



A Longitudinal Analysis of Community College Pathways to Computer Science Bachelor's Degrees

2016



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Additional reports from Google's Computer Science Education Research are available at g.co/cseduresearch.

Executive Summary

A Longitudinal Analysis of Community College Pathways to Computer Science Bachelor's Degrees is one in a series of Google reports designed to explore the pathways and experiences that community college students – especially those from underrepresented groups – follow to a bachelor's degree in computer science (CS) and the opportunities that exist or that might be created to ensure successful career advancement. While the companion report, *Student Perspectives of Community College Pathways to Computer Science Bachelor's Degrees* (Lyon & Denner, 2016), takes a qualitative approach to understanding the challenges facing underrepresented community college students in California who hope to transfer and complete a bachelor's degree in CS, this report investigates the national landscape of CS students at community colleges in order to better understand student behaviors and institutional characteristics that support or hinder community college students' efforts to attain a CS bachelor's degree.

Key findings and recommendations

In general, the data suggest that navigating the community college pathway to a CS bachelor's degree is complex and challenging, such that only students who are focused and fortunate are able to navigate the pathway successfully. To create more structured and supported pathways that will help a larger number of underrepresented community college students to attain a CS bachelor's degree, two- and four-year colleges – particularly those in major technology hubs – need to partner more closely together. In particular:

- » **Nearby community colleges and four-year colleges should work together to create CS-specific program maps** that guarantee acceptance to the destination college's CS-related majors if students complete specific courses with a specific grade point average.
- » **Program maps should include options for different levels of math and science preparation based on the specific requirements of certain CS subfields**, and should perhaps include a CS-specific pre-baccalaureate award as a formal stepping-stone to transfer, in order to entice more CS associate degree earners to transfer into CS programs at four-year colleges.
- » **Community colleges should proactively recruit underrepresented students into CS majors**, emphasizing the wide array of creative, prosocial, and well-paid careers available to those with CS expertise.
- » **Four-year colleges should encourage transfer students to select a major prior to transfer**, and for those who choose a CS major, provide tailored support services, proactively track progress, and intervene when students appear to be veering "off track."
- » **CS departments should emphasize the career rewards that come with completing a higher degree**, ensure that students encounter interesting and meaningful programming assignments, and encourage students to work collaboratively on assignments.

Introduction

According to the Bureau of Labor Statistics, in 2024 nearly 4.6 million jobs will be in computer science and related fields (Bureau of Labor Statistics, 2015). Computer science (CS) is the study of how computers are designed, and how to use computer programming or coding to create software, apps, games, websites, electronics, and other conveniences of modern life. The CS job sector is growing quickly and provides high wages (Lockard & Wolf, 2012; Rothwell, 2013), yet colleges have been unable to produce enough CS graduates to meet industry demand, with one analysis suggesting a shortage of nearly 100,000 CS graduates per year (Levis, 2012). The shortage is particularly severe among women and underrepresented minorities. Among the bachelor's degrees awarded in computer and information science in 2013–2014, only 18% were awarded to women, 11% to Black students, and 9% to Hispanic students (Snyder, de Brey, & Dillow, 2015, Table 318.30). And for women, the picture is not getting brighter. The proportion of bachelor's degrees in CS earned by women dropped from 23% in 2004 to 18% in 2014 (National Student Clearinghouse Research Center, 2015). Increasing the gender and racial/ethnic diversity of employees in CS careers is vital to the development of technology innovations that can meet the needs of more people. As one commentator put it: "Software developers create technology that matches their experience. We have endless iterations of technological solutions for the problems faced by the predominantly White, wealthy, male elite — in San Francisco, an individual with an iPhone and disposable income never has to wait for a cab, thanks to the proliferation of companies like Uber, Lyft, and Sidecar. However, the public transportation that serves the rest of the Bay Area remains notoriously unreliable" (Novak, 2014).

One potential source of increased diversity for the CS field is the nation's community colleges. Forty-five percent of all U.S. undergraduates are educated at community colleges, including 57% of Hispanic and 52% of Black undergraduates (American Association of

Community Colleges, 2016). Many community college attendees transfer to a four-year institution in order to earn a bachelor's degree or higher. Indeed, among students who receive bachelor's or master's degrees in science, technology, engineering, and mathematics (STEM) or health fields, around half attended a community college at some point; this percentage is even higher among female, Black, and Hispanic degree recipients (Mooney & Foley, 2011).

Unfortunately, students who follow the community college pathway to a baccalaureate encounter multiple challenges and obstacles along the way, regardless of their major. Only 14% of degree-seeking community college students transfer and earn a bachelor's degree within six years (Jenkins & Fink, 2016). Some of these students are thwarted by poor academic performance, but many otherwise successful students are stymied by the logistics of selecting and transferring to a four-year school — for example, the complex task of ensuring that they take courses that will apply to their destination school and program (Bailey, Jaggars, & Jenkins, 2015; Booth et al., 2013; Kadlec & Martinez, 2013; Monaghan & Attewell, 2015; Xu & Jaggars, 2016).

For students interested in pursuing CS and other STEM majors, the transfer process can be particularly problematic (Wang, 2015). At the university level, these majors tend to be highly selective and may have limited capacity, and often transfer students are regarded as a low priority for major admission (Wyner, Deane, Jenkins, & Fink, 2016). They also tend to have strict requirements in terms of courses students must take before being admitted to the major, and for some aspiring transfer students (especially those at small or rural colleges), these courses are not available at their local community college (Wyner et al., 2016). Moreover, many university-level CS programs are experiencing surges in enrollment and as a result are struggling with capacity constraints, which can create an unwelcoming and competitive environment (Roberts, 2016). For female and underrepresented minority students who have thrived in the supportive and collaborative environment of a community college, such a competitive culture can trigger stereotype threat, undermine confidence, or otherwise make them feel the field is a poor fit for their personality and interests, leading many to self-select out (Barker & Garvin-Doxas, 2004; Barker, O'Neill, & Kazim, 2014; Cech, Rubineau, Sibley, & Seron, 2011; Hausmann, Schofield, & Woods, 2007; Margolis & Fisher, 2002; Starobin

& Laanan, 2008; Walton & Cohen, 2007).

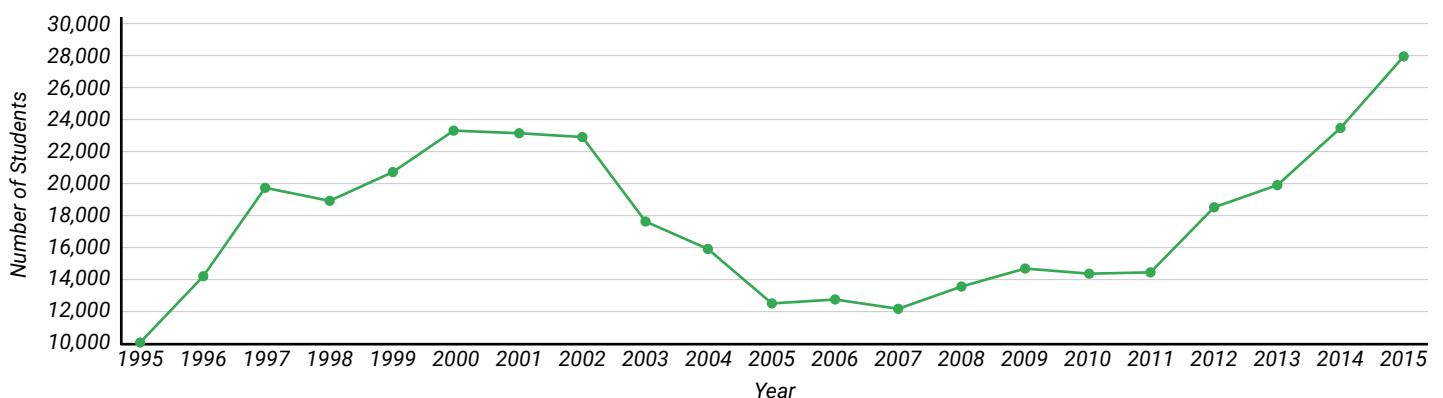
In general, although community colleges are potentially a rich and diverse source of CS students, many challenges stand in the way of these students transferring and earning a bachelor's degree. Given the selectivity of many STEM programs (including CS programs), these challenges may be more severe in STEM than in non-STEM areas. To explore these challenges, Google commissioned the Community College Research Center (CCRC) to study the pathways that first-time community college students follow to a bachelor's degree in CS. In this report, we use quantitative data to describe patterns of degree conferral in CS among students who initially enroll in community college. We also identify the student behaviors (e.g., length of community college enrollment, pre-transfer degree receipt) and institutional characteristics (e.g., selectivity, location) that increase the likelihood of a community college transfer student earning a bachelor's degree in CS compared with other STEM and non-STEM areas. We use these results to explore the larger question of how four-year colleges can recruit and retain more diverse groups of students seeking CS bachelor's degrees. In a companion Google report, Lyon and Denner (2016) investigate the qualitative experience of CS students who aspire to transfer.

The data for this research come from the National Student Clearinghouse (NSC), which maintains student-level enrollment and degree-completion records submitted by colleges and universities across the United States. We focus on the nearly 1.8 million students who entered higher education for the first time through a community

college in the 2007–2008 academic year, and follow those who eventually earned a bachelor's degree at a four-year college by August 2014. We chose the 2007–2008 cohort in order to allow students ample time to graduate within our tracking period; however, it is important to note that much has changed in the field of CS since 2007. As shown in Figure 1, in 2007 undergraduate CS enrollments at PhD-granting institutions were at their lowest level since 1995. As Roberts (2016) explained: "After the tech bubble burst in 2001, student interest in computer science waned throughout the United States, a downturn exacerbated by a popular mythology suggesting – entirely contrary to fact – that all jobs in technology were about to be shipped offshore to low-wage countries like India and China" (p. 2). In 2008, the downturn in enrollments began to reverse, and by August 2009 (when the typical CS bachelor's recipient in our dataset transferred to a four-year college), enrollments were on a clear upward trend, which in recent years has accelerated to the extent that many four-year university CS departments are now oversubscribed. Accordingly, our results reflect the situation at a point in time when CS programs were expanding their enrollments but probably had not yet encountered critical capacity constraints.

Figure 1.

NEWLY DECLARED COMPUTER SCIENCE/COMPUTER ENGINEERING UNDERGRADUATE MAJORS



Reproduced with permission from Zweben and Bizot (2016).¹

¹ Figure 1 includes PhD-granting institutions only. Trend data for master's-level institutions is available only for three years (see Tims, Zweben, Timanovsky, & Prey, 2015); data for lower tier institutions is not available.

Methods

In this section, we briefly describe the report's methods; additional details can be found in the Appendix. We restricted the data for this study to students whose first entry into higher education was through community college, excluding those whose only community college enrollment was concurrent with high school enrollment. All students were tracked until August 2014, or for approximately seven years. Students' associate and bachelor's degrees were classified into one of three mutually exclusive categories: CS and similar fields that can serve as a stepping-stone into CS, other non-CS STEM fields ("other STEM"), or non-STEM fields.

Due to incomplete coverage, we were not able to use race/ethnicity values from the NSC data. We were, however, able to derive measures of neighborhood socioeconomic status (SES) by merging students' geocoded home locations with U.S. census tract data. To capture college characteristics, we merged NSC data with Integrated Postsecondary Education Data System (IPEDS) data. Following the lead of Jenkins and Fink (2016), we also calculated metrics that captured each college's institutional-level performance in terms of its production of successful transfer students, including two community college metrics (*transfer-out rate* and *transfer-out bachelor's completion rate*) and one four-year college metric (*transfer-in bachelor's completion rate*). Colleges that intentionally create programmatic, advising, and policy structures that support transfer students are more likely to score well on these metrics (Wyner et al., 2016). For our analysis, we classified each college in the dataset according to whether it was above or below the national average on each relevant metric. To create a metric focused more specifically on how well CS and other STEM programs within each receiving institution support community college transfer students, we also calculated whether community college transfers were equally (or more) likely to be represented among degree

earners in those programs, compared with the typical four-year college student (see Appendix for more details).

In our primary analysis, we compared the types of bachelor's degree earners (CS, other STEM, or non-STEM) along a variety of student and college characteristics. As a supplemental analysis, we also identified students who earned a pre-baccalaureate degree or certificate (hereinafter collectively referred to as awards) in CS and compared those of them who never earned a bachelor's degree with those who did, with attention to the type of field in which they ultimately earned a bachelor's degree (see Appendix for more details).

Results

Overall, our results indicate that students who are successful in following the community college pathway to a CS baccalaureate have relatively strong socioeconomic backgrounds, are more likely to come from cities or suburban areas that have a strong technology industry, and attend institutions that have relatively strong transfer performance, particularly in the CS area. In addition, they begin college at a younger age and are more focused in terms of their enrollment behaviors, compared with community college students who earn bachelor's degrees in other fields.

Profiling the Typical Bachelor's Degree Earner Who Started at Community College

Figures 2–4 present selected individual-level and institutional characteristics of bachelor's degree earners overall, as well as bachelor's degree earners in non-STEM, STEM, and CS majors. On average, bachelor's degree earners tended to be female (54%), relatively socioeconomically advantaged (59% were from the top two SES quintiles, while only 22% were from the bottom two), and from the South or West.² Few (15%) were dually enrolled in community college during high school. On average, at around age 20 (average 19.9), they enrolled in a community college that was above average in its transfer effectiveness (63% attended a college that had an above average transfer-out rate, and 58% attended one with an above average transfer-out bachelor's completion rate). They stayed enrolled at the same college (only 23% switched between community colleges) for four continuous semesters (an average of 3.9 semesters enrolled, attending

an average of 86% of the fall and spring semesters between entry and transfer), with half of those semesters being full-time. They typically did not earn a pre-baccalaureate award (only 22% did so), and took about four months off before transfer (4.1 months), thus enrolling in their four-year destination approximately two years after community college entry (24.1 months). They tended to enroll in public, moderately selective four-year colleges, which on average were located 154 miles away from their community college. Most eventual bachelor's recipients (70%) enrolled in a four-year college that had strong bachelor's completion rates among community college transfer students, but few enrolled in colleges that had strong representation of transfer students among their CS and other STEM graduates (19% and 16%, respectively). Typically, they remained at the same four-year college (only 21% switched colleges) for two years (6.4 semesters), attending full-time and continuously (attending an average of 91% of all possible fall/spring semesters between time of transfer and time of graduation, with an average of 85% of those semesters being full-time).

Although this was the *average* pathway, it was not *typical*. Most individual student pathways varied substantially from the average. For example, although the aggregate statistics seem to imply that most students followed a “2 + 3” bachelor's degree path (attending continuously and mostly full-time for two years at one community college, then enrolling for three years at one four-year college), under 3% of the sample followed this particular pattern. Many students stayed a longer or shorter time at their two-year or four-year colleges, switched from full-time to part-time and back again, switched between colleges, or stopped out (did not enroll during some fall/spring semesters). For example, only 21% enrolled full-time for eight continuous fall/spring semesters (not shown).

² The South and West are strongly represented in our dataset in part due to demographics (35% of students in the larger NSC database lived in the South and 31% in the West) and in part due to the strong transfer performance of the large states of Florida, Texas, and California (see Jenkins & Fink, 2016).

Comparing CS Bachelor's Degree Earners With Other STEM and Non-STEM Degree Earners

As Figures 2–4 show, CS bachelor's degree earners varied substantially from other STEM and non-STEM bachelor's degree earners on a number of characteristics.³ Only 12% of CS bachelor's recipients were female, compared with 50% of other STEM graduates and 56% of non-STEM graduates. CS bachelor's recipients were also more likely to grow up near a technology hub (33% came from within 50 miles of a technology hub, compared with 27% of other STEM and 29% of non-STEM bachelor's recipients), but they were no more likely to grow up near other major cities. CS and STEM bachelor's degree earners were also more likely to start earning college credits while still in high school (18% and 19% respectively had participated in dual enrollment programs, compared with 13% of non-STEM bachelor's degree earners).

Only 12% of CS bachelor's recipients were female, compared with 50% of other STEM graduates and 56% of non-STEM graduates.

Figure 2.

SELECTED DEMOGRAPHICS BY BACHELOR'S DEGREE AREA

Demographic Variables	All Areas	Non-STEM	Other STEM	CS
Total count	235,388	170,391	49,839	3,290
Female	54%	56%	50%	12%
Census tract				
Top two SES quintiles	59%	60%	58%	60%
Bottom two SES quintiles	22%	22%	23%	22%
U.S. region				
Northeast	15%	15%	13%	13%
Midwest	20%	19%	22%	20%
South	40%	40%	42%	40%
West	26%	26%	23%	27%
Location				
Within 50 miles of tech hub	28%	29%	27%	33%
Within 50 miles of non-tech hub major U.S. city	18%	18%	16%	15%

³ Given our large sample size, all apparent differences between these groups – more than 1 or 2 percentage points' difference – are significant at $p < .05$ on a univariate basis.

Compared with other types of bachelor's recipients, CS bachelor's earners attended similar types of community colleges, but their enrollment patterns at those colleges were different. They were more likely to remain at the same college (only 17% switched, compared with 24% of other STEM and 22% of non-STEM graduates), spent less time in the two-year sector (an average of 3.5 semesters, compared with 3.7 for other STEM and 3.9 for non-STEM graduates), and were less likely to earn an award before transfer (19%, compared with 21% for other STEM and 23% for non-STEM graduates). Only 6% of CS bachelor's recipients earned a CS-related community college award before transferring, while only 8% of other STEM bachelor's recipients first earned a STEM community college award. (These low percentages are likely due to the fact that many community colleges do not offer transfer-oriented degrees in CS or STEM; see the Appendix.)

Figure 3.

SELECTED COMMUNITY COLLEGE CHARACTERISTICS, ENROLLMENT BEHAVIORS, AND AWARDS BY BACHELOR'S DEGREE AREA

Community College Variables	All Areas	Non-STEM	Other STEM	CS
Total count	235,388	170,391	49,839	3,290
Above average transfer-out rate	63%	63%	62%	61%
Above average transfer-out bachelor's completion rate	58%	59%	57%	57%
Dually enrolled during high school (17 or younger)	15%	13%	19%	18%
Community college enrollment				
Age at first enrollment	19.9	19.9	19.8	19.5
Total semesters enrolled	3.9	3.9	3.7	3.5
Percentage of terms enrolled (of fall/spring terms between entry and transfer)	86%	86%	83%	82%
Percentage of terms enrolled full-time (of all fall/spring terms enrolled)	50%	52%	44%	48%
Enrolled in more than one community college	23%	22%	24%	17%
Award earned prior to transfer				
CS-related area	< 1%	< 1%	1%	6%
Non-CS STEM	4%	1%	8%	2%
Non-STEM	20%	20%	10%	9%
Any award	22%	23%	21%	19%

In terms of their four-year college experience, CS and other STEM bachelor's degree recipients transferred to their four-year destination sooner (an average of 22.6 and 22.9 months respectively after initial enrollment, compared with 24.5 months for non-STEM degree recipients). CS and other STEM degree recipients were also more likely to transfer to a more selective destination (35%) than were non-STEM degree recipients (25%). CS graduates attended four-year colleges that were closer to home (132 miles from their community college, compared with 151 miles for other STEM and 155 miles for non-STEM graduates), and were also more likely to transfer to destinations that had strong representation of transfer students among their CS graduates (30% attended such colleges, compared with 18% of other STEM and 20% of non-STEM graduates). Similarly, other STEM graduates were more likely to attend a four-year institution that had strong representation of community college transfers among its other STEM graduates (22%), compared with CS (18%) and non-STEM (15%) graduates. CS graduates were more likely to stay at a single four-year college (13% switched,

Taking into account lengths of enrollment, switches between schools, and different numbers and lengths of stop-out breaks, the CS bachelor's degree earners in our dataset followed 1,213 distinct paths to graduation.

compared with 24% of other STEM and 21% of non-STEM graduates). On average, CS and STEM graduates remained at the four-year college longer (6.9 semesters) than their non-STEM peers (6.3 semesters).

A closer look at the enrollment data (not shown) indicates that for CS bachelor's degree earners, the most common enrollment pattern was a "1 + 4" pathway with no stopping out (5%), followed by a "2 + 3," "2 + 3.5," or "2 + 2.5" pathway with no stopping out (4%). Only 1% followed the traditional full-time "2 + 2" path. Taking into account lengths of enrollment, switches between schools, and different numbers and lengths of stop-out breaks, the CS bachelor's degree earners in our dataset followed 1,213 distinct paths to graduation.

Figure 4.

SELECTED BACHELOR'S DEGREE–GRANTING INSTITUTION CHARACTERISTICS AND ENROLLMENT BEHAVIORS BY BACHELOR'S DEGREE AREA

Four-Year College Variables	All Areas	Non-STEM	Other STEM	CS
Total count	235,388	170,391	49,839	3,290
Sector				
Public	80%	79%	80%	80%
Private nonprofit	18%	18%	16%	15%
Private for-profit	3%	3%	3%	5%
IPEDS selectivity				
Inclusive	17%	17%	14%	17%
Selective	55%	58%	50%	49%
More selective	27%	25%	35%	35%
Miles from student's last community college	154	155	151	132
Outcomes for community college transfer students				
Above average transfer-in bachelor's completion rate	70%	69%	69%	67%
Equal/better transfer representation among CS bachelor's recipients	19%	20%	18%	30%
Equal/better transfer representation among other STEM bachelor's recipients	16%	15%	22%	18%
Months from initial enrollment to transfer	24.1	24.5	22.9	22.6
Months between last community college and first four-year college enrollment	4.1	4.1	4.2	4.1
Total semesters enrolled	6.4	6.3	6.9	6.9
Percentage of terms enrolled (of fall/spring terms between transfer and degree)	91%	90%	92%	92%
Percentage of terms enrolled full-time (of all fall/spring terms enrolled)	85%	85%	85%	84%
Enrolled in more than one four-year college	21%	21%	24%	13%

Tracking CS Pre-baccalaureate Award Recipients

Figures 5–7 look at students who earned a pre-baccalaureate award in CS prior to any four-year college enrollment, and describe the differences between those who eventually earned a CS bachelor's degree and those who did not. These figures contain only the subset of pre-baccalaureate awards that could be positively identified as CS or CS stepping-stone awards, using a methodology discussed in the Appendix. Most community college students interested in CS earn a general associate degree while taking some courses in CS; these students are not captured in Figures 5–7 (see the Appendix for more discussion of this point). Of the nearly 1.8 million community college entrants in our dataset, we were able

to classify only 6,561 as earning a pre-baccalaureate award in CS or a similar stepping-stone field prior to any four-year enrollment.

Of the students we could positively identify as earning a pre-baccalaureate award in a CS field, 69% never transferred to a four-year college, likely because many CS-specific sub-baccalaureate awards are applied in nature and not designed for transfer. About 21% transferred but did not earn a bachelor's degree by the end of the study period; approximately 10% eventually earned a bachelor's degree, including less than 3% who earned a CS bachelor's. Overall, these bachelor's earners were older; while the average CS bachelor's degree earner first entered college at 19.5 years of age, the average CS bachelor's earner who also earned a CS-specific pre-baccalaureate award was 21.7 at first college enrollment.

Figure 5.

SELECTED DEMOGRAPHIC CHARACTERISTICS OF CS PRE-BACCALAUREATE AWARD RECIPIENTS, BY TRANSFER AND BACHELOR'S DEGREE OUTCOMES

Demographic Variables	Did Not Transfer	Transferred, No Bachelor's	Non-STEM Bachelor's	Other STEM Bachelor's	CS Bachelor's
Total count	4,531	1,348	220	278	184
Female	22%	18%	28%	17%	11%
Census tract					
Top two SES quintiles	47%	52%	56%	59%	55%
Bottom two SES quintiles	33%	29%	29%	27%	23%

Figure 6.

SELECTED COMMUNITY COLLEGE CHARACTERISTICS AND ENROLLMENT BEHAVIORS OF CS PRE-BACCALAUREATE AWARD RECIPIENTS, BY TRANSFER AND BACHELOR'S DEGREE OUTCOMES

Community College Variables	Did Not Transfer	Transferred, No Bachelor's	Non-STEM Bachelor's	Other STEM Bachelor's	CS Bachelor's
Total count	4,531	1,348	220	278	184
Primarily occupational	42%	40%	47%	37%	42%
Above average transfer-out rate	42%	55%	61%	63%	61%
Above average transfer-out bachelor's completion rate	41%	42%	51%	48%	49%
Age at first enrollment	26.8	23.3	22.7	21.8	21.7
Total semesters enrolled	7.3	7.6	5.9	6.0	6.0
Percentage of terms enrolled (of fall/spring terms between entry and transfer)	82%	90%	94%	94%	95%
Percentage of terms enrolled full-time (of all fall/spring terms enrolled)	50%	56%	69%	71%	73%
Enrolled in more than one community college	23%	21%	19%	18%	11%

Among the students who earned a CS pre-baccalaureate award, those who never transferred seemed to be older and lower income than those who earned some type of bachelor's within the timeframe under study. Compared with their peers who earned a CS bachelor's degree, they were twice as likely to be female. While they were similarly likely to attend a community college that had an occupational (vs. transfer) focus, their colleges had weaker transfer performance metrics.

Students who transferred but did not earn a degree fell between their non-transferring peers and their bachelor's-earning peers in terms of SES, age at first enrollment, and their community college's transfer performance. Compared with bachelor's degree earners, they also transferred to their

four-year college substantially later. They were less likely to attend community college full-time, less likely to remain continuously enrolled, more likely to switch between two-year colleges, and had a longer gap between community college and four-year enrollment. They were also more likely to switch between four-year colleges, and to attend inclusive or private for-profit four-years (sectors which market heavily to underrepresented students, and also tend to have lower graduation rates for transfer students; see Jenkins & Fink, 2016). In general, these students seemed to "swirl around" during their college years, which may reflect a struggle to stay focused on school while dealing with other life challenges. Given that they entered their transfer destination more than a year later than students who

graduated, we also examined the proportion who were still enrolled during the final semester of our tracking period (not shown); 51% were still enrolled, suggesting that they may eventually earn a bachelor's degree of some type.

Comparisons between CS pre-baccalaureate award recipients who eventually earned CS, other STEM, and non-STEM degrees are reminiscent of those observed for all bachelor's degree earners in Figures 2–4. In particular, students who graduated with CS bachelor's degrees were substantially more likely to attend four-year colleges that had strong representation of transfer students among their CS graduates. In contrast, those who eventually graduated with another type of STEM bachelor's degree were more likely to attend four-year colleges with strong representation

of transfers among their other STEM graduates, which may help explain why these CS pre-baccalaureate award recipients chose to switch from CS to another STEM field. Interestingly, we also found that CS pre-baccalaureate award recipients who eventually graduated with a non-STEM bachelor's degree were substantially more likely to have attended a primarily occupational community college, which may suggest that they earned an occupational (rather than transfer-oriented) CS pre-baccalaureate award. These occupational CS awards may not have articulated well with four-year colleges' CS programs – which may have prompted these students' switch away from CS.

Figure 7.

SELECTED BACHELOR'S DEGREE-GRANTING INSTITUTION CHARACTERISTICS AND ENROLLMENT BEHAVIORS OF CS PRE-BACCALAUREATE AWARD RECIPIENTS, BY TRANSFER AND BACHELOR'S DEGREE OUTCOMES

Four-Year College Variables	Transferred, No Bachelor's	Non-STEM Bachelor's	Other STEM Bachelor's	CS Bachelor's
Total count	1,348	220	278	184
Sector				
Public	89%	77%	77%	81%
Private nonprofit	18%	16%	17%	17%
Private for-profit	9%	7%	7%	2%
IPEDS selectivity				
Inclusive	35%	26%	23%	20%
Selective	54%	64%	64%	54%
More selective	12%	10%	13%	25%
Outcomes for community college transfer students				
Above average transfer-in bachelor's completion rate	43%	60%	48%	65%
Equal/better transfer representation among CS bachelor's recipients	17%	18%	11%	38%
Equal/better transfer representation among other STEM bachelor's recipients	16%	11%	18%	16%
Months from initial enrollment to transfer	54.9	36.1	36.9	36.5
Months between last community college and first four-year college enrollment	9.1	4.4	4.7	4.0
Total semesters enrolled	3.3	5.0	5.2	5.4
Percentage of terms enrolled (restricted to award recipients)		89%	88%	93%
Percentage of enrolled terms that were full-time (restricted to award recipients)		73%	73%	83%
Enrolled in more than one four-year college	9%	13%	11%	8%

Discussion

Overall, compared with their peers who eventually attained other STEM or non-STEM bachelor's degrees, community college students who eventually earned CS bachelor's degrees seemed to be both focused and fortunate. They were more likely to grow up near a technology hub city, and in a neighborhood with a relatively high SES, both of which circumstances may have supported their development of a CS goal from high school or earlier (cf. Google & Gallup, 2015). Their focus was apparent in that they were more likely to start community college while still in high school and were less likely to “swirl” among multiple institutions once they began college. Their luck was apparent in that their local community college happened to have strong transfer performance, and in the fact that there was a nearby four-year college with strong supports for CS transfers. However, the astounding variation in the unique paths that CS students followed to a bachelor's degree, together with the fact that they were less likely to earn a community college award – and that very few earned a CS-specific award – suggests that the CS pathway is not a well-structured and highly traveled one. In general, these students navigated the challenges of transfer by spending less time at the community college (where they would accrue credits that might not transfer) and more time at the four-year college.

While this confluence of focus and luck was most obvious for CS bachelor's earners, it was also apparent for other STEM bachelor's earners, who fell between the CS bachelor's earners and the other groups on a variety of characteristics and behaviors, and were most likely to attend a four-year college with strong supports for non-CS STEM transfers. In

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general, the data suggest that navigating the pathway to a CS bachelor's degree is most complex and challenging, followed by navigating the pathway to other types of STEM bachelor's degrees. As Google's companion report (Lyon & Denner, 2016) notes, students typically devise their own individualized pathway through transfer to a bachelor's degree in CS.

Creating Structured Pathways for Community College Transfer Students

Research suggests that two-year and four-year colleges need to partner together to create more structured transfer pathways (Bailey et al., 2015; Wyner et al., 2016). Our results show there is a leaky pipeline from the CS pre-baccalaureate award to a CS bachelor's degree, which intentional design and collaboration could help repair. For example, CS pre-baccalaureate award earners who switched into another STEM program for their bachelor's degree may have done so because they earned an applied CS award that did not articulate well with four-year CS degree programs, or because their chosen four-year college had stronger supports for other STEM transfers than for CS transfers.

Structured transfer pathways require two-year and four-year colleges to work both together and separately to support the success of transfer students in selected fields. Together, two nearby colleges need to create major-specific program maps, which clearly specify the courses students must take at the community college in order to transfer a full block of courses to the destination major without a loss of credit; ensure that students will be guaranteed acceptance to the destination major if they complete those courses with a specific grade point average; and establish a method for regularly discussing and updating those program maps (Bailey et al., 2015; Lyon & Denner, 2016; Wyner et al., 2016). The community college must work to help students determine their destination college and major as quickly as possible, continuously monitor students' academic progress, and intervene when necessary to get students back on track (Bailey et al., 2015; Wyner et al., 2016). It is also helpful for community colleges to integrate major-specific orientation material into key introductory courses for the major, which helps students understand the varieties of degrees and career options available, how to navigate the transfer system, financial aid issues, and other

factors that support successful transfer (Bailey et al., 2015; Starobin & Laanan, 2008). For its part, the destination four-year college should encourage transfer students to select a major prior to transferring, and it should make credit acceptance determinations for the major at the point of acceptance rather than after the student enrolls (Wyner et al., 2016). Four-year colleges should also assign dedicated advisors to transfer students, and tailor versions of their orientation and other services specifically for transfer students (Jackson & Laanan, 2011; Wyner et al., 2016).

Creating structured transfer pathways in CS may be more challenging than doing so in other areas, for two reasons. First, community college CS programs tend to have an applied focus, and are typically designed to prepare students to immediately enter a computer-related career, rather than to prepare students for transfer (Lundy-Wagner & Chan, 2016). As a result, most community college students interested in a CS bachelor's degree will follow a general education or Associate of Arts program while attempting to identify the CS courses that are appropriate for their desired four-year destination. These general associate programs often include requirements that are not required by the student's four-year CS program of choice, which may discourage students from completing the associate degree before transfer. These factors may explain why CS bachelor's recipients in our dataset were less likely to earn pre-baccalaureate awards and tended to transfer earlier than their peers – perhaps the courses they needed were not available at the two-year college, or perhaps the two-year college's CS curriculum was generally misaligned with that of the four-year program they desired to enter, or perhaps they were worried about whether or not their courses would transfer and wanted to play it safe (Lyon & Denner, 2016; Wyner et al., 2016).

Second, these students' decision-making processes are complicated by the fact that expectations in terms of coursework vary widely across CS programs. Indeed, a single large four-year university may have multiple CS-related programs, with some located in engineering, some in the arts and sciences, and some in other areas, each with different requirements. These programs may also be accredited by different industry commissions from one another, and by different commissions than the community college's programs. As a result, the lower division curriculum for a four-year college's most obvious "CS" program is sometimes quite different from that of the

local community college. Lower division courses at four-year colleges may emphasize theoretical and mathematical issues in computing, while community college courses may emphasize hands-on practice with programming. In some states, major-specific statewide articulation agreements may help ameliorate such challenges, but often, colleges must work together to identify the variety of bachelor's programs and map out the types of lower division coursework that lead to each (Wyner et al., 2016). In CS, such discussions could start with the Association for Computing Machinery/Institute of Electrical and Electronic Engineers (ACM/IEEE) curricular guidelines; while four-year CS programs are eligible for accreditation by the Accreditation Board for Engineering and Technology (ABET), two-year CS degree programs currently are not. However, ABET uses the ACM/IEEE curricular guidelines in CS to inform its program accreditation criteria (see ABET, n.d.; Association for Computing Machinery & IEEE Computer Society, 2013). It is also important to note that ABET does accredit associate degree programs in computer engineering.

Recruiting and Retaining More Diverse Student Populations in Computer Science

Compared with four-year colleges, community colleges may currently provide a more welcoming context for women and underrepresented minorities who are interested in STEM. While these populations often feel out of place in STEM classrooms at four-year research institutions (Lovitts, 2001; Sax, 1994; Seymour & Hewitt, 1997), the more diverse environment of the community college may help them feel more welcome in fields traditionally dominated by White men (Jackson & Laanan, 2011; Lyon & Denner, 2016; Starobin & Laanan, 2008).

In order to entice more underrepresented students into CS, both community colleges and four-year colleges may need to proactively recruit entering students into the field. Lyon and Denner (2016) found that female and underrepresented minority community college students

In order to entice more underrepresented students into CS, both community colleges and four-year colleges may need to proactively recruit entering students into the field.

became more interested in computing when they learned about the number of job openings in CS fields, the salaries that could be earned, and the broad possibilities for working in the field. Most college students are concerned not only about salaries but also about finding a job that interests them (such as something related to gaming, fashion, or entertainment) or a job that will make a positive difference in the world; thus, highlighting the variety of jobs available, and how those jobs impact quality of life for real people, can be important.

Many community college students may shy away from CS and other STEM degrees because they are worried about their ability to manage the related math requirements (Lyon & Denner, 2016). Indeed, an estimated 59% of entering community college students are deemed underprepared for college-level math and must complete noncredit developmental math courses before enrolling in college-level math or science courses, and very few of these students successfully do so (Bailey et al., 2010; Bailey et al., 2015). Applied CS associate degrees may be more appealing to community college students because they often have fewer math requirements than do CS transfer pathways. To address this math-anxiety issue, community colleges and their four-year partners can consider two complementary strategies. First, both community colleges and four-year colleges can maintain strict math requirements for some CS transfer programs, but community colleges can redesign their developmental and college-level math pathways to be more supportive of underrepresented students (e.g., see Bailey & Jaggars, 2016; Kazis & Cullinane, 2015; Treisman, 1985). Second, four-year colleges can ensure that programs in information science and other less math-intensive CS subfields include only the math prerequisites that are truly necessary for success in those subfields (e.g., see Huang, Hoang, Yesilyurt, & Thorn, 2016; Kazis & Cullinane, 2015; Rutschow & Diamond, 2015).

If community colleges are able to recruit more diverse student populations into CS transfer programs, then four-year colleges must continue to support these students after they transfer. In our dataset, among the community college students who earned a CS-specific pre-baccalaureate award and later transferred, 66% never earned a bachelor's degree (or were still working on it after seven years), while about 25% switched to and completed non-CS degrees. Such students are prime candidates for inducement into

completion of a CS bachelor's degree. They have already demonstrated an interest and aptitude in CS and an interest in earning a bachelor's degree, but some combination of factors derailed them in the four-year college. It is possible that many of these students instead leveraged their basic CS skills into a relatively well-paying full-time job. Indeed, Google's companion report (Lyon & Denner, 2016) details that five years after enrolling in an introductory programming class at a community college, many students were working in the CS field while having dropped out, stopped out, or continued their degree on a part-time basis. For these students, as well as those who switched away from CS, there are a variety of approaches that four-year colleges could pursue in order to resolidify students' commitment and motivation to earn a CS degree.

First, colleges might emphasize the career rewards that come with completing a higher degree (including not only money but also quality of work and life), and help arrange internships that make those careers more concrete in students' minds. As early as high school, most students believe that CS provides well-paying jobs, but women and Hispanic students are less likely to believe this (Google & Gallup, 2015), and so may be more likely to depart college if a relatively well-paying job opportunity presents itself, even if this opportunity may close off their options for further education and career advancement.

Second, four-year CS programs need to ensure that they are welcoming to female and underrepresented minority transfer students. At many four-year colleges, transfer students are last in line for institutional scholarships, on-campus housing, and other resources; colleges can make changes to try to ensure that some resources are available for promising transfer students (Wyner et al., 2016). In addition, four-year colleges can provide bridge programs or summer research programs for transfer students to create a positive first experience with the CS program; encourage transfer students to get involved in campus organizations and clubs; arrange mentoring programs that allow women and underrepresented minorities to meet people "who look like me" who work in related businesses and industry; and encourage students to work together collaboratively on assignments, rather than competing with one another (Barker, Hovey, & Thompson, 2014; Jackson & Laanan, 2011; Starobin & Laanan, 2008).

Third, CS faculty should ensure that transfer students encounter "interesting" and "meaningful" assignments in

their first courses at the four-year college (Bailey et al., 2015; Biggers, Brauer, & Yilmaz, 2008; Revell & Wainwright, 2009; Wilson, 2002). In particular, computing assignments should be relevant to students' personal interests, communities of origin, and career goals, and should show how CS can be useful to society. One large-scale study found that such meaningful assignments were the single most important predictor of students' commitment to a computing major, and this predictor was particularly strong among women and underrepresented minorities (Barker et al., 2014). In Google's companion study, Lyon and Denner (2016) found that female and underrepresented minority students at community colleges were excited about their CS courses when the tasks seemed applicable to real-world interests and challenges.

Alleviating Capacity Constraints at Four-Year and Community Colleges

CS departments at four-year colleges are beginning to grapple with capacity constraints that limit their ability to admit all qualified students (Roberts, 2016; Zweben & Bizot, 2016). Departments may find it difficult to expand their faculties in order to manage increased demand, given that many graduate students and tenure-track faculty are lured away by start-ups, and potential adjunct instructors are disinterested in the relatively low pay that colleges can offer (Roberts, 2016; Zweben & Bizot, 2016). Roberts (2016) speculated that many faculty openings at higher tier institutions are now being filled by drawing faculty "up the ladder" from lower tier institutions, including community colleges. As a result, community colleges and less selective four-year colleges may soon suffer from even stricter capacity constraints.

While students interested in computing are growing more diverse, this progress could be stalled or even reversed if colleges do not increase their capacity in a thoughtful way. For example, when colleges cap course enrollments to manage demand, they often grant priority admittance to students who have declared the major. Students already committed to the major are likely those who took computing courses in high school, and may be predominantly White or Asian men. In contrast, underrepresented minorities and those from high schools without CS offerings who wish to try computing courses

for the first time may be deterred by enrollment caps. As another example, colleges may attempt to manage demand by increasing class sizes, yet this tactic could also negatively impact the retention of women and underrepresented minorities. Large lecture courses are less personal, with less faculty–student and student–peer interaction — two significant predictors of retention in CS. In addition, when classes are large, it can be more challenging for students to establish ties with the peer networks that support learning and the development of an identity as a person who belongs in the field; as a result, underrepresented minorities and women who stand out as different may feel isolated.

To increase capacity in a way that will not negatively impact diversity, departments might consider a tactic that seemed to work well during a similar crisis in the 1980s: retraining faculty from related fields that are facing flat or declining enrollments to teach undergraduate CS courses (Roberts, 2016). Four-year CS departments might also create stronger collaborations with their local community colleges to relieve capacity constraints at the lower division level. Given that CS students in our sample were more likely to attend community colleges near urban technology hubs, and to transfer to nearby four-year colleges, it might be particularly important for institutions located in tech hub areas to pursue such collaborations. For example, four-year colleges could work with their local community colleges to create guaranteed 2 + 2 program maps, thus encouraging more students to earn a full 60 credits at the community college before transferring. Particularly constrained four-year colleges might even consider a 3 + 1 option with their local feeder community colleges. To further strengthen such pathways for diverse student populations, some four-year colleges have established dual-admission programs, such as the intensive three-year bachelor's program offered in collaboration between the community college Hartnell College and California State University Monterey Bay (see <https://sites.google.com/site/csitin3/>). Of course, in order for these collaborative program maps to function properly, community colleges must have enough well-trained CS instructors and facilities to offer the necessary courses. Local technology companies and foundations could help in this regard by funding CS facilities and equipment, sponsoring retraining opportunities for professors in related fields with flat or declining enrollments, or endowing chairs and professorships that will help attract qualified CS faculty.

Conclusion

Given the current labor shortage in the field of CS, it is critical to the continued strength and growth of the U.S. economy for colleges to supply more CS graduates. Moreover, in order to understand the problems faced by diverse populations and generate creative hardware and software solutions, the populations of CS graduates themselves need to be more diverse. Although community colleges represent a promising source for CS bachelor's-level graduates from groups underrepresented in the field, much work remains to be done in order for that promise to be fulfilled. The following findings from our analyses point to areas where further strides could be made toward supporting the success of community college students in CS:

- » **Community college students who eventually attained a CS bachelor's degree were unusually focused and fortunate.** Compared with their peers, community college students in our sample who attained a CS bachelor's degree were more likely to grow up near a technology hub city and in a neighborhood with a relatively high SES. They also seemed unusually focused on earning a degree, even from an early age. They were more likely to start community college while still in high school and less likely to move between institutions once they began college. They were fortunate in that their local community college had strong transfer performance, and in that there was a nearby four-year college with strong supports for CS transfers. In order to level the playing field, community colleges should proactively recruit underrepresented students into CS majors, emphasizing the wide array of creative, prosocial, and well-paid careers available to those with CS expertise. Nearby four-year colleges should work with those community colleges to create CS-specific program maps, which guarantee acceptance to the destination college's CS-related majors if students complete specific courses or a particular pre-baccalaureate award with a specific grade point average. Four-year colleges should encourage students to select a major prior to transfer, and for those who choose a CS major, provide tailored support services, proactively track progress, and intervene when students appear to be veering off track. And in general, CS departments should emphasize the career rewards that come with completing a higher degree, ensure that students encounter interesting and meaningful programming assignments, and encourage students to work collaboratively on assignments.
- » **CS bachelor's degree earners were less likely than their peers to earn a community college award.** Well-articulated transfer pathways often include a pre-baccalaureate award as a stepping-stone to the bachelor's degree. Yet CS bachelor's earners in our dataset were less likely to earn a pre-baccalaureate award, and very few earned one that was specifically designated as a CS-related award. Instead, these students seemed to navigate their own pathway, which included spending less time in community college and more time at the four-year college. Given that students who earn a transfer-oriented associate degree are more likely to complete a bachelor's degree than similar peers who transfer without a degree (Crosta & Kopko, 2015), colleges should consider including a CS-specific pre-baccalaureate award as a formal milestone along the structured transfer pathway.
- » **Although CS pre-baccalaureate award earners were more likely to be from underrepresented groups, few went on to earn a bachelor's degree in CS.** CS pre-baccalaureate award earners were much more likely to be female than eventual CS bachelor's recipients, and were also more likely to come from the lowest two socioeconomic quintiles. Unfortunately, few of them transferred to a four-year college and completed a bachelor's degree, and among those who did, most switched away from CS. This leaky pipeline may be due to a mismatch between CS associate degrees, which tend to be applied in nature, and the prerequisite demands of four-year CS degrees. To address this issue, four-year CS programs might rethink prerequisites for those CS subfields in which typical professional tasks are more applied and less math-intensive. Working in collaboration with local

community colleges, four-year colleges could create bridges from applied associate degrees to these programs in order to entice more CS associate degree earners into four-year bachelor's degree programs.

About Google

Google's core mission is to organize the world's information and make it universally accessible and useful. Google creates products to increase access to opportunity, break down barriers and empower people through technology. To help reach these goals, Google works to inspire young people around the world not just to use technology but to create it. There is a need for more students to pursue an education in computer science, particularly girls and minorities, who have historically been underrepresented in the field. More information on Google's computer science education efforts is available at g.co/csedu.

About CCRC

The Community College Research Center (CCRC), Teachers College, Columbia University, conducts research on the major issues affecting community colleges in the United States and contributes to the development of practice and policy that expands access to higher education and promotes success for all students. For more information about CCRC, visit ccrc.tc.columbia.edu.

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The National Student Clearinghouse® Research Center™ is the research arm of the National Student Clearinghouse. The Research Center works with higher education institutions, states, districts, high schools, and educational organizations to better inform practitioners and policymakers about student educational pathways. Through accurate longitudinal data outcomes reporting, the Research Center enables better educational policy decisions leading to improved student outcomes. For more information, visit <https://nscresearchcenter.org/>.

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Appendix

Cohort Identification and Tracking Period

Using enrollment and degree records from NSC, we selected students who enrolled in college for the first time at a community college during either the fall 2007 or spring 2008 semesters. We excluded students whose only community college enrollment occurred when they were younger than 18, to eliminate students who used their local community college only for dual enrollment purposes before matriculating directly into a four-year college, resulting in $N = 1,774,009$ community college students.

Comparing its database to IPEDS enrollments, NSC reports a national coverage rate of 92% for fall 2007 enrollments at public two-year institutions (coverage reported for fall terms only). Coverage varies by state; there are 14 states with less than 90% coverage, and there are no data on community colleges in Alaska, Delaware, or the District of Columbia. Detailed information on coverage by year and state for each postsecondary sector can be found at <https://nscresearchcenter.org/workingwithourdata/>.

While we excluded students who were exclusively dually enrolled, we included dual enrollment students who subsequently attended a community college for at least one non-summer term at age 18 or older. For these students, we began their college “clock” at age 18. For example, if a student attended community college part-time for one semester at age 16 and then full-time for two semesters at age 18 before entering a four-year college, that student would be flagged in our dataset as a dual enrollment student, but otherwise would be treated as a student who began college full-time at age 18 and attended community college for only two semesters.

We observed enrollment and degree records for students in the cohort for seven calendar years, from August 2007 to August 2014. The NSC database includes information regarding term of enrollment, college of

enrollment, and part-time or full-time status for that term. A *term of enrollment* represents a term in which a student enrolled in at least one formal course (whether developmental or college-level) and remained in that course through the college's census date for that term. Note that students may have some experiences with a given college that fall outside of a formal term of enrollment (e.g., orientations, internships, prematriculation bridge programs, or course auditing experiences); these are not captured in our data.

Transfer and Concurrent Enrollments

Using the same definition as Jenkins and Fink (2016), we identified students as transfers if they enrolled at a four-year institution for at least one term during the tracking period. This definition includes a small number of students who concurrently enrolled at a community college and a four-year college. We also tracked whether students ever enrolled at two or more colleges during the same term. Students were considered concurrently enrolled if they actively enrolled in two or more colleges during the same term. Active enrollments include enrollments of at least 60 days for fall and spring terms, or at least 30 days for summer terms.

Identification of Degrees in Computer Science and STEM Fields

NSC uses an automated algorithm to assign a Classification of Instructional Programs (CIP) code to each student's degree(s) based on the student's degree title(s) submitted by the student's degree-awarding college. Overall, 5% of bachelor's degree records had missing degree titles or otherwise could not be assigned a CIP code. These students were dropped from our analysis, as they could not be classified into one of our three bachelor's degree categories.

In consultation with Google staff members and CS faculty, we defined CS degrees using National Center for Education Statistics (NCES) CIP 2010 codes, as shown in Figure A1. First, we identified CIP codes to indicate degrees in CS. For community college students, we also included CIP codes for CS stepping-stone fields; if a community

college student earned a pre-baccalaureate award in one of these areas, it was classified as a CS award. For STEM awards, we used the same CIP ranges as Wyner et al. (2016), which are shown in Figure A2. CIP codes which met criteria of both CS and STEM were classified as CS.

Figure A1.

COMPUTER SCIENCE CIP CODE DEFINITIONS

Bachelor's Degrees		"Stepping-Stone" Community College Awards	
CIP Code	CIP Title	CIP Code	CIP Title
11.0101	Computer and Information Sciences, General	11.0103	Information Technology
11.0102	Artificial Intelligence	11.0401	Information Science/Studies
11.0104	Informatics	11.0501	Computer Systems Analysis/Analyst
11.0199	Computer and Information Sciences, Other	11.0901	Computer Systems Networking and Telecommunications
11.0201	Computer Programming/Programmer, General	11.1003	Computer and Information Systems Security/Information Assurance
11.0202	Computer Programming, Specific Applications	11.1004	Web/Multimedia Management and Webmaster
11.0203	Computer Programming, Vendor/Product Certification	11.1006	Computer Support Specialist
11.0299	Computer Programming, Other	14.1004	Telecommunications Engineering
11.0301	Data Processing and Data Processing Technology/Technician	14.1099	Electrical, Electronics and Communications Engineering, Other
11.0701	Computer Science	14.2701	Systems Engineering
11.0801	Web Page, Digital/Multimedia and Information Resources Design	14.4201	Mechatronics, Robotics, and Automation Engineering
11.0802	Data Modeling/Warehousing and Database Administration	14.4501	Biological/Biosystems Engineering
11.0803	Computer Graphics	15.0305	Telecommunications Technology/Technician
11.0804	Modeling, Virtual Environments and Simulation	15.0405	Robotics Technology/Technicians
11.0899	Computer Software and Media Applications, Other	15.0406	Automation Engineer Technology/Technician
14.0901	Computer Engineering, General	15.1201	Computer Engineering Technology/Technician
14.0902	Computer Hardware Engineering	15.1202	Computer Technology/Computer Systems Technology
14.0903	Computer Software Engineering	15.1203	Computer Hardware Technology/Technician
14.0999	Computer Engineering, Other	15.1204	Computer Software Technology/Technician
27.0303	Computational Mathematics	15.1299	Computer Engineering Technologies/Technicians, Other
27.0304	Computational and Applied Mathematics	15.1601	Nanotechnology
30.0801	Mathematics and Computer Science	26.0807	Genome Sciences/Genomics
30.1601	Accounting and Computer Science	26.1104	Computational Biology
30.3001	Computational Science	29.0204	Command & Control (C3, C4I) Systems and Operations
		29.0301	Combat Systems Engineering
		30.2501	Cognitive Science

Source: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics (2010).

Figure A2.

STEM CIP CODE DEFINITIONS: ASSOCIATE AND BACHELOR'S DEGREES

CIP Code	CIP Title
01.0000–01.9999	Agriculture, Agriculture Operations, and Related Sciences
03.0000–03.9999	Natural Resources and Conservation
10.0000–10.9999	Communications Technologies/Technicians and Support Services
11.0000–11.9999	Computer and Information Sciences and Support Services
14.0000–14.9999	Engineering
15.0000–15.9999	Engineering Technologies and Engineering-Related Fields
26.0000–26.9999	Biological and Biomedical Sciences
27.0000–27.9999	Mathematics and Statistics
40.0000–40.9999	Physical Sciences
41.0000–41.9999	Science Technologies/Technicians
47.0000–47.9999	Mechanic and Repair Technologies/Technicians
48.0000–48.9999	Precision Production
51.0000–51.9999*	Health Professions and Related Programs

Source: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics (2010).

*Excludes CIP codes and subcodes: 51.06–51.08, 51.18, 51.26, 51.33–51.37, and 51.39.

Of our nearly 1.8 million community college entrants, we were able to classify only 6,561 as earning a pre-baccalaureate award in CS or a similar stepping-stone field. This number is quite different from that provided by NCES (2012, Table 292), which estimated that in 2009–2010 (when one might have expected these students to graduate), the nation's public colleges conferred nearly 15,000 associate degrees in computer and information sciences. However, there are two distinct differences between the NSC dataset and the NCES dataset.

First, the two datasets are composed of different populations. NCES is assessing a "graduation cohort," or all students who earned pre-baccalaureate awards in 2009–2010, regardless of when they entered college; indeed, some may have first entered 10 or 20 years ago. In contrast, the NSC dataset used in this report represents an "entering cohort," or all students who began community college in 2007–2008, and follows them for only seven years. In addition, the NCES dataset includes students who began their careers at either a two- or four-year college, and who may have earned their pre-baccalaureate award after entering a four-year college, while we included only students who began at two-year colleges, and only those pre-baccalaureate awards earned prior to four-year college entry.

Second, individual-level degree title information submitted by each college to NSC does not necessarily

agree with aggregate information on degree CIPs that colleges submit to the federal government, which is used in NCES reports and IPEDS online databases. To submit data to NSC, colleges draw from their college-wide Student Information System (SIS), which may contain a general degree title (e.g., "Associate of Applied Science") or a specific degree title (e.g., "Associate of Science – Computer Science") for a given student. General degree titles are common in the two-year sector, where students often earn a degree in a general area with a concentration in a particular field (a concentration which may or may not be declared to anyone at the college, and, if declared, may or may not be recorded within the SIS). By contrast, in the four-year sector, degree titles tend to be specific.

To submit data to the federal government, colleges use CIP code information, which may be more specific regarding a given student's concentration (if that concentration is tracked by individual programs or the larger college). For example, if a student earned an Associate of Arts with a declared concentration in psychology, the individual-level degree title submitted to NSC may indicate only "Associate of Arts," while the community college may report to the federal government that the student earned an associate degree in psychology. While we cannot be sure how much of the discrepancy between our counts and the NCES counts arises from the difference between NSC's coding of degree title and the degree's actual CIP

code, the discrepancy may not be large; in our dataset, 82% of community colleges awarded at least one CS-specific degree title, which closely matches the proportion of community colleges reporting to IPEDS that they confer pre-baccalaureate awards in CS.

For our primary analysis, which required classification of bachelor's degree titles, the potential discrepancy between degree titles and actual CIP codes was not particularly problematic. For our classification of pre-baccalaureate award titles, however, we were only able to capture "CS" students who earned an award that was specifically designated as a CS award. Many students interested in CS pursue a general Associate of Arts and Sciences degree while taking CS-related courses. However, in general, community colleges are entirely unaware that such students are interested in CS, or interested in

transferring and earning a bachelor's degree in CS. In itself, this is potentially a serious problem: If colleges are not aware of which students are interested in CS, then they cannot provide students with information regarding which courses to take and other preparations required for success as a transfer student in CS. For more research on how community colleges can better help students choose, stay with, and complete a program of study suited to their aptitudes and interests, see Bailey et al. (2015).

Other Variable Definitions

Figure A3 provides information on the data sources and definitions of all other variables shown in Figures 2–7.

Figure A3.

VARIABLE DEFINITIONS

Variable	Source and Definition
Demographic characteristics	
Female	Information on the gender of student at first enrollment is provided to NSC by institutions.
Census tract: Top two SES quintiles; bottom two SES quintiles	We derived a standardized SES composite for each student from three U.S. Census measures: household median income, percentage of adults with a bachelor's degree or higher, and percentage of adults employed in managerial or professional occupations. Census tract data were used to create the SES composites and linked to student records based on students' geocoded home addresses at the time of community college entry. Top- and bottom-quintile contrast groups were created based on the distribution of community college entrants in the sample. See Crosta et al. (2006) for further description of this methodology.
U.S. region: Northeast; Midwest; South; West	Students' starting community college location was categorized according to the U.S. Census regions. To view a map of these regions, visit http://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf
Within 50 miles of tech hub	Tech hubs were identified using a Bureau of Labor Statistics ranking of the top 50 metropolitan areas high in CS jobs per thousand jobs, and, as a proxy for the tech sector, we used locations of Google's North American Tech Hubs and other Google offices housing software development and engineering teams. The following 22 locations were identified as tech hubs due to mutual overlap across the aforementioned criteria: Ann Arbor, MI; Atlanta, GA; Austin, TX; Boulder, CO; Cambridge, MA; Chicago, IL; Denver, CO; Detroit, MI; Huntsville, AL; Los Angeles, CA; Madison, WI; Minneapolis, MN; Mountain View, CA; Nashville, TN; New York, NY; Orange County, CA; Pittsburgh, PA; Raleigh-Durham, NC; Reston, VA; San Francisco, CA; Seattle, WA; and Washington, DC. Using students' geocoded home addresses, we created an indicator for each student who lived within 50 miles of a tech hub at community college entry.
Within 50 miles of non-tech hub major U.S. city	To create a comparison category for the tech hub variable, we identified students with geocoded home addresses within 50 miles of a non-tech hub major U.S. city. We used a list of the most populous U.S. cities, removed the tech hubs, and selected the 22 most populous cities that remained: Bakersfield, CA; Boise, ID; Columbus, GA; El Paso, TX; Fresno, CA; Grand Rapids, MI; Jacksonville, FL; Las Vegas, NV; Los Angeles, CA; Louisville, KY; Memphis, TN; Miami, FL; New Orleans, LA; Orlando, FL; Philadelphia, PA; Spokane, WA; Springfield, MA; Toledo, OH; Tucson, AZ; Tulsa, OK; Virginia Beach, VA; and Wichita, KS.

Variable	Source and Definition
Community college characteristics, enrollment behaviors, and awards	
Primarily occupational	Using IPEDS data on how many associate degrees were awarded in either academic or occupational fields at each community college, we classified colleges that awarded 40% or more occupational associate degrees as primarily occupational. See Jenkins and Fink (2016, p. 10) for further description.
Above average transfer-out rate	Using results from Jenkins and Fink (2016), community colleges with rates of transfer to four-year colleges higher than the national average of 33% were identified.
Above average transfer-out bachelor's completion rate	Using results from Jenkins and Fink (2016), community colleges with transfer students completing bachelor's degrees at rates higher than the national average of 42% were identified.
Dually enrolled during high school (17 or younger)	Based on students' age at first-time-in-college enrollment, students who were 17 or younger were identified as participants in high school dual enrollment courses.
Age at first enrollment	Student age at first enrollment is reported to NSC by institutions.
Total semesters enrolled	This variable represents the number of summer, fall, and spring terms in which a student was enrolled at a community college during the tracking period.
Percentage of terms enrolled	Using NSC enrollment records, we determined the percentage of fall and spring terms between initial enrollment and transfer in which the student was enrolled.
Percentage of terms enrolled full-time	Using NSC enrollment records, we determined the percentage of terms in which the student enrolled full-time (among fall/spring terms in which the student enrolled) between initial enrollment and transfer.
Enrolled in more than one community college	This indicator denotes students who enrolled at two or more different community colleges during the tracking period.
Award earned prior to transfer: CS-related area; non-CS STEM; non-STEM; any award	We counted pre-baccalaureate awards earned prior to transfer to a four-year college. CS-related areas are described in Figure A1. Non-CS STEM-related areas are described in Figure A2.
Bachelor's degree-granting institution characteristics and enrollment behaviors	
Sector: Public; private nonprofit; private for-profit	Institutions were categorized based on IPEDS data on college sector.
IPEDS selectivity: Inclusive; selective; more selective	Institutions were categorized using 2010 Carnegie Undergraduate Profile Classification indicators, accessed through IPEDS.
Miles from student's last community college	We calculated the map distance between transfer students' last pre-transfer community college and their first four-year transfer destination.
Above average transfer-in bachelor's completion rate	Using results from Jenkins and Fink (2016), four-year colleges with graduation rates among their transfer students from community colleges that were higher than the national average of 37% were identified.
Equal/better community college transfer representation among CS bachelor's recipients	For each four-year college, we used IPEDS data to calculate the percentage of bachelor's degrees that were in CS (for example, 10%) and used our dataset to calculate the percentage of transfer student bachelor's degrees that were in CS (for example, 5%). We then calculated the difference (in this case, a difference of negative 5 percentage points). Colleges in which transfer students had equal or better representation in terms of the likelihood of earning a CS degree (a difference of 0 or any difference in the positive direction) compared to all students were considered to have strong representation.

Variable	Source and Definition
Equal/better community college transfer representation among other STEM bachelor's recipients	We used the same methodology as for the previous variable, but instead of representation of the four-year college's CS graduates, we derived the representation of its non-CS STEM graduates.
Months from initial enrollment to transfer	Using NSC enrollment records, for each transfer student we counted the number of months from initial enrollment at the community college to initial enrollment at the first four-year college transfer destination.
Months between last community college and first four-year college enrollment	Using NSC enrollment records, for each transfer student we counted the number of months from the end of the student's last pre-transfer community college enrollment to the start of his or her first enrollment at a four-year college.
Total semesters enrolled	Using NSC enrollment records, we determined the number of summer, fall, and spring terms enrolled at a four-year college during the tracking period.
Percentage of terms enrolled	Using NSC enrollment records, we determined the percentage of fall and spring terms between initial enrollment and transfer in which the student was enrolled.
Percentage of terms enrolled full-time	Using NSC enrollment records, we determined the percentage of terms in which the student enrolled full-time (among fall/spring terms in which the student enrolled) between initial enrollment and transfer.
Enrolled in more than one four-year college	Using NSC enrollment records, we identified students who enrolled at two or more four-year colleges during the tracking period.