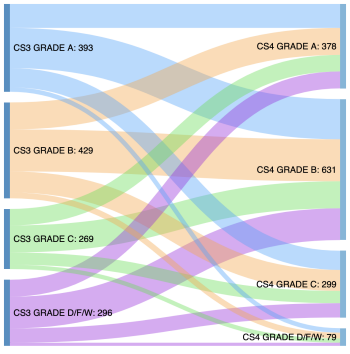

Fig. 24. CS3 and CS4 (Men).

2,625 men students), those taking both CS2 and CS3 are 2,208 students (403 women and 1,805 men), and those taking both CS3 and CS4 are 1,658 students (270 women and 1,388 men).

The diagrams look quite similar for women and men students, with perhaps the most significant differences in the sequence CS3 to CS4. We currently do not have any conjectures nor explanations for these differences.

The majority of students earning C+, C, D, F, or W in CS1 go on to earn D, F, or W in CS2. Interestingly, a significant fraction of students earning D, F, or W in CS2 go on to earn passing grades in CS3; similarly, a significant fraction of students earning C+ or C in CS2 go on to earn equivalent or higher grades in CS3. In addition, the grade distribution for CS2 seems to be the most challenging, although CS3 also has a larger fraction of D, F, or W. This data suggests the need to reexamine the CS2 course, especially in light of the lower retention rates for women students earning C+ or C in CS1 and D, F, or W in CS2 compared to men (and the low retention rates overall for all students earning these grades). In particular, we need to explore the question of why students earning passing grades of C+ or C in CS1 are unlikely to succeed in CS2, especially given that many students earning D, F, or W in CS2 go on to earn higher grades in CS3.

The data also suggests the need to explore the large fraction of D, F, or W in CS3, as retention rates for students earning D, F, or W are significantly lower than those for students earning higher grades, and the retention rate for women students earning D, F, or W in CS3 is lower than that for men students. In addition, most students earning D, F, or W in CS3 go on to earn passing grades in

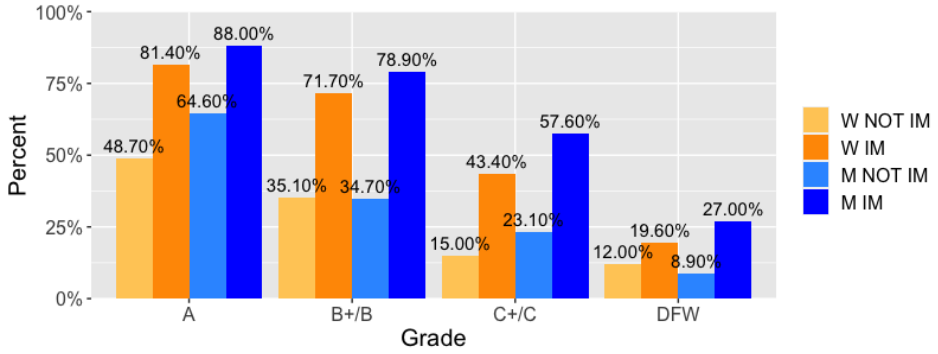

Fig. 25. Retention rates from CS1 to CS2 by CS1 grade for women students (W) and men students (M) who intend to major (IM) and do not intend to major (NOT IM) in CS.

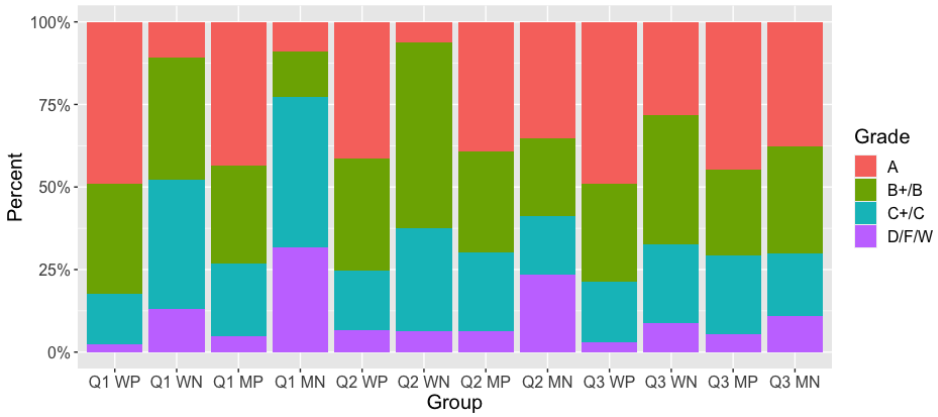

Fig. 26. CS1 grade distribution by attitudes. WP (MP) means women (men) students with positive attitude; WN (MN) means women (men) students with negative attitude.

CS4. We do note that the CS3 and CS4 courses are very different, with CS3 covering digital logic and architecture and CS4 covering algorithms.

The above data also emphasizes the importance of helping women students to gain a sense of confidence appropriate to their mastery of the material in a course. In particular, students earning As and Bs are likely to do well in the following, more advanced course, and should continue to pursue the major (unless, of course, they really do lose interest in the subject). Further, except for the CS1 to CS2 sequence, the majority of students earning a C+ or C go on to earn a passing grade in the following, more advanced course.

5.4.3 Grades and Intent to Major. Figure 25 shows the retention rates for women and men students accounting for intent to major in CS and grades. We observe that, generally, higher percentages of men students and higher percentages of students intending to major in CS continue on to CS2. The combined data shows that both grades and the intent to major in CS correlate with retention rates.

5.4.4 Grades and Student Attitudes. Figure 26 shows the distribution of grades for women and men students with positive and negative attitudes (see Section 5.3). Clearly, grades are highly correlated

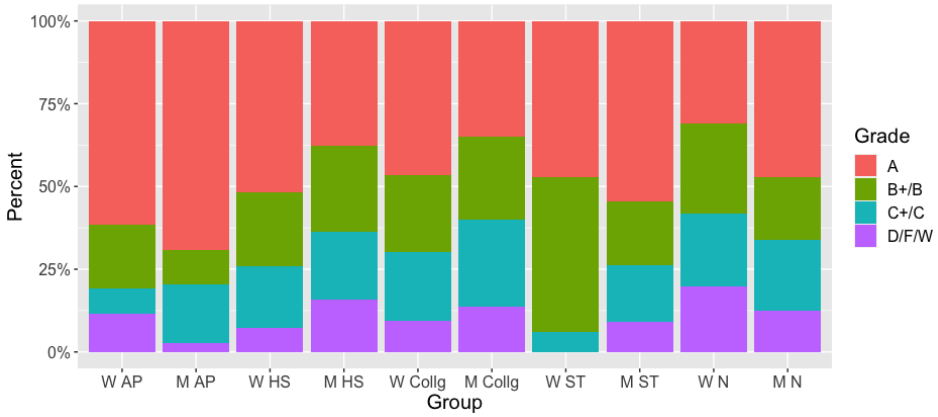

Fig. 27. CS1 grade distributions for women (W) and men (M) students with various types of prior experience. HS = High school, Collg = College, ST = Self-taught, N = None. For each type of prior experience, the difference in the grade distribution between women and men students is not statistically significant.

with positive attitudes. This fact is consistent with findings above showing that women students are less confident than men in their ability to succeed in CS and the retention rates for women students are lower compared to men students at every grade level. Other studies also suggest that, for students receiving the same grades, men are more confident in their abilities than women [36, 44].

5.4.5 Grades and Prior Experience. Previous work [3] has found that students with formal prior experience in computing obtained higher grades in college CS courses at various levels than students without prior experience. Particularly, the study found that students with AP experience obtained higher grades (by up to half a point, on average) than students without prior AP experience.

We explore this correlation by showing the distributions of grades earned by women and men students with various types of prior experience in Figure 27. This figure uses the same data as Section 5.2, that is, Introductory Survey results from Spring 2016 and Spring 2017, and grades for the survey respondents from the Registrar data set. Unfortunately, because of the small number of students in each group, the differences observed in this graph are not statistically significant. Here, we used the Fisher's exact test to determine the statistical significance of the difference between groups, due to small student counts in some of the groups.

6 CONCLUSIONS

In this paper, we have used student data from the CS department at a large public R1 research university to assess the gender gap in the undergraduate student body as they take the introductory course (CS1) for the CS major and then progress through a sequence of three additional core courses required for the major. We find that there are significant gender gaps in all four courses, with the gap increasing as students progress toward graduating with a CS major. The gender gap in our introductory course narrows between 2015 and 2017, but the narrowing stops after 2017. This trend is observed consistently in the other courses with time delays as cohorts of students progress toward the CS major (although CS4 does not yet show the flattening). We also find that the gender gaps are larger for transfer students compared to students entering as freshmen.

Given the finding of an increasing gender gap as students progress in the CS major, we proceed to explore the correlation between student retention and several factors. We find that the lower retention rates for women students compared to men correlate with at least several interrelated

factors, including proportionally lower intent to major in CS when taking CS1, less prior experience, and lower confidence. In addition, retention rates for women students are almost always lower than those for men in equivalent groups; for example, retention rates are lower for women compared to men students earning the same grades, for women students intending to major in CS compared to men, etc. Interestingly, when we compare students entering as freshmen and transfer students, the observed correlations do not always hold. For example, a higher percent of women transfer students taking CS1 intend to major in CS compared to students entering as freshmen, yet the retention rate for women transfer students is lower.

Overall, our findings are not necessarily surprising: we know that work is required on many fronts to further decrease the gender gap and, so, increase gender diversity (and, more generally, overall diversity) in CS. Our work does give concrete quantitative information from a large undergraduate CS program likely to be representative of a number of peer institutions that, together, produce a significant fraction of CS graduates in the US.

Our work also serves to inform our efforts to increase diversity in CS at the departmental, school, and university levels, as well as provide a basis for quantitative assessment of progress. In particular, a summary of our findings on retention from CS1 through CS4 include:

- A larger fraction of women compared to men students take CS1 without prior experience in CS, which is possibly related to a smaller fraction of women students intending to major in CS when taking CS1. Both factors correlate with lower retention rates for women students compared to men students.
- For students continuing to CS2 after having taken CS1, the retention rates for transfer students are lower than the retention rates for students entering as freshmen, with a larger difference for women than for men between transfer students and students entering as freshmen. These lower retention rates may be partially due to significant differences in grade distributions in CS1 for the two categories of students.
- Women students have lower levels of confidence than men students, which correlate with lower retention rates. This finding also correlates well with lower retention rates for women students compared to men students at every grade level, and possibly with the increasing difference between retention rates for women and men students after taking CS1 with decreasing grades (from A to C).
- The overall grade distribution of CS2 and the high rate of D/F/W may be contributing to the widening gender gaps from CS1 to CS4.

Informed by the quantified gender gaps and the above findings with respect to student retention, some of our efforts toward increasing diversity in our program include:

- Strategically expanding outreach and collaborative efforts with middle and high schools in our state, targeting the expansion of CS offerings and attracting more women students (and students from all underrepresented minority groups) to explore CS and take AP CS courses in high school;
- Seeking to partner with community colleges in our state to review, improve, and expand pathways for students transferring to our university to help them succeed;
- Revising CS1, CS2, and several other required courses along a number of different dimensions, including implementing mastery-based grading and adding assignments that are more clearly related to real-world challenges; and,
- Developing co-curricular programs such as peer mentoring (especially between women students) to foster confidence, community building, and improved sense of belonging.

Finally, our work suggests some future work directions:

- Explore the gender gaps for transfer students more fully, including understanding of students transferring from 2-year colleges and other 4-year colleges and universities;
- Explore the gender gaps for students taking CS courses at 2-year colleges and pathways for transferring to 4-year colleges and universities; and,
- Qualitatively understand the lower retention rates for women students to complement our quantitative findings in this paper.

As discussed in Section 2, many related efforts have or are exploring the above directions, along with many other directions. However, additional understanding at disciplinary-specific, different types of institutions, and possibly regional levels will be valuable in efforts to promote DEI in CS throughout the nation.

For those interested in carrying out a self-study as we did, a painful lesson learned is that preserving the same survey questions across time is critically important to gathering large amounts of consistent data as well as analyzing trends. As novices in conducting surveys, we felt the need to modify and improve the surveys, which was necessary but interfered with the consistency of the data gathered at various times. Fortunately, we found colleagues both inside and outside of our university that readily helped us to improve our surveys.

As already mentioned, it is our hope that other CS programs and universities will find the reported data, findings, and the self-study methodologies of use in their efforts for increasing diversity in CS.

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APPENDIX

In this appendix, we show an example of our Introductory Survey and an example of our Exit Survey. These surveys were given during the Spring 2017 semester. While surveys varied slightly among semesters, the content stayed similar. The questions we used in this paper stayed the same through all semesters for which we report student responses.

Introductory Survey

Please indicate if your basic demographic data (age, gender) and your performance on class evaluations, e.g., tests, quizzes, homework, and exams can also be used for this research. This data will also be used to determine the factors that contribute to student success and/or failure in the introductory computer science courses. Agreeing to include your demographic and performance data is voluntary; not agreeing to include your demographic and performance data will have no adverse effects on your standing in the course. If you agree that your basic demographic data and course performance data can be included in this research, please provide your consent by clicking on the "I Agree" button below. If you do not want your basic demographic data and course performance data included in this research, please click on “I Do Not Agree” button below. You will then exit this program. I agree to participate in educational research.

- I agree.
- I do NOT agree

How old will you be on December 31 of this year?

What is your gender?

- Male.
- Female.
- Other.

What is your major?

What is your graduation year?

What is your minor?

Have you declared your major yet?

- Yes.
- No.

What are your plans after graduation?

- IT Work.
- Graduate School (CS).
- Graduate School (Other).
- Non Tech related Work.
- Programmer.

From which high school did you graduate? (name and city)

How many semesters did you take a mathematics course in high school?

Have you taken any programming courses prior to this course?

- Yes.
- No.

Have you learned computer programming by yourself (as opposed to learning it in a formal class):

- Yes.
- No.

How many hours per week, on average, do you spend using the internet?

How many hours each week, on average, do you spend playing computer games?

How many hours each week, on average, do you spend using productivity software (word processing, spreadsheets, databases and/or presentation software packages)?

Have you ever received encouragement (from your family, teachers, peers, etc.) to pursue computer science?

- Yes.
- No.

What is your level of CS knowledge?

- AP Computer Science.
- Some high school classes.
- College.
- Self-learned.
- None.

Please rate your familiarity with the following programming language (0 = not known, 5 = expert):

- Basic.
- C.
- C++.
- HTML.
- Java.
- JavaScript.
- Pearl.
- Python.

Please rate your familiarity with the following technology (0 = indifferent, 5 = very passionate):

- Computers.
- Cell phones.
- Robotics.
- Electronics.
- Gadgets.

Please rate your interest in (0 = indifferent, 5 = very interested):

- Computer Science.
- Programming.

Please rate yourself in (0 = lowest, 5 = highest):

- Computer Science knowledge.
- Programming proficiency.
- Problem Solving ability.
- Mathematical ability.

What is the probability with which you will pursue additional study in Computer Science?

- 0%.
- 25%.
- 50%.
- 75%.
- 100%.

Please rate yourself (0 = very unlikely, 5 = very likely):

- How likely are you to ask/answer questions in class?
- How likely are you to ask questions during recitation?
- How likely are you to ask questions during office hours?

Please rate the following: ((0 = very easy, 5 = very difficult): How difficult do you think this class will be?

How do you usually prefer working on your homework and studying for exams?

- By myself.
- With a group.
- Both by myself and with a group.

Please rate the following: (0 = very comfortable, 5 = very anxious) How do you feel about working with computers on programming assignments?

The following questions ask how you would characterize yourself when you use computers. For each adjective listed below, please circle the qualifier that best matches a description of yourself when you interact with computers: (Strongly disagree, Disagree, Neutral, Agree, Strongly agree).

- Spontaneous.
- Conscientious.
- Unimaginative.
- Experimenting.
- Serious.
- Bored.
- Flexible.
- Mechanical.
- Creative.
- Erratic.
- Curious.
- Intellectually stagnant.
- Inquiring.
- Routine.
- Playful.
- Investigative.
- Constrained.
- Unoriginal.
- Scrutinizing.
- Uninventive.
- Inquisitive.
- Questioning.

How difficult do you think it is to write computer programs in general? ((0 = very easy, 5 = very difficult))

How often, if at all, have you participated in a special event at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in a Degree requirements information session at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in a What can I do with a major in CS session at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in a College Fair at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in an Alumni career Panel at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in a Faculty meet and greet event at your high-school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you participated in a Computing student group meeting at your high school hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

How often, if at all, have you received a personal invitation to a recruiting event at your high school hosted by Rutgers University - Computer Science?

- Never.
- Once.

- More than once.

How often, if at all, did you participate in a Computer science open house hosted by Rutgers University - Computer Science?

- Never.
- Once.
- More than once.

Please name any other events or activities that contributed to your interest in computing and indicate your level of participation.

Exit Survey

Please indicate if your basic demographic data (age, gender) and your answers for this survey can also be used for research. This data will be used to determine the factors that contribute to student success and/or failure in the introductory computer science courses. Agreeing to include your demographic and performance data is voluntary; not agreeing to include your demographic and performance data will have no adverse effects on your standing in the course. If you agree that your basic demographic data and course performance data can be included in this research, please provide your consent by clicking on the "I Agree" button below. If you do not want your basic demographic data and course performance data included in this research, please click on “I Do Not Agree” button below. I agree to participate in educational research.

- I agree.
- I do NOT agree.

If you had to declare your major today, what would it be?

Did you have a strong prior interest in computer science before taking [CS1]?

- Yes.
- No.

When deciding to take this course, what was your level of interest in computer science?

- I was considering a computer science major.
- I was considering a computer science minor.
- I was considering both a computer science major and a computer science minor.
- None of these apply to me.

How was this course compared to your expectations?

- Much more difficult than expected.
- More difficult than expected.
- Just as expected.
- Easier than expected.

Were the topics and curriculum presented in [CS1] similar to what you expected to be covered in an introductory computer science class? For example: boolean logic, Java programming, Object Oriented programming, efficiency, sorting and search.

- Yes.
- No.
- Don’t know.
- Other.

If you answered "Other" to the previous question, what was your answer to the question: “Were the topics and curriculum presented in [CS1] similar to what you expected to be covered in an introductory computer science class?”?

How do you feel about a computer science major as of today?

- More likely to major/minor in CS.
- Likely to major/minor in CS.
- Neutral about majoring/minoring in CS.
- Less likely to major/minor in CS.
- Much less likely to major/minor in CS.
- I was never interested in a computer science major.

How much do you agree with the following statement: “I feel comfortable approaching the instructor with questions.”

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

How much do you agree with the following statement: “I feel comfortable approaching the peer leader with questions.”

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

How much do you agree with the following statement: “I feel comfortable asking the tutors [...] for help.”

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.
- N/A (I never went to [the tutors]).

How much do you agree with the following statement: “I enjoy interacting with the other students in the [tutoring center].”

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.
- N/A (I never went to [the tutoring center]).

How much do you agree with the following statement: “I enjoy interacting with the other students in my section of [CS1].”

- Strongly agree.

- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.
- N/A (I never went to [the tutoring center]).

How much do you agree with the following statement: "The Autograder was a useful resource to me."

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

If I get stuck on my homework or feel confused about something I learned in class, I prefer to:

- Ask the peer leader for help.
- Ask the instructor for help.
- Ask the tutors at the CAVE.
- Ask other students in class.
- None of these.

Please indicate how often you asked the peer-leader for help:

- Once a week.
- A few times a month.
- Once a month.
- A few times a semester.
- Never.

Please indicate how often you went to the [CS1] instructor's office hours:

- Once a week.
- A few times a month.
- Once a month.
- A few times a semester.
- Never.

Please indicate how often you asked the tutors [...] for help:

- Once a week.
- A few times a month.
- Once a month.
- A few times a semester.
- Never.

Please indicate how much you agree with the following statement: "I can be successful in computer science courses."

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

Please indicate how much you agree with the following statement: "I believe that if I study hard, I can be successful in computer science."

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

Please indicate how much you agree with the following statement: "I need to work harder than other students to be successful in computer science."

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

Please indicate how much you agree with the following statement: "I feel comfortable raising my hand and asking a question in my classes."

- Strongly agree.
- Agree.
- Neither agree nor disagree.
- Disagree.
- Strongly disagree.

What did you find useful about the Autograder?

What did you find frustrating about the Autograder?

Do you have any further comments about the Autograder?