Who Takes Intro Computing? Examining the Degree Plans of Introductory Computing Students in Light of Booming Enrollments

Linda J. Sax
Department of Education
UCLA
Los Angeles, CA, USA
lsax@ucla.edu

Jennifer M. Blaney
Department of School Psychology and Educational Leadership
Idaho State University
Pocatello, ID, USA
jenniferblaney@isu.edu

Christina Zavala
Department of Education
UCLA
Los Angeles, CA, USA
zavalac@ucla.edu

Kaitlin N. S. Newhouse
Department of Education
UCLA
Los Angeles, CA, USA
k.newhouse@ucla.edu

***Abstract*—This article examines the major and minor degree intentions of undergraduates enrolled in introductory computing courses. Focusing on three primary groups (computing majors, non-computing majors, and undecided majors) we examine specific major choices, double major combinations, and minors. Further, we examine the degree intentions of women and underrepresented racially minoritized students compared to their male and majority counterparts. Findings reveal wide variation in the degree plans of intro students and that degree intentions vary by gender and race/ethnicity in several ways.**

Keywords—Computer science education, CS1, broadening participation, booming enrollments, degree intentions

I. Introduction

The enrollment boom in undergraduate computing has received significant attention in recent years, with reports from prominent organizations—including the Computing Research Association (CRA) [1] and the National Academies of Sciences, Engineering and Medicine (NAS) [2]—addressing the urgency of understanding and responding to growing demand for computing courses. In fact, computing departments in the United States have experienced record growth in the last decade; the 2017-2018 academic year alone witnessed a 13.3% increase in undergraduate computer science majors from the prior year [3]. Recent research reveals that this enrollment boom has had a particularly significant impact on the size and composition of introductory (or intro) computing courses [1].

In light of the surging interest and enrollments in computing, reasonable concerns remain about the representation of women and underrepresented racially minoritized[1] (URM) students pursuing computing courses and majors. This is in part because previous surges in computing enrollments have typically resulted in decreases in the representation of women (even when their overall numbers have risen) [5]. Yet, in this current enrollment surge, the percentage of both women and URM students has increased modestly [3, 5]. However, introductory computing courses have been diversifying much more quickly than the computing major. For example, from 2010 to 2015, the median percentages of Black, Latinx, and Native students who were non-computing majors in intro computing courses increased 43% relative to only a 9% increase in the median percentage of Black, Latinx, and Native students enrolled as computing majors [1]. Despite their increased participation in computing courses, both women and URM students remain underrepresented in computing degree attainment. In 2016, women earned 57.2% of all bachelor's degrees, but only 18.7% of bachelor's degrees in computing, while students from Black, Latinx, and Native groups collectively earned 23.1% of all bachelor's degrees in 2016 but were just 19.7% of computing bachelor's degree recipients [5].

Given changes in the composition of intro course enrollments, particularly among non-computing majors whose representation in intro courses has increased 177% between 2005-2010 [1], growing attention has been given to the nature and function of these courses. For example, scholars have recently focused on the interdisciplinary nature of computing itself and some suggest that making interdisciplinary applications more explicit may serve to attract more women and URM students to computing [6, 7, 8]. More broadly, being mindful of the needs of women and URM students in intro courses is particularly important given the possibility that efforts to manage surging enrollments (e.g., capping enrollments in popular courses or raising minimum requirements) run the risk of undermining the goal of diversifying computing [1].

While recent reports have provided insight into the changing composition of intro computing students, little is

[1] We use the term "underrepresented racially minoritized students" as opposed to the more common "under-represented minority students" to acknowledge minoritization as a socially constructed process in keeping with Benitez's usage [4]. Underrepresented racially minoritized students include those from Black, Latinx, and/or Native groups.

known about the specific degree plans of students who contribute to booming enrollments or how these plans might vary by gender and race/ethnicity. As departments grapple with the well-documented trend of attrition after intro computing courses among women and URM students, a more nuanced understanding of students' academic orientations may inform initiatives and efforts to successfully recruit and retain women and URM students [9, 10].

This study uses data from a fifteen-campus study of diversity efforts in computing to address this gap in the literature, focusing on the degree plans of the three primary groups of students in intro computing courses: computing majors, non-computing majors, and undecided majors. Accordingly, the following questions frame this inquiry:

1. What proportion of introductory computing students are computing majors, non-computing majors, and undecided majors? How does this vary by gender and race/ethnicity?
2. Of the computing majors enrolled in an introductory computing course, what are their specific degree plans, and how does this vary by gender and race/ethnicity?
3. Among introductory students not majoring in computing, what are their degree plans, and how does this vary by gender and race/ethnicity?
4. Among students who enter introductory computing undecided on a major, what majors are they considering, and how does this vary by gender and race/ethnicity?

II. METHOD

A. Data Collection and Measures

This study relies on survey data received from n = 3,656 intro computing students across fifteen doctoral-granting research universities. The survey—developed in collaboration with Center for Evaluating the Research Pipeline at the Computing Research Association—was administered to nearly 12,000 students during the 2015-2016 academic year and had a response rate of 31%. Notably, participating institutions are all members of the BRAID initiative to broaden participation in computing. Despite the unique characteristics of the institutional sample, trends in the representation of women and URM student respondents at BRAID institutions parallel national trends in computing [11].

Students indicated their gender as female, male, or non-binary. Analyses by gender do not include non-binary students due to small sample sizes. Our analyses by race/ethnicity are based on student reports of their race/ethnicity which were aggregated into underrepresented racially minoritized (URM) and majority groups in computing, in keeping with recent definitions [12, 13]. Specifically, URM students include the following: African American/Black; American Indian or Alaska Native; Arab/Middle Eastern/Persian; Latinx; Native Hawaiian or Pacific Islander. Majority students include those who indicated only a white and/or Asian race/ethnicity. Women and URM students account for 33% and 27% of respondents, respectively.

Students were also asked to indicate up to two majors and two minors on the survey. For the purpose of this study, students were grouped into three mutually exclusive categories: computing majors[2], non-computing majors, and undecided majors. All non-computing majors and minors were aggregated into the following categories: Engineering (not including computer/software engineering); Humanities; Biological Sciences; Business; Education; Physical Sciences; Math and Statistics; Health; Social Sciences; or Other. Students who indicated that their major was undecided were asked to indicate their most probable major; those responses were aggregated into the categories listed above.

B. Analytical Procedures

This study relies on frequency distributions and z-tests to examine differences in degree constellations by gender and URM status. When possible, we also consider gender and URM status together as intersecting identities (i.e., we compare URM women, majority women, URM men, and majority men).

III. FINDINGS

A. Who Takes Intro Computing (RQ1)

Over half (52.8%) of the intro course students in our sample were computing majors, another 41.5% represent non-computing majors, and 5.7% were undecided on their major. Notably, among the 41.5% of non-computing majors in the intro course, one-third had a computing minor.

Compared to women, men much more frequently reported a computing major (61.0% vs. 37.7%; $z = -12.64$, $p < .000$), while women more frequently reported a non-computing ($z = -10.83$, $p < .000$) or undecided ($z = 4.09$, $p < .000$) major. At the same time, 61.8% of URM students were computing majors, compared to 50.0% of their counterparts from majority racial/ethnic groups ($z = 5.98$, $p < .000$); majority students also more frequently reported having either a non-computing ($z = -4.78$, $p < .000$) or undecided ($z = -2.81$, $p = .005$) major, compared to their counterparts from minoritized groups.

Disaggregating further to account for intersecting identities (see Table I), the greatest representation of computing majors was among URM men (69%), followed by majority men (58%), URM women (48%), and majority women (34%).

B. A Closer Look at Computing Majors (RQ2)

As illustrated in Table II, we found that nearly three-quarters of the computing majors in intro computing had a single major with no minor. At the same time, 17.7% of computing majors reported having a single major with at least one minor, 6.7% reported having a double major with no minor,

[2] Adapting Zweben and Bizot's definition [14] to accommodate the major/minor offerings at BRAID institutions, we define computing broadly to include the following: Computer Science; Computer Information Systems/Informatics; Bioinformatics; Computing and Business; Information Technology; Data Science; Game Design; Computer/Software Engineering; and Other Computing.

and 2.3% reported having a double major and at least one minor. These findings differed by gender, with women more frequently reporting a double major, compared to men. While there were no significant differences by URM status, additional analyses revealed that majority women were more frequently double majors compared to their male counterparts from both minoritized ($z = 3.37$, $p = .001$) and majority ($z = 2.92$, $p = .004$) groups; no other differences emerged.

TABLE I. COMPUTING, NON-COMPUTING, AND UNDECIDED MAJORS BY GENDER AND URM STATUS

	Percent Among			
	Majority Men (a) n=1,573	***Majority Women (b) n=794***	***Minoritized Men (c) n=573***	***Minoritized Women (d) n=293***
Computing	58.0_{bcd}	33.8_{acd}	69.3_{ab}	48.1_{abc}
Non-Computing	36.7_{bcd}	57.4_{acd}	28.3_{ab}	45.7_{abc}
Undecided	5.2_{bc}	8.8_{ac}	2.4_{abd}	6.1_{c}

Note. Subscripts indicate significant differences from corresponding groups after accounting for the Bonferroni correction. For example, 69% of minoritized men were computing majors, which is significantly different from the rate at which majority men and majority women major in computing.

Next, we examined the specific majors represented among intro students majoring in computing. As shown in Table III, the majority (63.5%) of computing majors reported a major in computer science, with computer engineering as the next most popular major (18.4%). Compared to men, women more frequently reported a major in bioinformatics or "other computing". Men more frequently reported a major in computer engineering. There were no significant differences between URM and majority students. Beyond the results shown in Table III, we also ran analyses comparing minoritized women, majority women, minoritized men, and majority men, revealing that women from majority racial/ethnic groups more frequently pursued bioinformatics compared to men from majority groups ($z = 3.14$, $p = .002$) and less frequently pursued computer engineering compared to both minoritized men ($z = -2.76$, $p = .006$) and majority men ($z = -3.20$, $p = .001$). No other differences emerged between intersecting groups.

Next, Table IV summarizes the double major combinations among those with a computing major, revealing that the most popular double major combinations were computing + business (18.2%) followed by computing + math/statistics (17.5%). Due to small sample sizes, we did not run significance testing on double majors by gender, race, or intersecting identity groups.

Finally, Table V summarizes the different minors reported among computing majors. We found that, in addition to being the most common double major among this group, math/statistics was also one of the most common minors (19.3%). While no significant differences emerged by gender or race alone, we found that majority women were more frequently biology minors relative to their male counterparts from majority groups (1.9% vs. .3%; $z = 2.70$, $p = .007$).

C. *Non-Computing Majors (RQ3)*

Focusing on the 41.5% of intro students in our sample who were non-computing majors, we see that about half reported having a single major and no minor, 36.6% reported having a single major and at least one minor, 8.5% had a double major, and the remaining 5.0% had a double major and at least one minor (see Table VI). While no differences emerged by URM status, men more frequently had a single major compared to women. No differences emerged between intersecting groups.

TABLE II. MAJORS/MINORS AMONG INTRO STUDENTS MAJORING IN COMPUTING, BY GENDER AND RACE

	Percent Among						
	All students	***By Gender***			***By Race***		
	All (n=1917)	***Women (n=415)***	***Men (n=1319)***	***Z***	***Minoritized (n=536)***	***Majority (n=1186)***	***Z***
Single major	73.2	68.0	75.3	-2.94*	75.6	72.3	1.43
Single major + one or more minors	17.7	19.0	17.1	0.89	17.0	18.0	-0.50
Double major	6.7	9.9	5.5	3.16*	5.2	7.3	-1.62
Double major + one or more minors	2.3	3.1	2.1	1.18	2.2	2.4	-0.25

Note. *$p<0.0125$. The significance level has been adjusted using the Bonferroni correction.

TABLE III. DISTRIBUTION OF MAJORS AMONG INTRO STUDENTS WITH A COMPUTING MAJOR, BY GENDER AND RACE

	Percent Among						
	All Students	***By Gender***			***By Race***		
	All (n=1931)	***Women (n=416)***	***Men (n=1330)***	***Z***	***Minoritized (n=541)***	***Majority (n=1193)***	***Z***
Computer Science	63.5	62.7	64.3	-0.59	66.2	63.1	1.25
Computer Engineering	18.4	13.7	19.8	-2.81*	19.0	18.4	0.30
Information Technology	8.0	7.7	8.3	-0.39	5.5	9.1	-2.56
Computer Information or Systems Informatics	4.9	6.5	4.4	1.73	4.6	4.8	-0.18
Bioinformatics	1.6	3.6	1.0	3.67*	1.5	1.6	-0.16
Other Computing	1.8	3.6	1.1	3.45*	1.3	1.9	-0.89
Information Science Studies	1.5	1.9	1.0	1.46	1.7	1.0	1.23
Computing and Business	1.3	1.7	1.2	0.78	1.3	1.3	0.00

Note. *$p<0.0063$. The significance level has been adjusted using the Bonferroni correction. Percentages add to more than 100 because some students indicated more than one major.

TABLE IV. COMBINATIONS OF COMPUTING DOUBLE MAJORS ENROLLED IN INTRO COURSES, BY GENDER AND RACE

	Percent Among				
	All students	***By Gender***		***By Race***	
	All (n=143)	***Women (n=45)***	***Men (n=85)***	***Minoritized (n=34)***	***Majority (n=97)***
Computing + Business	18.2	20.0	18.8	8.8	22.7
Computing + Math/Statistics	17.5	22.2	16.5	17.6	18.6
Computing + Another Computing Major	16.1	13.3	18.8	23.5	14.4
Computing + Engineering	15.4	8.9	18.8	8.8	17.5
Computing + Arts and Humanities	13.3	20.0	5.9	11.8	10.3
Computing + Biological Sciences	8.4	2.2	12.9	14.7	7.2
Computing + Other	7.7	13.3	4.7	14.7	5.2
Computing + Physical Sciences	3.5	0.0	3.5	0.0	4.1

Note. This table includes no significance testing due to small sample sizes among groups.

TABLE V. DISTRIBUTION OF MINORS AMONG COMPUTING MAJORS ENROLLED IN INTRODUCTORY COURSES, BY GENDER AND RACE

	Percent Among						
	All Students	***By Gender***			***By Race***		
	All (n=384)	***Women (n=92)***	***Men (n=254)***	***Z***	***Minoritized (n=108)***	***Majority (n=248)***	***Z***
Computing (minor)	19.3	12.5	20.5	-1.70	23.3	16.1	1.62
Math/Statistics	19.3	16.3	21.3	-1.37	22.3	19.0	0.72
Arts and Humanities	18.2	26.1	16.5	2.01	17.5	20.2	-0.59
Business	17.4	18.5	17.3	0.26	13.6	19.4	-1.32
Other	12.8	10.9	13.8	-0.70	14.6	12.0	0.68
Social Sciences	7.3	8.7	6.7	0.63	7.8	7.0	0.27
Engineering	3.6	3.3	3.9	-0.26	2.9	4.1	-0.55
Biological Sciences	2.9	7.6	1.6	2.80	1.9	3.3	-0.73
Physical Sciences	2.6	1.1	2.8	-0.92	1.9	2.5	-0.66
Education	0.3	0.0	0.4	-0.61	0.0	0.4	-0.66
Health	0.3	0.0	0.4	-0.61	0.0	0.4	-0.66

Note. We tested for significant differences by gender/URM status, using the Bonferroni adjusted significance level, $p<0.0045$. No significant differences emerged. Percentages add to more than 100 as some students had more than one minor.

TABLE VI. MAJORS AND MINORS AMONG NON-COMPUTING MAJORS IN INTRODUCTORY COURSES, BY GENDER AND RACE

	Percent Among						
	All Students	***By Gender***			***By Race***		
	All (n=1510)	***Women (n=596)***	***Men (n=751)***	***Z***	***Minoritized (n=299)***	***Majority (n=1036)***	***Z***
Single major	49.8	46.0	55.3	-3.39*	56.9	49.6	2.22
Single major + one or more minors	36.6	37.8	33.4	1.68	33.4	36.1	-0.86
Double major	8.5	10.7	7.1	2.33	6.0	9.4	-1.84
Double major + one or more minors	5.0	5.5	4.3	1.02	3.7	4.9	-0.87

Note. *$p<0.0125$. The significance level has been adjusted using the Bonferroni correction.

Next, Table VII displays the specific major fields reported among this group. Engineering majors represented nearly a third of non-computing majors in the intro course, followed by math/statistics, social sciences, and biological sciences. Some gender differences emerged, revealing that, compared to women, men twice as frequently reported an engineering major, while women more frequently majored in the social or biological sciences. Notably, while 20% of female non-computing majors in intro courses were engineering majors, this figure was 30% among URM women ($z = -3.10$, $p = .002$).

D. *Undecided Majors (RQ4)*

More than half of all undecided majors in intro computing courses reported that if they had to choose a major today, it would most likely be computing. However, gender differences reveal that men were significantly more likely than women to anticipate choosing computing as a major (72.6% vs. 48.9%; $z = -3.29$, $p = .001$). No other significant differences emerged for women and URM students. Due to small sample sizes, we did not run analyses by intersecting groups.

IV. DISCUSSION

This paper provides an overview of the majors and minors pursued by intro computing students, focusing on differences by gender and URM status. At a time of booming enrollments and increasing interest in broadening participation in computing, it is useful to understand the disciplinary pursuits of students taking computing courses. In addition to offering insight into how instructors can tailor their course to provide relevant content and responsive pedagogy, understanding students' degree plans may also help in identifying students who may be open to being recruited to a computing major. These considerations are especially important in the context of intro computing courses that attract students from a variety of majors and are often pivotal in determining whether students will pursue computing as a major or career [15].

TABLE VII. DISTRIBUTION OF MAJOR FIELDS AMONG INTRODUCTORY STUDENTS NOT MAJORING IN COMPUTING, BY GENDER AND RACE

	Percent Among						
	All Students	***By Gender***			***By Race***		
	All (n=1510)	***Women (n=597)***	***Men (n=753)***	***Z***	***Minoritized (n=300)***	***Majority (n=1038)***	***Z***
Engineering	31.9	20.3	41.7	-8.36*	36.7	31.1	1.83
Math/Statistics	17.8	19.3	16.1	1.54	15.7	17.8	-0.85
Social Science	13.0	19.8	8.2	6.23*	10.0	14.2	-1.89
Biological Sciences	11.9	16.4	9.4	3.86*	11.3	12.9	-0.70
Business	11.0	9.9	11.6	-1.00	7.7	11.7	-1.97
Arts and Humanities	7.0	7.5	6.4	0.79	5.3	7.4	-1.26
Physical Sciences	5.5	5.5	6.1	-0.47	5.3	5.9	-0.39
Other	5.2	6.7	3.9	2.31	8.3	4.1	2.93*
Education	1.3	2.0	0.8	1.91	1.7	1.3	0.52
Health	1.1	2.0	0.5	2.55	0.7	1.3	-0.85

Note. *$p<0.005$. The significance level has been adjusted using the Bonferroni correction.

It is noteworthy that nearly half of students enrolled in intro computing courses are not themselves computing majors. While a small portion of non-computing majors are undecided (and may ultimately choose to major in computing), over 40% are majoring in other fields of study, the majority of which do not have a computing minor. Still, by enrolling in the intro course, students in all of these groups have an expressed interest in computing. Therefore, one way to broaden participation in computing may be to encourage students majoring in other fields to adopt a double major in computing. Doing so may have other implications for equity later in careers, as pursuing computing as part of a double major is associated with increased salaries after college [16, 17].

Instructors ought to be aware of the disciplinary diversity in their intro computing courses and consider pedagogical approaches that would appeal to their students. The possibilities for making interdisciplinary connections are vast, as evident by computing departments from a variety of institutions that have restructured their intro courses to highlight how computing skills can be applicable to art and design, biology, music composition, robotics, and digital media production [18, 19, 20, 21, 22, 23]. Bringing in content, examples, and projects that have multi-disciplinary ties can enhance learning and interest from non-computing majors as well as computing majors who may have a broader range of interests. In fact, there is evidence that students who take CS1 courses with interdisciplinary applications may earn higher course grades, be more likely to persist in the major, and have higher confidence in their computing skills relative to students in a more traditional CS1 course [24, 25, 26]. Indeed, the ACM Retention Committee recommends interdisciplinarity as a best practice for CS1 instructors and the National Center for Women in Information Technology has created EngageCSEdu, a clearinghouse of course materials and supporting research to assist instructors in infusing their courses with interdisciplinary content [27, 28, 29].

A second set of key findings relates to gender. Among the women enrolled in intro computing, only 38% were majoring in a computing field, relative to 61% among men. Further, among computing majors, women were significantly more likely to be double majors compared to men (9.9% vs. 5.5%), which is notable given that college men and women generally tend to double major at the same rates [30]. Also, among the women who were still undecided about their major (and could theoretically pursue computing), fewer than half indicated interest in selecting a computing major, compared to nearly three-quarters of undecided men. Women from all of these groups—those already pursuing a computing major, those pursuing a different major, and those who have not yet decided—represent an opportunity for instructors to cultivate the computing interests that led them to the intro course.

Turning our attention to URM students in intro courses, our findings suggest that, contrary to prior literature [e.g., 1], URM students in the intro course were actually more frequently majoring in computing than their counterparts from majority racial/ethnic groups. At a time when there is a nationwide push to diversify the computing field, the presence of a sizeable number of URM students in intro computing courses who plan to earn a computing degree is noteworthy—though URM students are still the minority of students in these courses, accounting for only about a quarter of all intro course students. While this presents a significant opportunity, it is important to remember that aspirations are not synonymous with degree attainment; across STEM fields, retention rates for URM students are significantly lower than for their white and Asian peers [31]. In light of this, future research should continue to examine the intro course experiences that predict retention in computer science for all students and URM students in particular. For now, this study expands upon existing literature on broadening participation in computing by providing a more detailed picture of the types of degrees students are pursuing as they enter the intro computing course.

V. LIMITATIONS AND FUTURE DIRECTIONS

While this paper contributes to our understanding of the disciplinary pursuits of intro computing students, it is important to consider several limitations. Given our survey response rate of 31%, some results may have been affected by non-response bias. Specifically, computing majors may have a greater propensity to respond to a survey about computing experiences. Thus, our findings may underestimate the participation of non-computing majors in intro computing.

Additionally, data for this study were drawn from fifteen institutions, all of which represent doctoral-granting research universities. Thus, we do not know the extent to which our findings are applicable to students at different institution types (e.g., liberal arts colleges, community colleges, etc.). Similarly, some of the findings may be related to the degree offerings at the specific participating institutions, which may look different than those offered at other institutions. Further, the institutions included in this research represent a self-selected sample where the computing department chair volunteered to be part of the BRAID project (though as noted earlier, diversity trends in computing at BRAID institutions closely mirror national trends). Still, student experiences at the BRAID schools may not be generalizable to other institutional contexts. Future research should examine this topic among students who attend varying institution types and in more controlled settings.

While this paper compared students on the basis of gender and URM status, we did not have a sufficient sample to disaggregate racial/ethnic groups. Sample size limitations also prevented us from fully exploring intersecting identities of gender and race. In particular, the findings for all women or all URM students may not hold true for URM women who are marginalized in computing due to both their gender and racial/ethnic identities. We mitigated this limitation as much as possible by running additional analyses comparing intersecting groups, though small sample sizes limit our ability to detect significant differences. While these data only allowed for a cursory examination of such differences, the results do point to variation in major/minor plans between URM women and other intersecting groups. Future research should utilize larger and more diverse samples to examine this topic with consideration of intersecting identities.

Finally, our findings descriptively point to both gender and racial/ethnic differences in the specific degree constellations that students pursue when they enter intro computing courses. Future research should examine these patterns longitudinally, considering implications for career outcomes and social stratification over time.

VI. CONCLUSION

Students enrolled in introductory computing courses hail from a wide range of disciplines, with some of these students still exploring their interests. This study helps to illuminate the range of majors and minors represented among students enrolled in these gateway courses and highlights important gender and racial/ethnic differences in these patterns. This information should enable instructors to better meet the needs of their students, recognizing the kinds of fields they are likely to pursue, and thus designing courses that have clear application to fields such as business, biological sciences, and social sciences. Clear interdisciplinary applications may be one way to recruit more students to computing degrees and to better engage students who can apply these skills to their non-computing major.

ACKNOWLEDGMENT

The data used in this study were provided by the UCLA BRAID Research Project, whose collection of these data was supported AnitaB.org and NSF (#1525737). Additionally, we are grateful to the students who took our survey, the members of the BRAID Research team who managed data collection, and reviewers who provided feedback to improve this research.

REFERENCES

[1] Computing Research Association, Generation CS: Computer science undergraduate enrollments surge since 2006, 2015, Available from: http://cra.org/data/Generation-CS/.

[2] National Academies of Sciences, Engineering, and Medicine, *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments*, Washington, D.C.: The National Academies Press, Available from: https://doi.org/10.17226/24926

[3] S. H. Zweben and E. B. Bizot, "2017 Taulbee Survey: Another Year of Record Undergrad Enrollment; Doctoral Degree Production Steady While Master's Production Rises Again". *Computing Research News*, vol. 30, no. 5, pp. 2-48, 2018.

[4] M. Benitez Jr., "Resituating culture centers within a social justice framework: Is there room for examining Whiteness?", *Culture Centers in Higher Education: Perspectives on Identity, Theory, and Practice*, Lori Patton Davis (Ed.). Stylus Publishing, Sterling, VA, pp. 119-134, 2010.

[5] National Center for Education Statistics, "Digest of education statistics: Bachelor's degrees conferred by postsecondary institutions, by race/ethnicity and field of study: 2014-2015 and 2015-2016 (Table 322.3) and Bachelor's degrees conferred by degree-granting institutions, by field of study (Table 322.50)", 2017. Available from: https://nces.ed.gov/programs/digest/2017menu_tables.asp [Accessed November 29, 2017].

[6] L. N. Cassel, " Interdisciplinary computing is the answer: Now, what was the question?" *ACM Inroads*, vol. 2, no. 1, pp. 4-6, February 2011.

[7] K. J. Lehman, L. J. Sax, and H. Z. Zimmerman, "Women planning to major in computer science: Who are they and what makes them unique?" *Computer Science Education*, vol. 26, no. 4, pp. 277-298, January 2017. Available from: DOI: 10.1080/08993408.2016.1271536

[8] J. Margolis and A. Fisher, *Unlocking the Clubhouse: Women in Computing*, Cambridge, MA: MIT Press, 2003.

[9] L. C. Kaczmarczyk, A. Monge, J. Offutt, H. Pon-Barry, and S. Westbrook, "You should (and absolutely can) keep diversity in sharp focus during the enrollment surge", *Research in Equity and Sustained Participation in Engineering, Computing, and Technology* (RESPECT'15), pp. 1-3, Charlotte, NC: Institute of Electrical and Electronics Engineers Inc. Available from: https://doi.org/10.1109/RESPECT.2015.7296492, 2015.

[10] J. M. Cohoon, "Recruiting and retaining women in undergraduate computing majors", *SIGCSE Bulletin*, vol. 34, no. 2, pp. 48–52, June 2002. Available from: https://doi.org/10.1145/543812.543829

[11] L. J. Sax, "Year 1 first look: Research findings", Presentation at the Annual BRAID Summit, Snowbird, UT, 2016.

[12] National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017*. Available from http://www.nsf.gov/statistics/wmpd/, 2017.

[13] B. Tamer and J. G. Stout, *Recruitment and Retention of Undergraduate Students in Computing: Patterns by Gender and Race/Ethnicity*, 2016. Available from: http://cra.org/cerp/research-findings/

[14] S. H. Zweben and E. B. Bizot, "2015 Taulbee Survey: continued booming undergraduate CS enrollment; doctoral degree production dips slightly," *Computing Research News*, vol. 28, no. 5, pp. 2-60, May 2016.

[15] J. Cohoon, "An introductory course format for promoting diversity and retention", *ACM SIGCSE Bulletin*, vol. 39, no. 1, pp. 395-399, March 2007.

[16] A. F. Del Rossi and J. Hersch, "Double your major, double your return?" *Economics of Education Review*, vol. 27, no. 4, pp. 375–386, August 2008.

[17] S. W. Hemelt, "The college double major and subsequent earnings," *Education Economics*, vol. 18, no. 2, pp. 167-189, June 2010. Available from: DOI: 10.1080/09645290802469931

[18] P. Gestwicki and B. McNely, "Interdisciplinary projects in the academic studio", *ACM Transactions on Computing Education*, vol. 16, no. 2, Article 8, pp. 1-24, March 2016. Available from: https://doi.org/10.1145/2732157

[19] I. Greenberg, D. Kumar, and D. Xu, "Creative coding and visual portfolios for CS1", *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (SIGCSE'12), New York, NY: ACM Press, 2012, pp. 247-252.

[20] M. Guzdial, "Exploring hypotheses about media computation," *Proceedings of the 9th International ACM Conference on International Computing Education Research* (ICER'13), New York, NY: ACM press, 2013, pp. 19–26.

[21] M. Haungs, C. Clark, John Clements, and D. Janzen, "Improving first-year success and retention through interest-based CS0 courses", *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (SIGCSE'12), New York, NY: ACM Press, 2012, pp. 589-594.

[22] C. Kitts and N. Quinn, "An interdisciplinary field robotics program for undergraduate computer science and engineering education", *Journal for Educational Resources in Computing*, vol. 4, no. 2, pp. 1-22, June 2004. Available from: https://doi.org/10.1145/1071620.1071623

[23] A. Misra, D. Blank, and D. Kumar, "A music context for teaching introductory computing", *Proceedings of the 14th annual ACM SIGCSE conference on Innovation and technology in computer science education* (ITiCSE'09), New York, NY: ACM Press, 2009, pp. 248-252.

[24] Z. Dodds, R. Libeskind-Hadas, and E. Bush, "When CS 1 is biology 1: Crossdisciplinary collaboration as cs context", *Proceedings of the 15th Annual Conference on Innovation and Technology in Computer Science Education* (ITiCSE'10), New York, NY: ACM Press, 2010, pp. 219–223. Availble from: https://doi.org/10.1145/1822090.1822152

[25] A. Forte and M. Guzdial, "Motivation and nonmajors in computer science: Identifying discrete audiences for introductory courses", *IEEE Transactions on Education*, vol. 48, no. 2, pp. 248–253, May 2005.

[26] S. A. Rebelsky, J. Davis, and J. Weinman, "Building knowledge and confidence with mediascripting: A successful interdisciplinary approach to CS1", *Proceedings of the 44th ACM Technical Symposium on Computer Science Education* (SIGSCE'13), New York, NY: ACM Press, pp. 438-488. Available from: https://doi.org/10.1145/2445196.2445342

[27] A. E. Monge, C. L. Fadjo, B. A. Quinn, and L. J. Barker, "EngageCSEdu: Engaging and retaining CS1 and CS2 students", *ACM Inroads*, vol. 6, no. 1, pp. 6–11, March 2015. Available from: https://doi.org/10.1145/2714569

[28] NCWIT, *EngageCSEdu: Engage your intro students, share your course materials, and support diversity.* Available from: https://www.ncwit.org/project/engagecsedu.

[29] H. M. Walker, "ACM retention committee: Retention of students in introductory computing courses: Curricular issues and approaches", *ACM Inroads*, vol. 8, no. 4, pp. 14–16, December 2017. Available from: https://doi.org/10.1145/3151936

[30] R. N. Pitt and S. Tepper, *Double majors: Influences, identities, and impacts (Prepared for The Teagle Foundation)*, Nashville, TN: The Curb Center, Vanderbilt University, 2010. Available from: http://www.vanderbilt.edu/curbcenter/cmswp/wpcontent/uploads/Teagle_Report_Final_3-11-13.pdf

[31] M. J. Chang, J. Sharkness, S. Hurtado, and C. B. Newman, "What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups", *Journal of Research in Science Teaching*, vol. 51, no. 5, pp. 555–580, May 2014. https://doi.org/10.1002/tea.21146