Better Late Than Never: Exploring Students' Pathways to Computing in Later Stages of College

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ABSTRACT

While introductory computing courses (i.e., CS1) continue to enroll large proportions of first- and second-year computing majors, more non-majors than ever before are enrolling in CS1 at later points in their college careers. These “latecomers” to computing are a unique population that may be more diverse, given that prior research indicates students from historically underrepresented groups often develop an interest in computing later than White and Asian men. Thus, as computing departments grapple with the pressures to broaden participation, latecomers to CS1 may be a population from which to recruit women and underrepresented students of color. Using survey data from a nationwide study of CS1 course takers, this study explores the demographic and academic background characteristics of students who took CS1 in their third year or beyond. We also analyzed the characteristics and CS1 experiences that predict latecomers’ decisions to major or minor in computing. Findings indicate that latecomers came from a variety of academic disciplines and were more likely than computing majors who take CS1 courses earlier in college to be women. However, latecomers who were women were less likely than men to be recruited to a computing major or minor. Additional findings and implications for practice are discussed.

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KEYWORDS

College students; CS1; Introductory computing courses; Computing major; Computing minor; Gender; Race/ethnicity

1 INTRODUCTION AND BACKGROUND

As the SIGCSE community looks to shape the next 50 years of computing education, we must attend to college enrollment trends and how those trends shape who participates in computing degree programs. Recently, collegiate computing courses have been characterized by a rapid influx of students [6, 18]. This growth in computing is often referred to as the “enrollment boom” [1]. Though computing majors are an important part of the enrollment boom, majors are not the only students creating this growth. In fact, according to a 2017 report by the Computing Research Association (CRA) [6], non-majors’ enrollment in introductory computing courses grew by 177% between 2005 and 2015 compared to the 152% growth among computing majors. Further, non-major students in CS1 may serve as a pool from which to recruit historically underrepresented students to the major. For example, a recent study found that, compared to computing majors, non-computing majors enrolled in CS1 are more likely to be women than men. [23]. Further, this same study found that approximately half of non-computing majors enrolled in CS1 were in their third year or later of college [23]. Thus, recruiting non-majors, specifically those taking CS1 in their third year or later, to a computing major or minor may represent one way to increase diversity in computing courses and build a more equitable pipeline into computing.

With scholars and organizations alike strategizing ways to broaden participation and increase gender and racial/ethnic diversity in computing, CS1 courses represent an important environment from which to recruit diverse students [4, 8, 20]. In assessing the timing of computing interest in college, prior research has suggested that women and underrepresented racially minoritized students (URM; i.e., Black or African American; Hispanic or Latinx; American Indian or Alaskan Native; Native Hawaiian or Pacific Islander; Arab, Persian, or Middle Eastern students) tend to develop interest in computing later than men or their majority counterparts [16, 6]. That is to say, women and URM students' later discovery of computing may mean that they begin as non-majors and enroll in CS1 after their first two years of college. These "latecomers" to computing may not have been in the position to pursue computing previously, but they may develop interest in computing degrees later on in college. CS1 courses are a key experience during which departments can increase computing interest among students from underrepresented backgrounds [11, 14, 21]. If students, such as those taking CS1 in their third year or beyond, have positive experiences and interactions in CS1, they may be more prone to pursue a computing major or minor.

Studying CS1 courses is important because they are viewed as a gateway into the field of computing [6]; however, the introductory course does not necessarily represent a marker of sustained commitment in computing unto itself. For students who are introduced to computing later in their college career, they may find that CS1 prompts their interest in changing majors, as about one third of postsecondary students (across all majors) stray from their original major intentions in college [19]. Students may also see value in *adding* a computing major to their degree plan; indeed, recent estimates report that over 25% of undergraduate students pursue a double major [22]. Alternatively, students may not have the credits or time to pursue a computing major but seek a minor instead. A minor in computing represents a unique way, in addition to a major, to ascertain students' computing commitment after CS1. Further, as indicated by CRA's *Generation CS* report [6], 78% of doctoral-granting units described an increase in the number of minors; the new growth in these minors is indicative that students view a computing minor as a valuable tool. These enrollment patterns demonstrate that there is reason to target advanced students (i.e., third- and fourth-year students) to cultivate longer-term computing interest among non-majors, women, and URM students. However, little prior research has investigated the academic pathways of such students. Using a multi-institutional nationwide sample, this study is well-poised to extend important work on diversifying computing [2, 3, 6], specifically as it relates to generating latecomers' longer-term interest in computing. The purpose of this study is to understand the characteristics of students who complete CS1 in their third or later year of college and to examine what characteristics and experiences predict such students' declaration of a computing major or minor by the following year. As such, this study is guided by the following research questions:

1. Among non-computing students taking an introductory computing course in their third year or beyond (i.e., "latecomers"), what proportion declare a computing major or minor within one year? Does this vary by gender and URM status?
2. What are the characteristics (i.e., demographic traits, academic characteristics, and career aspirations) of latecomers? How do these characteristics of latecomers compare to first- and second-year computing students (i.e., "early adopters")?
3. To what extent do the introductory course and departmental experiences of latecomers influence the declaration of a computing major or minor?

2 CONCEPTUAL FRAMEWORK

2.1 Model of Undergraduate Socialization

This study is guided by Weidman's model of undergraduate socialization, which takes a sociological approach to understanding the impact of college on student outcomes such as major or minor selection [24, 25]. Since the college environment does not account for all of the experiences and contexts that shape student outcomes, Weidman's model incorporates students' background characteristics as well as factors from their external communities that may relate to socialization outcomes [24, 25]. This model is particularly useful for this study because latecomers' decisions to pursue computing are influenced not only by their experiences in CS1 but also by their background characteristics, career aspirations, and other college experiences.

Figure 1: Weidman's Model of Undergraduate Socialization [25], as adapted for this study

This framework has been widely used to guide the research design of studies on college students, with many examining outcomes for students in science, technology, engineering, and math (STEM) fields [e.g., 9, 10, 13]. This paper builds on prior work and expands the use of Weidman's model by investigating the predictors of latecomers' sustained interest in computing. Figure 1 illustrates how the variables in our model map on to Weidman and colleagues' 2014 model.

3 METHODS

3.1 Data Source and Sample

This study used longitudinal survey data from a nationwide study of CS1 course takers at 15 institutions. Specifically, data were drawn from a merged sample that included two cohorts of students who took a survey at the end of CS1 in either the 2015-2016 or 2016-2017 academic year and a follow-up survey administered in the fall of the following year (approximately 6-12 months later). The first survey was developed in conjunction with CRA's Center for Evaluating the Research Pipeline. It explored students' introductory course experiences in addition to learning more about their backgrounds and other collegiate environments. The follow-up survey aimed to learn more about students' longer-term trajectories in collegiate computing (e.g., sustained commitment in computing and upper-division course experiences) and post-college plans. Among the first cohort of students, approximately 19% responded to the end-of-course survey and 43% to the follow-up survey. Response rates for the second cohort of students were 17% and 44%, respectively. To address generalizability and non-response bias, the research team compared our sample to CRA's Data Buddies Survey and found our students' demographic traits and experiences in computing to be generally representative of the broader population of students in computing at research universities.

Drawing from both cohorts of students, the overall matched sample included 2,738 students. Among this group, we focus on two primary populations: (1) non-computing students who took CS1 in their third or later year of college (i.e., "latecomers") ($n=279$, 10.2% of overall matched sample) and (2) computing majors or minors who took CS1 in their first- or second-year (i.e., "early adopters") ($n=633$, 23.1% of matched sample). Excluding students taking CS1 in their third year or later but who had *already* declared a computing major or minor provided us a way to measure *new* interest in a computing major or minor following the introductory course.

3.2 Measures

All background characteristics were observed on the end-of-CS1 survey¹; we replaced missing data on these traits with students' responses from the follow-up survey when available. Due to limited sample sizes of some racial/ethnic and gender identities among latecomers, binary variables were created for gender (0=man; 1=woman) and race/ethnicity (0=White or Asian/Asian American; 1=URM). We also drew measures of students' self-efficacy and major during CS1 from the first survey, while all other measures were observed on the follow-up survey. In addition, several latent constructs were created via exploratory and confirmatory factor analysis using principal axis factoring to highlight the underlying nature of students' perceptions. The factor loading threshold for variables to be included was set at 0.4, and constructs included: Computing Self-Efficacy ($\alpha=0.818$),

Perceptions of Inclusive Departmental Climate ($\alpha=0.884$), Peer Support in Computing ($\alpha=0.890$), and the Role of the Introductory Course in Fostering Computing Interest ($\alpha=0.835$). Finally, the dependent variable for RQ3 was derived from the follow-up survey and coded as a dichotomous measure of declaring a computing major/minor (0=non-computing major or minor; 1=computing major or minor).

3.3 Data Analysis

To address the first research question, we used frequencies to explore how many latecomers declared a computing major or minor within one year of completing CS1 and then used two-way crosstabulations to compare differences by students' gender and URM status. The second research question also employed two-way crosstabulations to understand more about latecomers' demographic traits, academic characteristics, and career aspirations. Then, we used z-tests to identify significant differences between latecomers and early adopters.

Prior to conducting inferential analyses among latecomers, the research team conducted multiple imputation (MI) to account for missing data ($m=50$). MI is considered a robust way of addressing missingness, as it provides less-biased estimates and smaller standard errors [15]. Little's MCAR test ($p=0.093$) revealed that the data were missing at random (MAR) or missing completely at random (MCAR), and no variable was missing more than 10% of associated values.

The third research question focuses exclusively on latecomers and examines the predictors of declaring a computing major or minor within one year of CS1. Our team used Weidman et al.'s model of undergraduate socialization [25] to identify relevant independent variables (see Fig. 1). Then, we employed binary logistic regression to examine the relationships between these predictors and students' decisions to pursue a computing major or minor. The cut point for the logistic regression was set at the mean of the dependent variable (.143). Further, we standardized continuous variables prior to employing logistic regression to allow for direct comparisons across predictors. Coefficients in logistic regression are reported in log odd units, which prompted us to use the exponentiated coefficients (i.e., $\exp(b)$) for ease of interpretation.

3.4 Limitations

The results that follow represent an important examination of students' sustained interests in computing when taking CS1 later in college; however, some inherent limitations must be mentioned. First, this paper focused primarily on the experiences of latecomers to computing with a secondary focus on differences by students' gender and racial/ethnic identities. As we were most interested in the experiences of latecomer students, we did not further disaggregate some gender and racial/ethnic groups due to small sample sizes; however, we acknowledge that the students within these aggregated gender and racial/ethnic groups have

¹ Including socioeconomic status, gender, race/ethnicity, and parent career.

unique experiences that may be masked in this study. Second, given the limited sample size and scope, we did not parse out the nuances of whether latecomers who ultimately selected a computing major or minor did so by switching majors or minors or by adding another major/minor. Further, while our definition of latecomers captured those who took CS1 later on, other pathways for latecomers to computing were not captured in this study, such as those who tested out of CS1 or took it at a community college. Lastly, although we addressed latecomers' commitment to computing one year after CS1, we were not able to determine whether these students ultimately graduated with a computing major or minor. Future research should examine latecomers' longer-term trajectories in computing, both in terms of degrees awarded and in their career decisions.

4 RESULTS

4.1 Latecomers Declaring Computing Majors and Minors

Of the 279 latecomers who took CS1, 16% (n=40) went on to indicate a computing major (n=28) or minor (n=12) by the follow-up survey (see Table 1). However, there were key differences in the characteristics of latecomers who went on to pursue computing degrees and those who did not. A significantly larger proportion of students who had a non-science, engineering, or mathematics (SEM) major (21.7%) while taking CS1 went on to pursue computing than SEM majors (9.1%). Additionally, nearly 22% of latecomer men went on to pursue a computing major or minor, compared to about 7% of women. We also examined differences by students' URM status but none were statistically significant.

Table 1. Characteristics of Latecomers Who Declared a Computing Major or Minor Within One Year of CS1 (n=40)

	Percent
<i>Gender</i>	
Men	21.5
Women	6.8
<i>Racial/Ethnic Group</i>	
URM Students	20.7
White or Asian/Asian American Students	12.7
<i>Academic Major During CS1¹</i>	
SEM	9.1
Non-SEM	21.7

Note: Bolded numbers indicate significant differences ($p < .05$). ¹SEM stands for science, engineering, and math. Technology (i.e., computing) majors were excluded from this sample, as latecomers were non-computing students.

4.2 Background Characteristics of Latecomers and Early Adopters

4.2.1 Demographic and Academic Traits of Latecomers. The second research question concerns the characteristics of latecomers to CS1 and how they compare to those of early adopters. As shown in Table 2, latecomers to CS1 were split nearly equally between men and women, and they largely identified as White or Asian/Asian American. A large proportion of latecomers

reported their socioeconomic status as average (42.8%) and that they attended community college (41.6%; see Table 2). Further, Table 3 shows that latecomers came from diverse fields of study, including engineering (28.7%), the social sciences (17.1%), biology (12.4%), and mathematics (11.2%).

Table 2. Comparison of Early Adopters' and Latecomers' Demographic Backgrounds

	Percent Among	
	Early Adopters (n=633)	Latecomers (n=279)
<i>Gender</i>		
Men	64.9	52.2
Women	35.1	47.8
<i>Racial/Ethnic Group</i>		
White, Caucasian, or European American	36.9	51.4
Asian or Asian American	33.4	25.2
Black or African American	5.1	4.0
Hispanic or Latinx	10.5	7.9
Native American	0.3	0.4
Arab, Middle Eastern, or Persian	1.7	2.2
Multiracial: URM	6.3	6.5
Multiracial: White, Asian	4.1	2.2
Other	1.6	0.4
<i>Socioeconomic Status</i>		
Poor or Below Average	22.2	27.3
Average	49.1	42.8
Above Average or Wealthy	28.7	29.9
<i>Attended Community College</i>	20.9	41.6

Note: Bolded numbers indicate significant differences ($p < .05$).

4.2.2 Comparison of Latecomer and Early Adopter Characteristics. We noted several unique characteristics of latecomers compared to early adopters. First, a significantly larger proportion of the latecomer group were women (47.8%) than were the early adopters (35.1%). Additionally, while the majority of students in both groups reported being White or Asian/Asian American, latecomers were more likely to report their race/ethnicity as White (51.4%) than were early adopters (36.9%), whereas a larger proportion of the early adopters reported their race/ethnicity as Asian/Asian American (33.4%) than did latecomers (25.2%). Further, latecomers were much more likely to report that they had attended a community college (41.6%) than computing students who enrolled in CS1 earlier in their academic careers (20.9%). There were also many differences between early adopters' and latecomers' career aspirations, with latecomers reporting more diverse career aspirations, evidenced by clinical psychologist, K-12 professional, and librarian topping the list (see Table 4).

Table 3. Latecomers' Majors During CS1 (n=258)

	Percent
Engineering	28.7
Social sciences	17.1
Biology	12.4
Mathematics	11.2
Double Major: Neither Computing	8.1
Business	7.4
Other	5.4
Physical Sciences	4.7
Humanities	3.9
Health	1.2

Table 4. Comparison of Early Adopters' and Latecomers' Most Popular Career Aspirations

	Percent Among	
	Early Adopters (n=622)	Latecomers (n=279)
Management Role in Computing	33.4	2.9
Computer or Information Analyst	7.9	3.9
Business Owner or Entrepreneur in Computing	7.2	1.4
Database or Systems Admin.	7.1	0.4
Software Developer, Programmer	5.9	2.9
Computer or Information Research Scientist	5.5	1.4
Game Developer	4.2	1.4
Cyber Security Analyst	4.0	1.8
Dentist/Orthodontist	4.0	5.0
Network Architect	3.1	0.0
Clinical Psychologist	2.7	7.5
Computer Support Specialist	1.6	0.4
Librarian	1.1	4.7
Other K-12 Professional	0.8	6.8
Musician	1.0	4.3
Electrical, Electronic Engineer	0.0	3.9
Human Resources	0.6	3.6
Finance	0.3	3.2
Other Engineering	0.6	2.9
Research Scientist	0.0	2.9

Note: Bolded numbers indicate significant differences ($p < .05$). Among 83 career options on the follow-up survey, we identified the most popular careers reported by latecomers and early adopters; this list is not exhaustive of all intended careers.

The most notable differences pertain to computing careers; larger proportions of early adopters reported that they wanted a computing management role or to be a computer/information analyst, computing-related business owner/entrepreneur, or database/ systems administrator than did the latecomers. Latecomers were more likely than early adopters to aspire to non-computing careers, particularly in helping fields (i.e., psychologist, K-12 professional, and librarian).

4.3 Predicting Latecomers' Declaration of a Computing Major or Minor

The third research question addresses the predictors of latecomers' decisions to pursue a computing major or minor within one year of taking CS1. As shown in Table 5, three predictors emerged as significant, including gender, having computing career aspirations, and students' major when they took

CS1. Identifying as a woman resulted in a 70% decrease in the likelihood that a latecomer would pursue a computing major or minor within a year of taking CS1. In other words, latecomer men were over three times as likely as women to pick up a computing major or minor. Students who aspired to a computing career were significantly more likely to later select a computing major/minor than those who did not. In fact, computing career aspirations was the strongest predictor in our model, such that students who reported a desire for a computing career were 14.6 times as likely to report having a computing major or minor within one year of CS1 than latecomers who did not aspire to computing careers. Finally, among the higher education experience variables, students' major when they took CS1 was an important factor in their computing major/minor decision. As suggested by the descriptive findings reported above, being a SEM major during CS1 decreased the likelihood that a latecomer would adopt a computing major or minor by 73%.

Table 5. Blocked Logistic Regression Predicting Latecomers' Declaration of a Computing Major or Minor (n=279)

Variable	b	SE	Exp(b)
Student Background			
Socioeconomic Status	-0.38	0.23	0.69
Gender: Women	-1.20	0.50	0.30
Race/Ethnicity: URM	0.11	0.52	1.11
Computing Self-Efficacy ⁺	-0.04	0.26	0.96
Personal Communities			
Parent w/ a STEM Career	0.55	0.45	1.74
Professional Communities			
Computing Career Aspirations	2.69	0.50	14.60
Higher Education Experience			
<i>Normative Contexts</i>			
SEM Major	-1.32	0.45	0.27
CS1 Course Grade	-0.04	0.24	0.97
Inclusive Departmental Climate in Computing ⁺	0.38	0.23	1.46
<i>Socialization Processes</i>			
Peer Support in Computing ⁺	-0.13	0.23	0.88
Role of CS1 Course Fostering Computing Interest ⁺	0.09	0.28	1.09

Note: Bolded numbers indicate significant differences ($p < .05$). ⁺ indicates that this variable is a factor.

5 DISCUSSION AND IMPLICATIONS

5.1 Pathways of Latecomers to Computing Majors and Minors

This study reveals important information about the backgrounds of non-computing students who enroll in CS1 courses in their third or later year of college. In some ways, these "latecomers" look similar to "early adopters," or computing students who take CS1 in their first two years of college (e.g., they have similar racial/ethnic and socioeconomic backgrounds). However, there are at least two important ways in which they differ. First, women make up a significantly larger proportion of latecomers than they do the early adopters group, confirming suggestions that computing departments should consider the non-majors enrolled

in CS1 as a potential pool from which to recruit women [23]. Second, latecomers are more likely to have attended a community college. This supports the idea that varying educational trajectories may influence the timing of students' exposure to computing and lead some, particularly those from underrepresented groups, to come to their interest in computing later in their college career [16, 17, 23]. More research is needed on the trajectories of community college students in computing.

Given that the latecomers in our study were in at least their third year of college, they naturally came to the course with another disciplinary affiliation. While many of them identified other science, engineering, or math fields as their major during CS1 (see Table 3), few students with SEM majors ultimately added or switched to a computing major or minor. Indeed, being a SEM major was a significant, negative predictor of selecting a computing major or minor. Future research should investigate this further, but we speculate several possible reasons for this. First, SEM majors may be less inclined to add or switch to a computing major given their degree of commitment to (and course-taking investment already made in) their current major. Further, whereas SEM majors may have clear career trajectories associated with their majors, non-SEM majors may have an incentive to add or switch to a computing major or minor because of the possible career benefits. Indeed, latecomers may be making a wise investment, as evidence suggests adding a double major in computing significantly predicts higher earnings [12].

Once they have completed CS1, our findings show that a small but significant portion (16%) of latecomers choose to switch to or add a computing major or minor. Related to the conversation above, we expected that most latecomers would add a minor given the time constraints of adding a second major or switching to a new major. However, among those who did select a computing major or minor, more than twice as many reported adding a computing major than reported adding a minor. This finding supports the literature showing that many college students change majors at least once during college [19].

5.2 Leveraging the Latecomer Pool to Recruit Women to Computing

An overarching question guiding this study was whether computing fields might be able to diversify by recruiting from students who enroll in CS1 later in college. As discussed above, findings suggest that these "latecomers" are a good potential pool from which to recruit women into computing majors but may offer less of an opportunity to recruit URM students. Still, regression results show that men who are latecomers are much more likely to take on a computing major or minor after CS1 than women. This represents a missed opportunity to recruit women, given that women make up nearly half of the latecomer group.

In considering one of the other significant positive predictors in our model (having computing career aspirations), we conducted post-hoc analyses to look further into this group. We found that among the latecomers who reported computing career interests

(which represented only 17% of the latecomer sample), 58% of the men ultimately switched to or added a computing major or minor, compared to 33% of the women. Relatively few latecomer women have computing career aspirations, and in fact most latecomers' career interests cluster around helping fields, as the largest proportions of latecomers say they want to be psychologists, K-12 professionals, or librarians. Thus, computing departments and CS1 instructors wishing to recruit more women into computing majors and minors ought to consider using their intro classrooms as a space to not only teach students about what computer science is, but what one can do with it. Research has suggested that one way to recruit women to STEM fields is to focus on the social value of those careers [7]. Hence, helping latecomers, particularly women, learn more about computing careers and making explicit connections to the social value of computing may be useful in recruiting them to computing majors and minors.

In light of our findings concerning latecomers to computing, we suggest that computing departments, when developing CS1 policies and practices, be aware of the students who may discover computing later in their college careers. In doing so, departments may be able to foster interest in computing among students who had not previously seen themselves as computer scientists.

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