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Exploring Gender Diversity in CS at a Large Public R1 Research University*

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ABSTRACT

With the number of Computer Science (CS) jobs on the rise, there is a greater need for Computer Science graduates than ever. At the same time, most CS departments across the country are only seeing 25-30% of female 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 using three data sets that span thousands of students across 3.5 academic years. By combining these data sets, we can explore interesting issues such as retention, as students progress through the CS major. For example, we find that a large percentage of women taking the Introductory CS1 course for majors do not intend to major in CS, which contributes to a large increase in the gender gap immediately after CS1. This finding implies that a large part of the retention task is attracting these women to further explore the major. We correlate our findings with initiatives that some CS programs across the country have taken to significantly improve their gender diversity, and identify initiatives that we can start with in our effort to increase the diversity in our program. These findings may also be applicable to the computing programs at other large public research universities.

Keywords

Gender diversity; Student retention; Introduction to Computer Science.

1. INTRODUCTION

The need for computing majors in the workforce is greater than ever. The U.S department of labor estimates that only 61% of computing jobs will be filled by U.S. degree-earners in 2018 at current graduation rates [15]. Computer Science (CS) is not widely taught in middle school and high school, and colleges don't generate the number of graduates the computing workforce requires.

Over the last several years, there has been an increase in enrollments in CS departments across the country, although they are still not enough to cover the estimated number of jobs. From a diversity perspective, only about 25-30% of enrolled students are women (and even fewer are ethnic minorities) [16]. Increasing the number of women with Computer Science degrees is critical in providing needed workforce in computing. At the same time, it is important to have both men and women contribute to the creation of technology [14].

The gender gap in college has been extensively studied [22]. Sax has pointed out that it is important to study each discipline separately [23], rather than looking at all STEM disciplines together as in previous work [22], since different disciplines deal with different gender gaps. Along this line, there have also been multiple studies of the gender gap in CS [1, 14, 28]. In this work, we add to this body of knowledge using extensive data sets from Rutgers University. We believe that this data and the accompanying analyses will prove to be valuable because large departments at institutions similar to ours generate a considerable percentage of the computing workforce in the country.

Specifically, in this paper, we analyze student data from a set of four core courses 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 we give to our CS1 students 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 about the usefulness of resources that were available to them in CS1 and how likely they were to major in Computer Science before and after taking CS1 (among other information). We describe these data sets in more detail in Section 3.

Using these data sets, we answer the following research questions:

- **Gender gap and retention rates:** What is the gender gap in CS at Rutgers University? Is the gender gap growing over time? Does it persist or increase from the beginning of the major through to graduation?

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- **Factors that affect retention:** Is there a correlation between the gender gap and our students' intention to major in CS when taking CS1? Is there a correlation between our students' grades and their retention? Do women and men arrive to our program with significant differences in background in CS? If yes, does prior experience make a difference in retention? Is there a gender difference in whether or not students with the same background stay in the major?

A main contribution of our work is the combining of our three data sets to answer 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 program, and show the retention rates for men and women who take the CS1 course intending to major in CS compared to those not intending to major in CS. Additional results match current knowledge and accepted wisdom, but we provide concrete numbers from Rutgers University.

Finally, many universities across the country are making efforts to diversify their student population in computing. A few efforts [12, 14] have successfully led to classes that are more diverse, some with up to 40-50% women. We use results from our analyses to hypothesize that certain initiatives implemented by other CS departments would be effective at our university. By extension, these initiatives may also be likely to succeed at large public universities with diverse student bodies similar to ours.

We hope to implement these initiatives in the near future and measure their impacts. There are other diversity initiatives we do not address that have been successfully implemented at universities nationwide. Even though our data does not provide information about these initiatives, it does not mean they would not be effective at a university such as Rutgers. Rather, our data just does not address those areas. Thus, our intention is to start with initiatives that we hypothesize are most likely to have an impact based on available data, instead of those we have no data yet to support. Our data collection is on-going, and we hope to expand the types of data collected.

2. RELATED WORK

A number of studies [1, 28] have looked at computing students' enrollment data and analyzed gender differences in enrollment numbers and pass/fail rates in CS classes. Our work integrates data on enrollments, grades, and surveys to dig deeper and answer questions about intent to major, how many students actually change their mind about majoring, and what are our actual retention rates. Other related papers report on survey data [5, 7] or on data from interviews [6, 10, 14] and assess the female students' attitudes, motivations and confidence in computing. We use both surveys and enrollment data to link our observations on gender differences with grades.

One paper analyzes students' grades on seven projects in an introductory programming course [19] and fits these grades to a mixture model with two gaussian distributions. While this work also analyzes student data, it is mainly focused on students' grades and the analysis does 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 freshmen survey [11] provided one of the largest such databases. Their data has been extensively analyzed [22] and has answered questions on how men and women attending college are different in terms of background, achievement, perceptions of their environment, etc. Our work focuses on gender differences in Computer Science specifically.

Previous work has also addressed the issue of low female representation in STEM disciplines [25], 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 [2, 3, 5, 6, 10, 14] and strategies to close the gender gap have been proposed [1, 4, 7, 8, 13, 17, 21, 24].

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 class to include more real-life applications [9, 12], offering learning opportunities to students who did not have prior experience [26, 12], providing research projects for undergraduate female students [26, 12], building a solid community of women in computing [12, 14], engaging faculty in recruitment [26] and training them on how to design engaging classes [9], increasing the diversity of the faculty [26], and reaching out to middle schools and high-schools [26, 9].

3. METHODOLOGY

This research was conducted at Rutgers, the State University of New Jersey. Our student body is made up of more than $67,000$ students from all 50 states and more than 100 countries. The percentage of women is about 50%, and the percentage of students who self-identify as non-white is also about 50%.

To answer diversity questions about our CS students, we use three data sets. All the data is anonymized, but allows entries to be linked together between data sets by anonymized student ids.

The first data set focuses on student demographics (gender, graduation year, and ethnicity) and grades. We call this data set the Registrar data. It allows us to track students taking a sequence of four classes as they make their way through the CS major. These classes broadly cover foundational CS concepts, including Introduction to Programming (CS1), Data Structures (CS2), Computer Architecture (CS3), and Algorithms (CS4). All four are required for the undergraduate CS major. The first three classes, CS1, CS2, and CS3, form a direct sequence, with CS3 requiring CS2 as a prerequisite, and CS2 requiring CS1. The 4th class, CS4, requires CS2 as a prerequisite, and so may not always be taken after CS3. However, it is the highest level class required for the major, and the vast majority of our students delay 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.

The Registrar data contains all the students who took any of these classes during the semesters between Fall 2012 and Fall 2015 ($n = 8,078$) and, therefore, all the students in the other two data sets.

The second data set, the Introductory Survey, comes from surveys taken at the beginning of CS1 in each of the following semesters: Fall 2012, Spring 2013, Fall 2013, Spring

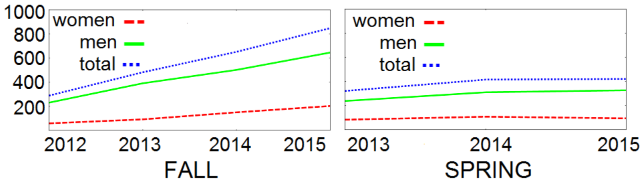

Figure 1: Enrollments in CS1 for the last 4 years (for Fall and Spring semesters)

2014, and Fall 2015. Each survey asks students about demographic information (age and gender), what is the students' tentative or declared major, what kind of prior programming experience they have (with the options: high-school advanced placement, self-taught, other college course, and none), and what is the probability they will continue in CS (with options 0%, 25%, 50%, 75%, and 100%). This data set contains answers from a subset of students taking the introductory class CS1 ($n = 1,831$).

The third data set, the Exit Survey, comes from a survey taken at the end of our CS1 class during the Fall 2015 semester ($n = 592$). It asks students how likely they were to major in CS before and after taking the class, how many lectures they attended, how many hours per week they spent on the class on average, how often they used the resources offered, 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 above data sets complement each other to give a more comprehensive picture of who our students are, what are their backgrounds, what classes they take, and how the CS1 class impacts them. When analyzing our data, we use the chi-square test for statistical significance to detect significant differences between groups. In the remaining of the paper, we always explicitly point out whenever we talk about differences that are not statistically significant. All other differences discussed are statistically significant.

4. RESULTS

In this section we analyze our data sets to answer questions about the gender gap in our department, retention rates, and factors that may affect retention.

4.1 Gender Gap and Retention

We begin with answering the most basic question: is there a gender gap is our CS classes? Figure 1 shows our enrollments in CS1 over time. Table 1 shows the percentages of men and women in CS1 through CS4. Both are derived from the Registrar data. Clearly, there is a significant gender gap that is close to national averages [16].

The data also answers three additional important questions. First, is our gender gap growing over time, especially with the recent rapid rise in enrollment? Encouragingly, Figure 1 shows that, although the gap is not narrowing, it is also not growing. This is in contrast to findings reported for the last boom in CS enrollment, where the percentage of women entering college interested in the CS major rose much slower compared to the percentage of men as enrollments increased rapidly during the boom [20].

Second, is the gender gap growing as students progress toward graduation? We can see that the gender gap does indeed grow as students move toward graduation, starting

Table 1: Gender distribution by course

	Female	**Male**
CS1	783 (22.85%)	2643 (77.15%)
CS2	341 (17.02%)	1663 (82.98%)
CS3	192 (15.64%)	1036 (84.36%)
CS4	139 (15.03%)	786 (84.97%)

with about 23% female students in CS1 and dropping to about 15% in CS4.

Finally, when do women drop out of the CS undergraduate program? The only statistically significant drop in women participation is between CS1 and CS2. After CS2, there is a slight but noticeable drop in the percentage of female students between CS2 and CS3. While this difference bears watching and reanalysis as we gather more data, it is currently not statistically significant. The drop between CS3 and CS4 is smaller, and also not statistically significant. We conclude that most women drop out after taking CS1, although there may be a trend of further smaller losses as students progress toward graduation. This observation matches conventional wisdom, but our data provides concrete evidence for this accepted fact.

4.2 Factors that Affect Retention

Given the significant gender gap in our classes, and the fact that it grows as students progress in the major, we now explore a number of factors that may be influencing the observed retention rates.

4.2.1 Intention to Major in CS

We start with an important but unexpected question: is there a difference in the level of interest for majoring in CS between the men and women taking CS1? We did not expect this question to be a factor when we began this study because our CS1 class is intended for CS majors and has a reputation for being difficult; we have several non-major courses with very large annual enrollments. However, we did ask our students about their intended major in our Introductory Survey for completeness.

Specifically, the survey included two questions, with the first asking what is the students' intended or declared major and the second asking students to estimate the subjective probability (in quartiles) they will continue in Computer Science. A student is considered as intending to major in CS if he/she has either answered "Computer Science" to the first question or $\geq 75\%$ to the second question or both. This criterion offers the broadest interpretation for intention to major in CS.

Using the above formula, we find that only about 55% of the female students in CS1 intended to major in CS before taking the class compared to about 79% of the male students. Both of these numbers were surprising to us![1] Tables 2 through 5, derived by correlating the Introductory Survey data and the Registrar data, show the impact of these numbers.

The numbers in Tables 2 and 3 include students from Fall 2012 through Spring 2014, while those in Tables 4 and 5

[1] In retrospect, perhaps we should not have been surprised. CS1 can be used to meet parts of the School of Arts and Sciences's goal-based Core Curriculum, which is required for all students regardless of major. Many students seem to be taking the more rigorous CS1 course rather than the non-major courses toward this purpose.

include only students from the Fall 2012 and Spring 2013 semesters (since students need a longer length of time to get to CS4).

Table 2: CS1 students who intend to major in CS

	Do not take CS2	**Do take CS2**
Female	48 (47.52%)	53 (52.48%)
Male	189 (35.26%)	347 (64.74%)

Table 3: CS1 students who do not intend to major in CS

	Do not take CS2	**Do take CS2**
Female	82 (67.77%)	39 (32.23%)
Male	105 (66.46%)	53 (33.54%)

Table 4: CS1 students who intend to major in CS

	Do not take CS4	**Do take CS4**
Female	33 (63.46%)	19 (36.54%)
Male	143 (58.37%)	102 (41.63%)

Clearly, in terms of progressing from CS1 to CS2, the percentages are higher for students who intend to major in CS than for students who do not intend to major in CS. When this fact is coupled with the high percentage of women taking CS1 but not intending to major in CS, we find a possible major factor for the loss of women from CS1 to CS2. *The gender gap between interest in the CS major is larger than the gap between men and women taking CS1.* That is, many women 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 often lose interest in CS before they reach college level. Yet, it also points to an opportunity: if we can (re)kindle interest for the CS major in these women who choose to take CS1, we have a chance to avoid the current loss of women after CS1.

Interestingly, Table 3 shows that a non-trivial percentage (32.23%) of women 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 not all women not intending to major in CS are lost immediately following CS1. We currently do not know whether the students are taking CS2 because they became interested in the CS major or for other reasons. We plan to survey CS2 students in the near future. Unfortunately, Table 5 shows that by CS4, most of the women have chosen to not continue with the major. This implies that there is work to be done in classes beyond CS1.

In addition, Table 2 shows that a significantly higher percentage of women intending to major in CS leave the major after CS1 than men.

Finally, Tables 4 and 5 show that the percentages of men taking CS1 persisting to CS4 are higher than those of women, for both populations of students intending and not intending to major in CS. These differences are currently not statistically significant because the necessity for following students through multiple years limited us to studying the smaller subset of data from just two semesters. We will continue to monitor these percentages as more data become available over time. Our numbers mirror those reported at the national level [18], which indicate Computer Science retention rates of around 40%.

Table 5: CS1 students who do not intend to major in CS

	Do not take CS4	**Do take CS4**
Female	37 (94.87%)	2 (5.13%)
Male	71 (87.65%)	10 (12.35%)

Table 6: Prior experience by Gender

Prior experience	**Female**	**Male**
High-school AP	22.35%	20.14%
Self-taught	14.6%	25.39%
Other college course	27.88%	26.62%
None	35.18%	27.85%

4.2.2 Prior Experience

Does prior experience with computing affect retention? Table 6 shows the percentages of men and women with different types of computing experience coming into our CS1 class. Table 7 shows the rates of men and women proceeding to CS2, broken out by the types of computing experience they have before taking CS1.

The most striking difference in Table 6 is that for self-taught students: about 15% for women vs. greater than 25% for men. This is consistent with the known fact that men are more likely to explore computers and computing before college than women [14], but our data provides concrete numbers for a large population of students at Rutgers University. Interestingly, higher percentages of women took high school AP CS or a college course than men. While statistically significant, these differences are small.

Table 7 shows that prior experience from high school AP CS or students having taught themselves programming, correlate positively with students continuing to CS2, with almost 68% of the students in CS1 who have CS AP experience and almost 62% of the self-taught students going on to take CS2. When we break down these percentages by gender, we find that there is no significant gender difference in the rates with which the students with AP experience continue taking CS2. For self-taught students and students with no prior experience, male students are significantly more likely to take CS2 than female students. These findings point to the potential importance of the high-school AP experience for women retention, and prior experience for all students. It also points to the potential importance of better addressing the needs of students without prior experience in CS1. We discuss this further in Section 5.

4.2.3 Grades

How do grades correlate with our CS1 students' decision

Table 7: Continuation rates to CS2 by Prior Experience

Prior experience	**Do not continue**	**Continue**
High-school AP	32.37%	67.63%
Self-taught	38.32%	61.68%
Other college course	52.72%	47.28%
None	53.98%	46.02%

Table 8: Continuation rates by Gender by CS1 Grades

CS1 Grade = A

	Do not take CS2	**Do take CS2**
Female	51 (38.06%)	83 (61.94%)
Male	148 (26.76%)	405 (73.24%)

CS1 Grade = B/B+

	Do not take CS2	**Do take CS2**
Female	89 (45.41%)	107 (54.59%)
Male	232 (35.15%)	428 (64.85%)

CS1 Grade = C/C+

	Do not take CS2	**Do take CS2**
Female	86 (72.88%)	32 (27.12%)
Male	185 (58.54%)	131 (41.46%)

to take CS2? We use our Registrar data and divide the students into groups by the grades they received in CS1. For each group, we look at how many of our students end up taking CS2 and find that for a given grade in CS1, men are more likely than women to take CS2 (Table 8). This finding suggests that there might be other factors that affect women's decision to leave the major. But are grades correlated at all with our female students' decision to stay or leave? If we split our students into groups by gender, we see that, for each gender group, students who get higher grades in CS1 are more likely to continue than students with lower grades. From Table 8, we see, for example, that almost 62% of the women who earned an A in CS1 went on to take CS2. The percentage decreases to around 55% for women who got a B or a B+ in CS1, and 27% for women who got a C or a C+. Therefore, grades do seem to have a positive correlation with the women's decision to continue in the major.

To better understand the correlation between grades and our students' decision to major, we use our Exit Survey data to identify students who change their minds about majoring in Computer Science after taking CS1. More specifically, we use the students' responses to two of the questions from our Exit Survey ("How likely were you to major in CS before taking this class?" and "How likely are you to major in CS after taking this class", both using a 5 level Likert scale) and their grades from the Registrar data. For men, we find a significant difference in grades between students who change their minds and students who do not change their minds about majoring. For women, the difference in grades between the two groups is not statistically significant. Thus our data shows a correlation between grades and students changing their intentions to major in CS for male students but not female students. This is an interesting contrast to the correlation between grades and actual continuation shown in our Registrar data.

5. IMPLICATION OF OUR RESULTS

In this section, we correlate our results with initiatives that other universities have successfully used to increase the gender diversity of their computing student body. Specifically, we hypothesize, based on our findings, that the following initiatives would be important and effective at our university, and, by extension, potentially at any large public research university.

First, our data shows that we should both recruit and retain more women (Section 4.1). The following initiatives have been suggested to address these areas [4].

Send a welcoming letter to prospective students. Carnegie Mellon has implemented this recruitment strategy to help increase the enrollment of women in their computing department. By sending a welcoming letter and promotional materials to prospective students, we believe that recruitment of women and underrepresented minorities could increase significantly.

Offer students, especially female students, a summer of research between the freshmen and sophomore years. This strategy has been implemented by multiple universities and it has been linked with increased retention rates [27]. Rutgers has strong programs for involving junior and senior undergraduate students in research. We believe that an organized effort to involve students in research early on in their studies may make a significant difference in the retention of our female students.

Second, our data shows that some prior programming experience correlates positively with our CS1 students continuing to CS2 (Section 4.2.2). The following initiatives provide some experience to students who do not have a computer science background.

Offer multiple points of entry to the major. Harvey Mudd College has split their Computer Science classroom into sections based on the students' prior experience. By offering a different section to students with no prior experience, we can provide that experience before students take classes with peers who already have advanced computing knowledge. Also, research has shown that women are intimidated by their classmates who seem to already know a lot [14] and a separate class for less experienced students could bridge the knowledge gap between the two groups.

Invest in AP CS teachers. Carnegie Mellon organized a two-week workshop to train AP CS high-school teachers both in the course material and in raising awareness about the gender gap in computing [14]. Our department is already engaged in this effort and will continue to do so.

The following initiative has been suggested both to improve the recruitment and retention of female students and to provide some prior experience in computing.

Reach out to middle schools and high-schools. Part of Georgia Tech's Georgia Computes! program were a few initiatives to attract middle and high school students by organizing summer camps and after school programs. Our department already has some outreach activities, but we intend to redouble our efforts.

6. CONCLUSIONS

In this paper we have used student data from the CS department at Rutgers University to analyze the gender gap in computing, where in the program we lose or fail to attract most of the women and looked at how intention to major, prior computing experience, and grades in CS1 affect retention rates. We related our data with existing diversity initiatives to suggest where a department could start if they were to invest into increasing the diversity of their computing student population.

It is our hope that departments can use our data and/or methodologies to launch and publish similar initiatives and to efficiently and effectively implement changes that will have the greatest positive impact on diversity.

7. ACKNOWLEDGMENTS

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