Examining the Enrollment Growth: Non-CS Majors in CS1 Courses

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ABSTRACT
As enrollments in computer science (CS) undergraduate programs are booming, CS departments are struggling to accommodate more students while also seeking to bring more women and underrepresented minority (URM) students into the field. A particular burden has been placed on introductory CS (i.e., CS1) courses to navigate these important, but sometimes competing, realities. As CS departments employ strategies to manage growing enrollments and recruit more diverse students into their CS1 courses, administrators and faculty will benefit from knowing more about the students who take these courses and how they may differ based on their major (CS majors and non-majors), gender, and race/ethnicity. This paper presents findings from a national study of CS1 courses and discusses key differences in introductory course students' demographic and background characteristics and pre-course experiences across these groups.

Keywords
CS1; Non-majors; Gender; Race/ethnicity

1. INTRODUCTION
Burgeoning enrollments in introductory computer science (CS) courses have become a primary focus for the computer science community. Data from the most recent Taulbee Survey indicate that the number of new undergraduate computing majors has increased for the eighth consecutive year; further, computer science departments in the United States reported a 24.1% increase in new majors from 2014 to 2015 [17]. This "boom" is also reflected in computer science degree attainment, as Taulbee data reveal that the number of bachelor of science degrees granted in computer science and computing engineering has been growing steadily over the past six years (from a recent low of fewer than 10,000 degrees in 2010 to more than 20,000 degrees in 2016) at Ph.D.-granting institutions [17]. At the same time, an increasing number of non-CS majors are enrolling in introductory CS courses, as well as more advanced computing courses [4].

Computing departments have been struggling to accommodate this increasing interest in computing majors and courses by introducing or expanding introductory computer science (i.e., CS1) courses [4]. With this increase, departments are now faced with difficult decisions about whether they should increase class sizes, hire more faculty and/or teaching assistant to expand the number of course sections, implement differential tuition, or even turn away interested students [4].

These decisions have important implications for efforts to diversify the computing field, as some enrollment management strategies, such as larger classes, may negatively and differentially affect women and students of color [4, 7]. Scholars and administrators are justified in their concern, given that during previous periods of expansion, the computing field has tended to become more homogenous, and the gender gap has widened. In fact, a recent study of women's interest in computer science across time found that in 1990, at the beginning of the "dot-com boom," 3.3% of entering male college students and 1.5% of entering female college students indicated plans to major in computer science [14]. However, by 2000, 9.3% of incoming college men planned to major in CS, while only 1.9% of women did. After interest in the computing fields receded, the gender gap remained (e.g., Sax et al. [14] and colleagues report that by 2011, 3.3% of incoming male students planned to major in CS, but only .4% of women did). Women's and URM students' participation in the field continues to be a pressing concern, as women earn about 18% of all CS degrees [9], and URM students, including Black or African American, Latino/a, and Native American students, earn around 19% of all CS degrees [11].

As departments seek to manage increasing enrollments in CS courses, as well as continue to attract and retain diverse students to the field, scholars and administrators have focused on students' experiences in the introductory CS course. In fact, students' initial experiences in these first CS courses are pivotal, as they have been linked to students' intent to major [2] and persist in CS [15]. Further, CS1 courses serve a key role in recruiting and retaining diverse students to the field [12]. To that end, many computer science departments have implemented changes to their introductory courses [8, 12, 13] as a way to welcome more women and allow for a more gradual introduction to computing [8].

A great deal of research has focused on efforts to improve CS1 courses [2, 8, 12, 13, 15], but less attention has been paid to the students who enroll in them. Further, most research on students in computing has been devoted to understanding the experiences and characteristics of students majoring in CS. While many of the students who enroll in CS1 courses are or will become CS majors, part of the increasing enrollments in CS1 courses can be attributed to non-majors [4]. The few studies that have examined the characteristics of majors and non-majors in computing courses suggest that female students enrolled in a CS course are less likely than their male counterparts to express interest in taking another CS course [2] and that female CS majors have less confidence in their computer skills than do male *non*-CS majors, even after controlling for ACT scores [3]. Hence, there are key differences in the way students who are majors and non-majors experience computing courses, particularly when these differences are further examined by gender.

As CS departments strategize ways to balance increasing enrollments with diversity imperatives, scholars, administrators, and faculty will benefit from understanding the characteristics of

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the students who enroll in their CS1 courses and how these students may differ based on their intention to major in CS, gender, and race/ethnicity. Further, departments may be more successful in efforts to retain students who take the introductory CS course in a computing major if they understand why students enroll in introductory CS classes in the first place, as research has shown a strong association between students who enroll in an introductory programming class because of an interest in studying computing and plans to major in computing [5].

2. PURPOSE

As discussed above, there is limited knowledge about the characteristics of students who enroll in introductory CS courses. Further, much of the research on students in introductory CS courses is limited by relying on data from a single-institution [2, 3, 6, 16]. Such studies provide important experiences of students in local contexts but cannot provide a national perspective on the characteristics of students who enroll in computing courses. At a time when enrollments are rapidly growing, it is crucial to understand the types of students who take introductory CS courses, particularly those who are taking these courses but do *not* plan to earn a computing degree. Further, given that in previous periods of rapid expansion, computing has become less diverse, computer science faculty and administrators will benefit from understanding differences between women and men and majority and URM students in their introductory CS courses.

This paper presents preliminary findings from a nationwide study of 15 computer science departments across the U.S. that are engaged in efforts to increase the percentage of women and students of color majoring in computer science. This initiative, established in 2014, is known as BRAID (Building, Recruiting, and Inclusion for Diversity). This paper will explore the background and demographic characteristics and pre-course experiences of students who enrolled in an introductory CS course at participating BRAID institutions in the fall of 2015. Further, this paper will discuss differences between students who are CS majors and non-majors, women and men, and majority and URM students. Therefore, the questions guiding this study are:

1) What are the background and demographic characteristics and pre-course experiences of students enrolled in introductory CS courses?

2) How do these characteristics differ between CS majors and non-majors, women and men, and majority and URM students?

3. DATA and METHODS

3.1 Data Source and Sample

The data for this study were drawn from UCLA BRAID research team's student surveys administered as part of a national study of computer science departments and their efforts to diversify their undergraduate majors. Specifically, the data for this study include student responses to pre-test surveys for the 6,498 students enrolled in introductory CS courses at 9 of the participating BRAID institutions[1] during the fall of 2015. The instruments were developed by the BRAID research team in consultation with the staff of the Computing Research Association's (CRA) Center for Evaluating the Research Pipeline (CERP). The surveys focus on students' experiences in their introductory computing course, but also ask about students' background and demographic characteristics, their general experiences with and views of computing, and their major, degree, and career aspirations. Students are incentivized to complete the surveys in two ways: 1) the first 400 students to complete the survey received a $15 electronic Amazon gift-card and 2) all participants were entered into a drawing to receive one of two $125 electronic Amazon gift-cards. In the fall of 2015, a total of 6,498 students enrolled in an introductory computer science course at the participating institutions, and 2,228 students responded to the pre-test, resulting in a 34% response rate.

3.2 Data Analysis

The research team examined frequency distributions and cross-tabulations on survey items relating to students' Demographic and Background Characteristics (e.g., gender, race/ethnicity, and parents' careers) and Pre-Course Experiences (e.g., class standing, major, prior computing experiences, and reasons for enrolling in the course). Additionally, crosstabulations were run to compare the responses of CS majors to non-CS majors, as well as to compare differences between men and woman and majority and URM differences. Z-tests were run to determine if differences found were significant (p=.05); the research team employed the Bonferroni correction to adjust p-values for alpha inflation.

4. RESULTS and DISCUSSION

4.1 Demographic and Background Characteristics

4.1.1 Gender

While women earn only 16% of computing bachelor's degrees awarded at participating institutions, they represent a much larger share of students enrolled in introductory CS courses (32.9%). There is an even greater representation of women among *non*-CS majors taking introductory courses (47.3% female) than among those who are CS majors (24.0% female).

4.1.2 Race/Ethnicity

Nearly half (48%) of students in introductory CS courses are White/Caucasian, followed by 22% Asian/Asian American, 7% Black/African American, 11% Hispanic/Latino, 9% Multiracial, and 3% Other. Racial/ethnic diversity is greater among female students taking CS relative to their male counterparts, with women more likely than men to be Asian/Asian American or Black/African American (see Table 1).

Table 1. Racial/Ethnic Distribution in Introductory CS Courses, by Gender

Racial/Ethnic Group	% Among Women	% Among Men
White	44.1	50.3
Asian/Asian American	24.5	20.9
Black/African American	8.6	6.3
Hispanic or Latino/a	9.8	11.2
Two or more race/ethnicity	9.8	8.5
Indigenous	0.7	0.6
Other	2.5	2.2

[1] All 15 BRAID institutions are currently participating in the introductory course survey administrations. However, in the fall of 2015, some institutions were still securing local IRB approval, so 9 institutions were included in that administration.

4.1.3 Parents' careers

The vast majority of students in introductory CS classes report that their parents work in non-computing careers, however as many as 23% of women and 20% of men report that at least one parent has a computing or technology career (programmer, systems analyst, computing teacher, etc.). These figures are about tenfold greater than the percentage of college students across all majors who have a parent who is a computer programmer [5], though admittedly the latter is a more narrowly-defined category.

4.2 Pre-Course Experiences

4.2.1 Major and Class Standing

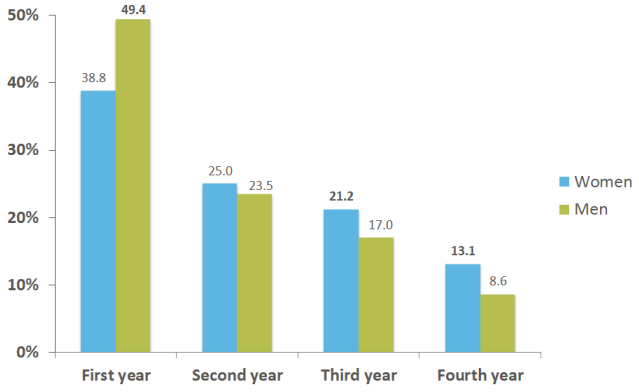
While the majority of students enrolled in introductory CS courses are computing majors, this varies significantly by gender. A full three-quarters (74.6%) of male students in these classes are computing majors, compared to only half of the women (50.9%). In these classes, women and men are equally likely to represent majors in engineering, business, and the physical sciences, but women are more likely than men to report majors in math (12.6% of women vs. 6.5% of men), biological sciences (8.0% of women vs. 2.7% of men), social sciences (8.0% of women vs. 2.9% in men), and humanities (4.9% of women vs. 1.6% of men). Thus, women enrolled in introductory CS represent a broader range of major fields than do the men (see Table 2).

Table 2. Major Field of Introductory CS Students, by Gender

Major Field	% Women	% Men
Computing	50.9	**74.6**
Math	**12.6**	6.5
Engineering	8.5	7.2
Biology	**8.0**	2.7
Social Science	**8.0**	2.9
Humanities	**4.9**	1.6
Business	4.6	3.3
Other	**3.1**	1.1
Physical Science	1.6	2.0
Education	0.7	0.3
Health	**0.7**	0.1
Undecided	4.9	3.2

Note: Percentages in bold are significantly higher at p<.05. Percentages add to more than 100 since some students are double majors.

In terms of class standing, introductory CS courses attract students from all years, though the majority are in their first or second year of college. Some gender differences exist, with men more likely than women to take introductory CS in their first year of college (49.4% of men vs. 38.8% of women) (see Figure 1). However, this is largely attributable to the fact that women in introductory CS courses are less likely to be CS majors (who tend to take the course earlier in their college career). Still even when accounting for whether students are CS or non-CS majors, men are more likely than women to take the introductory course in their first year (see Figures 2 and 3).



Note: Percentages in bold are significantly higher at p<.05.

Figure 1. Introductory CS Course Students' Class Standing, by Gender.

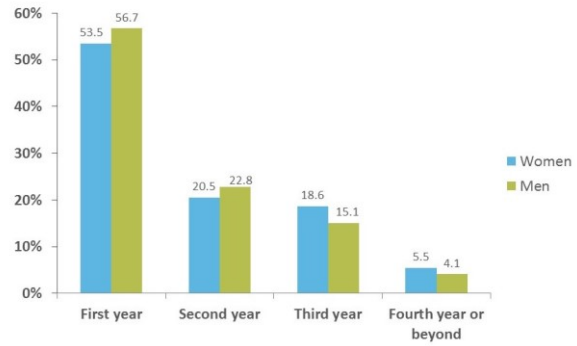


Figure 2. Class Standing in Introductory CS Courses, Computing Majors by Gender.

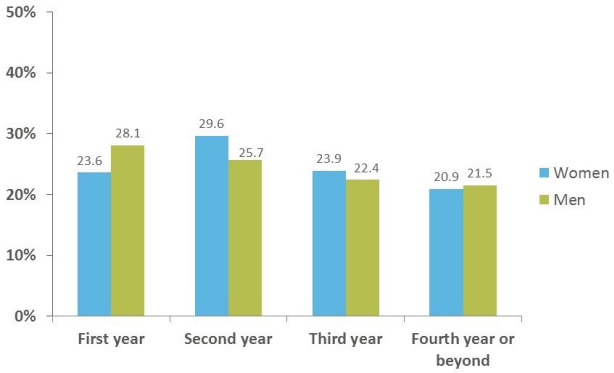
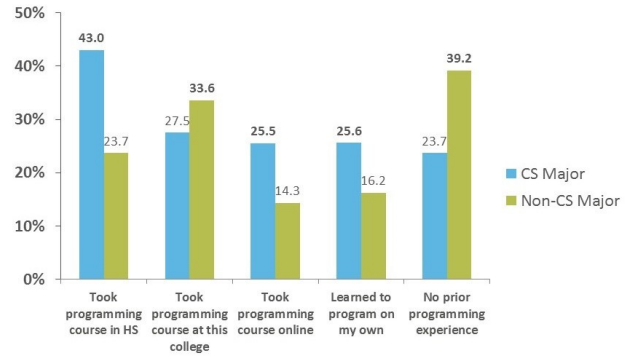


Figure 3. Class Standing in Introductory CS Courses, Non-Computing Majors by Gender.

4.2.2 Prior computing experiences

Students in introductory CS come from a wide range of computing backgrounds. This variation is most notable when comparing CS and non-CS majors (see Figure 4). Specifically, among introductory course students, CS majors were significantly more likely than non-CS majors to have taken a computer programming course in high school (43.0% of CS majors vs. 23.7% of non-CS majors), to have taken a computer programming course online (25.5% of CS majors vs. 14.3% of non-CS majors) or to have *not* taken a programming course but learned how to program on their own (25.6% of CS majors vs. 16.2% of non-CS majors). Non-CS majors were significantly more likely than CS majors to report that they did not have any programming

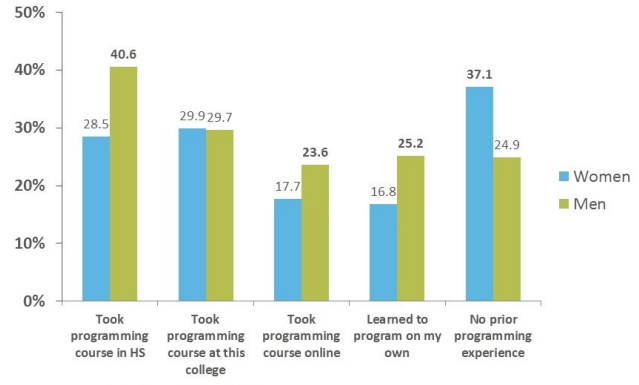
experience prior to this course (39.2% of non-CS majors vs. 23.7% of CS majors). The non-CS majors were also more likely to have taken a prior computer programming course at their respective institution (33.6% of non-CS majors vs. 27.5% of CS majors). This latter finding reflects the fact that non-CS majors tend take introductory CS later in their college careers (as discussed earlier), but also remind us that, for many students, an introductory computer science class does not actually serve as their first computing course.



Note: Percentages in bold are significantly higher at p<.05.

Figure 4. Introductory CS Course Students' Programming Experiences, by Major.

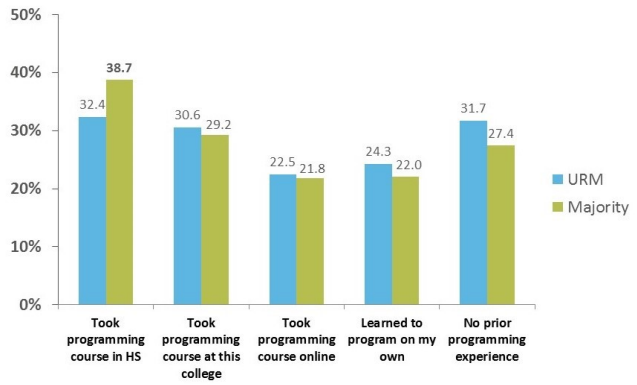
Prior computing experiences also vary by gender (see Figure 5), with women in introductory CS courses significantly less likely than the men to have taken a computer programming course in high school (40.6% of men vs. 28.5% of women), to have taken a programming course online (23.6% of men vs. 17.7% of women), or to have learned to program on their own without having taken a course (25.2% of men vs. 16.8% of women). By contrast, women were significantly more likely than men to have no prior programming experience (37.1% of women vs. 24.9% of men).



Note: Percentages in bold are significantly higher at p<.05.

Figure 5. Introductory CS Course Students' Programming Experiences, by Gender.

Differences in prior programming experience were less evident between Majority and URM students (see Figure 6), with one exception: Majority students were significantly more likely to have taken a computer programming course in high school (38.7% of Majority vs. 32.4% of URMs), though this gap is far smaller than was observed between women and men.

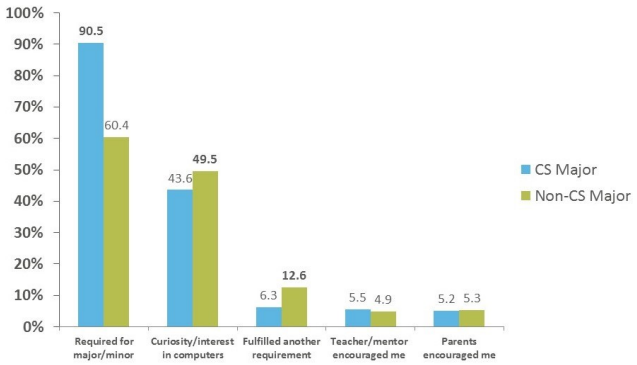


Note: Percentages in bold are significantly higher at p<.05.

Figure 6. Introductory CS Course Students' Programming Experiences, by URM Status.

4.2.3 Reason for course enrollment

Students in introductory CS courses provide a range of reasons for enrolling in the class, with the most common reason being that it was required for their major or minor (see Figure 7). Naturally, this response was significantly more common among CS majors (90.5%) than non-CS majors (60.4%). In addition, about half of students (43.6% of CS majors vs. 49.5% of non-CS majors) report taking the introductory class because of their curiosity or interest in computers. Students were less likely to take the class because it fulfilled another requirement (6.4% of CS majors vs. 12.6% of non-CS majors), and approximately 5% of CS and non-CS majors report taking the class because they were encouraged by a teacher, mentor or their parents.



Note: Percentages in bold are significantly higher at p<.05.

Figure 7. Introductory CS Course Students' Reason to Enroll, by Major.

5. IMPLICATIONS and DISCUSSION

This study highlights a number of key characteristics of students enrolled in introductory CS courses. One important theme across the findings is that non-majors who enroll in introductory courses are more likely to be women and to be upper class students (i.e., third or fourth year and beyond) than are computing majors in those courses. Given that results from this study demonstrate that many non-majors enrolled in introductory CS courses are women. CS departments can leverage CS1 courses to recruit more women into the major, as suggested by leading scholars and computing organizations [8, 10]. Even though results show that many of these women are in their third or fourth years and may not have the time or interest to complete a CS major, they could be recruited into a computing minor or certificate program. Additionally, findings from this study suggest that the non-CS

major women who are taking introductory CS courses come from diverse fields including math, biology, the social sciences, and the humanities. Hence, one strategy that may be effective for CS departments as they seek to balance enrollments and diversify their major is to work with other departments across campus to create interdisciplinary programs. Future research should examine students who take introductory CS courses during their junior and senior years to better understand their reasons for enrolling and how they utilize the knowledge gained in these courses.

The findings from this study reveal that while most of the students enrolled in CS1 courses are taking the class because it is a major/minor requirement, approximately half of the students, both majors and non-majors, are enrolled in the course because they find the topic interesting. This finding is encouraging, as previous research on introductory programming course students has shown a link between interest in studying computing and ultimately majoring in computing [5]. Thus, as CS departments seek to sustain the booming interest in computing, they grow not only their departments, but the field at large.

Finally, this study provides important information about students' computing backgrounds prior to taking an introductory CS course. While many students enter the course with some programming experience, there is still a sizeable population, particularly among women and URM students, who have no prior experience. This finding supports the idea that introductory course students may benefit from differing levels of support based on their level of experience. Many institutions, such as Harvey Mudd College, have found success in offering different sections of the introductory CS course based on students' prior exposure to programming [1]. As institutions are adding additional sections of introductory courses to accommodate growing enrollments, this may be one strategy for offering support to underrepresented students.

Because data from this study only utilized pre-test data and only from 9 of the 15 BRAID institutions, plans for future research include analyzing survey responses for all students responding to the pre-test, post-test, or both between 2015 and 2016. Although the data were derived from a national sample of participating institutions, findings should not be interpreted as representative of all types of institutions and CS departments. Thus, future research should continue to investigate characteristics and experiences of introductory course students, particularly how they may differ by major, gender, and race/ethnicity, so that CS departments can design courses and employ teaching strategies that allow them to make space for more students while maintaining their commitments to diversity.

6. ACKNOWLEDGMENTS

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