

Tracking CS Graduates and Non-Retained Students to the Following Year's Academic Programs

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What happens to students who depart from their computer science program but remain in academia? How many students go on to study at the next degree level? When they do, are they still studying CS? How many who don't get a degree go to other computing programs, or other STEM programs? This paper addresses these questions through a study of nearly 400,000 students who were enrolled in U.S. computer science bachelor's and associate's programs in 2017-2018. The results will be of interest to computing educators and academic leaders, who can compare their local data with these national level data.

INTRODUCTION

Questions are often asked about the fraction of computer science (CS) bachelor's degree graduates who go on to graduate school the following year. There are some data to approximate the answer to this question. The Integrated Postsecondary Education Data System (IPEDS) [3] compiles data about degree completions at all levels in a given year. The IPEDS data are obtainable by discipline using CIP codes [4] to identify the discipline, and the completions data can be disaggregated by gender, race/ethnicity, and institution type. The CRA Taulbee Survey [8] reports data on new master's and doctoral students in doctoral granting departments, but only by department type (e.g., computer science, computer engineering, Information, or

Canadian) and institution type (public or private, for U.S. CS departments). From these two sets of data, one might estimate the fraction of CS bachelor's graduates from one year who entered CS graduate programs at doctoral-granting departments in the following year. But such estimates are crude. They do not account for CS graduates who enter graduate school the following year in a program other than CS, nor do they account for students who entered graduate school in CS from a program other than CS, or who entered graduate school but graduated prior to the previous academic year. These estimates also do not account for CS graduates who entered graduate programs at non-doctoral-granting computing departments. Furthermore, the data reported by CRA about newly enrolled graduate students are not disaggregated by gender or race/ethnicity.

Similar questions can be asked about graduates of CS associate's programs, which in the U.S. are generally two-year post-secondary degree programs that can prepare the student to immediately enter certain careers or as a stepping stone toward a four-year bachelor's program. How many of these graduates immediately go on to study at bachelor's programs? When they do, are they continuing to study CS, or are they studying in another discipline? If they are studying in another discipline, is it another computing discipline?

Another set of questions about CS students concerns those students who leave the CS program before getting their degree. The demographics of these "non-retained students" are of

particular interest because of long-standing concerns about diversity in the discipline. The recent CS enrollment surge further heightens interest in these students. Where do they go when they leave the CS program? If they stay at their current institution, to what programs are they most likely to transfer? What about students who leave their former institution but continue their education elsewhere?

This paper provides some answers to these questions, using data about students enrolled in U.S. postsecondary educational programs obtained from the National Student Clearinghouse Research Center (NSC) [5]. Previous articles have used NSC data to quantify and understand the demographics of students enrolled in U.S. computing programs, and of those enrollees who remained in the same computing program in the following academic year [1,7,9,10]. Because the data reported by institutions to NSC allow tracking by individual student, using CIP codes to identify the student's current program of study, the data also can be used to shed light on the various questions raised above about graduates of the program and students who are not retained.

For this investigation, we restricted attention to students who were enrolled in a CS bachelor's or associate's program in 2017-2018. CS students are those enrolled in a program of study identified by CIP codes 11.0101 or 11.0701, the same codes used in previous studies [1,9,10].

Our study is intended to provide the community with an understanding of what non-retained CS students and CS graduates choose to do if they remained in academia in the following year. To help interpret the data, we include various analyses of statistical differences with respect to gender, race/ethnicity, and institutional characteristics. These significance tests are 2-tailed z-tests. However, our purpose is not to explain why the data should produce the observed results. Other research has identified individual and institutional factors that impact retention in CS programs. For example, Pantik and Clarke-Midura offer an interesting literature review relative to factors that influence gender diversity [6]. We hope that those who study issues related to improving retention and improving diversity in CS programs can use our national-level results to offer such explanations and to help demonstrate the effectiveness of their approaches.

The next section discusses the data about non-retained CS students, with separate subsections about bachelor's and associate's students. We then discuss what we learned about CS graduates from 2017-2018 who went on to study at the next academic level in 2018-2019, again with separate consideration of bachelor's graduates and associate's graduates. Following these presentations, we offer observations about how results for these CS students can be compared with data from other disciplines.

What happens to students who depart from their computer science program but remain in academia? How many students go on to study at the next degree level? When they do, are they still studying CS?

NON-RETAINED U.S. CS STUDENTS

A student enrolled in a program of study during 2017-2018 is considered not retained if the student neither graduated from that program in 2017-2018 nor was still in that program in 2018-2019. As shown in Table 1, 24.2%

of the CS bachelor's students were not retained, and 50.7% of the CS associate's students were not retained.

Table 1: 2017-2018 Non-retained students from CS bachelor's and associate's programs

	Enrolled	Retained	Not Retained	Percent Not Retained
Bachelor's students	283,080	214,461	68,619	24.2%
Freshman	46,316	28,232	18,084	39.0%
Sophomore	48,309	35,569	12,740	26.4%
Junior	57,209	46,244	10,965	19.2%
Senior	73,443	61,204	12,239	16.7%
Unreported Class Rank	57,803	43,212	14,591	25.2%
Associate's students	106,356	52,454	53,902	50.7%

The table disaggregates the bachelor's data by class rank, as reported by the institution. Typically, class rank as used here is a function of the total credits earned by the bachelor's student. The freshman level is generally used for students who have earned fewer than $\frac{1}{4}$ of the total degree credits, with the sophomore, junior and senior levels denoting each successive quartile of credits earned. It is interesting that the bachelor's enrollment counts from freshman to senior year are monotonically increasing. To some, this may seem counterintuitive. After all, overall enrollment in the CS major has increased during each of the past four years. So, we might expect a greater influx in the lower ranks in each successive year.

However, this is countered by several factors. First, students enter the program of study at different times, depending on the admission-to-program requirements of the institution. It is common for students transferring from other 2-year institutions to enter the program as juniors through articulation agreements, which can explain why the junior enrollment is higher than that of sophomores. New students also can enter from other institutions as sophomores, for example if they enrolled in a community college program to help them obtain general education credits or introductory classes to their intended major at lower cost. At many institutions, students cannot enter the major immediately upon matriculation. The timing of entry to the major may be at the end of the first year or may be at other times. Students who want to study CS but have not yet been admitted to the CS major may or may not be

given an interim program of study designation that links with a CS program. This could cause sophomore enrollments to include many of the previous year's freshmen who were not yet majors and not associated with the CS program as freshmen. Finally, students often are seniors for multiple years for a variety of reasons. This, coupled with the over 80% retention of juniors, contributes to the senior class enrollment being higher than the enrollment in the previous year's junior class.

The NSC data are able to track students who were not retained if they continued their education and were enrolled at one of the institutions reporting to NSC during 2018-2019. In aggregate, 37,253 (54.3%) of the non-retained bachelor's students and 23,337 (43.3%) of the non-retained associate's students could be tracked. For the bachelor's students, this included 63.1% of freshmen, 68.3% of sophomores, 57.8% of juniors, 28.7% of seniors, and 50.0% of those whose class rank was unreported. Associate's students are not disaggregated by class rank.

The non-retained students who could be tracked were disaggregated into three sets: those who stayed at the same institution but went to a different program, those who went to another institution but were in pursuit of a degree at the same level, and those who went to another institution but pursued a degree at a different level (for bachelor's students, the different level was associate's, and for associate's students, the different level was bachelor's). We did not track students who may have entered graduate programs without having received their degree.

NON-RETAINED BACHELOR'S STUDENTS

Figure 1 shows that, for the bachelor's students, two-thirds of those who were enrolled in some other program in 2018-2019 were at the same institution. Of the 32.9% who went elsewhere, 19.3% stayed in a bachelor's program and 13.7% changed to an associate's program. Note that some of the students who went elsewhere continued to study CS (we will provide more specifics later in this section), while those staying at the same institution were not studying CS.

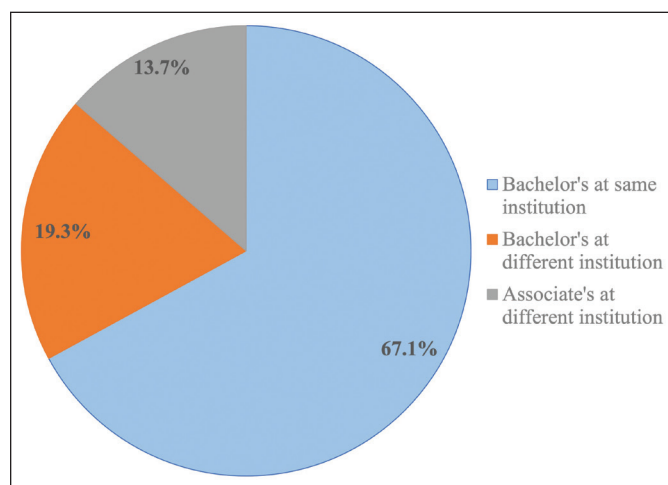


Figure 1: Non-retained Bachelor's Students Still in Academia in 2018-2019

Table 2 shows the percentages of non-retained students of a given gender, major race/ethnicity category, and class rank, who stayed at their institution, went to a bachelor's program at another institution, and went to an associate's program at another institution.

Table 2: 2017-2018 Non-retained Bachelor's Students Still in Academia, by Gender, Race/Ethnicity, and Class Rank

	% at Same Institution	% in Bachelor's at Different Institution	% in Associate's at Different Institution
Male	64.8%	20.2%	15.0%
Female	71.8%	18.1%	10.1%
Asian	67.9%	19.8%	12.2%
Black	63.1%	19.7%	17.2%
Hispanic	62.2%	18.8%	18.9%
Non-resident	72.3%	18.5%	9.1%
White	67.7%	18.8%	13.5%
Freshman	63.3%	16.9%	19.7%
Sophomore	70.0%	19.6%	10.4%
Junior	70.5%	21.3%	8.2%
Senior	72.1%	18.8%	9.1%

Female students were more likely to remain at the same institution than were male students (71.8% vs 64.8%). Male students were more likely than female students to pursue a program at another institution, whether it was at the bachelor's or associate's level. Each of these differences is statistically significant at the .01 level.

Among the major race/ethnicity categories of Asian, Black, Hispanic, Non-resident and White, Non-residents had the highest percentage remaining at the same institution (72.3%) and the lowest percentage pursuing associate's programs (9.1%). Asian students also were less likely than average to pursue associate's programs (12.2%). Black and Hispanic students were less likely than average to stay at the same institution (63.1% and 62.2%, respectively; not significantly different from each other) and more likely than average to pursue an associate's program (17.2% and 18.9%, respectively; a significant difference at the .05 level). As was the case with gender, there were smaller differences among race/ethnicity categories in the percentages of students who left their institution to pursue another bachelor's program (18.5-19.8% among the five major ethnicity categories).

Non-retained freshmen were significantly less likely than the other class ranks to remain at the same institution. They also were significantly more likely than the other class ranks to pursue an associate's program. Both significance results are at the .01 level. Since freshmen would likely be the least invested class at their institution, and the freshman year is the one during which a student's readiness for a bachelor's program is the least validated, neither of the results is surprising. What may be surprising is that the percentage of non-retained seniors who

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went to associate's programs is somewhat greater than the percentage of non-retained juniors who did so. This difference is not statistically significant. Furthermore, there are many more non-retained juniors than non-retained seniors who remained in academia. The actual number of non-retained juniors who went to associate's programs is greater than the actual number of non-retained seniors who did so.

Table 3 shows the percentages who stayed at the same institution, went to a different institution's bachelor's program, and went to a different institution's associate's program, based on the type of institution in which they were enrolled during 2017-2018. Students at public institutions were distributed across the three sets almost identically to the overall distribution of Figure 1. Non-retained students at private non-profits who went to another institution were more likely to pursue a bachelor's program (21.5%) and less likely to pursue an associate's program (12.3%). There is no significant difference between public and private non-profit institutions in the percentages staying at the same institution. However, there are significant differences at the .01 level between public and private nonprofit institutions, in both the percentages going to study at the bachelor's level at different institutions and the percentages going to study at the associate's level at different institutions. Non-retained students at Minority Serving Institutions (MSI) were significantly less likely to stay at the same institution and significantly more likely to pursue an associate's program (both at the .01 level), compared with students at non-MSIs. Non-retained students at non-doctoral-granting institutions were significantly less likely to stay at the same institution and significantly more likely to pursue an associate's program (again, both at the .01 level), compared with students at R1 institutions¹.

Table 3: 2017-2018 Non-retained Bachelor's Students Still in Academia, by Type of Institution

Institution Type	% at Same Institution	% in Bachelor's at Different Institution	% in Associate's at Different Institution
Public	66.5%	18.9%	14.6%
Private Nonprofit	66.2%	21.5%	12.3%
For-Profit	83.7%	12.0%	4.4%
MSI	62.5%	21.9%	15.6%
Non-MSI	68.5%	18.4%	13.0%
R1	75.3%	14.8%	9.9%
R2	64.7%	19.1%	16.2%
Non-R1 or R2	63.1%	22.0%	15.0%

We identified for further investigation several possible areas of interest that the non-retained students might have pursued for their program of study. Each of these investigations used the

data aggregated from students across all institution types. Table 4 shows the program of study areas identified for disaggregation, and the relevant CIP Codes for each of these areas. The codes for those areas within "other computing," other than Data Science and Multidisciplinary, are the same as the codes used in previous studies [1,9]. The Data Science and Multidisciplinary areas were not investigated in those studies.

Table 4: Program of Study Areas of Non-Retained Students

AREA	CIP CODES
Computer Science	11.0101, 11.0701
Other Computing	Computer Engineering (14.0901, 14.0902); Cybersecurity (11.1003, 43.0116); Information Systems (11.0401, 11.0501, 52.1201, 52.1206, 52.1299); Information Technology (11.0103, 11.0201, 11.0202, 11.0301, 11.0801, 11.0802, 11.0804, 11.0899, 11.0901, 11.1001, 11.1002, 11.1004, 11.1005); Software Engineering (14.0903); Data science (30.70xx and 30.71xx); Multidisciplinary that are closely connected to computing or CS (30.0801, 30.1601, 30.3001, 30.3101 and 30.3901)
Non-computing STEM	Engineering codes other than computer engineering or software engineering; engineering technology (15.xxxx), biological and biomedical sciences (26.xxxx), math and statistics (27.xxxx), biological and physical sciences (30.0101), physical sciences (40.xxxx), science technologies/technicians (41.xxxx), homeland security (43.03xx), and telecommunications management (52.2101)
Liberal Arts and Sciences	24.0101
Business	52.xxxx that are not in IS or Non-computing STEM
Social Sciences	45.xxxx
Visual and Performing Arts	50.xxxx
Other	All other CIP Codes

Since the vast majority of the non-retained students stayed at the same institution, we will discuss this group separately, and then discuss the two subgroups of students who went to other institutions. Figure 2 illustrates the programs of study that non-retained students pursued when they stayed at their institution.

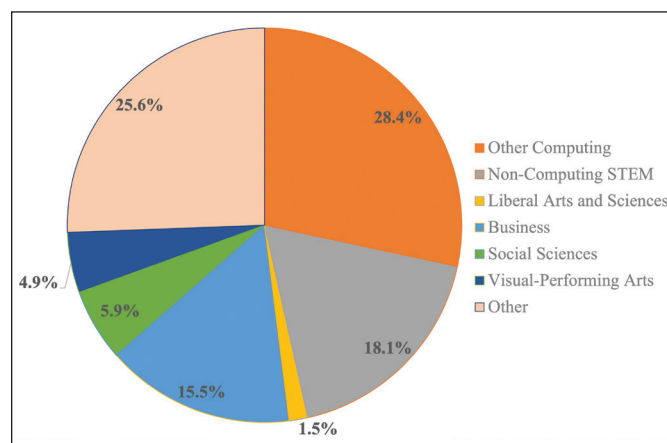


Figure 2: Students at the Same Institution in 2018-2019

¹ R1 institutions are those from Carnegie Classification "Doctoral-Very High Research" and R2 institutions are those from "Doctoral-High Research." See [2] for a description of these classifications.

Of the students staying at the same institution, 28.4% went into another computing program. Another 18.1% went into some other STEM program, and 15.5% went to a business program. Within each of these three choices of programs of study, Table 5 disaggregates the data by gender and among the major race/ethnicity categories. The rows in this table do not add to 100% since they do not include the Liberal Arts and Sciences, Social Sciences, and Visual-Performing Arts program areas.

Among those going into another computing program, there was quite a difference in gender; whereas 30.2% of male students went into another computing program, only 22.8% of female students did so (significantly different at the .01 level). Conversely, female students were much more likely than male students to select programs of study outside of the areas we defined. These so-called “Other” programs were selected by 29.9% of female students but only 24.4% of male students.

Black students also were significantly more likely than students of the other major race/ethnicity categories to go into another computing area (35.4%) and significantly less likely to go into another STEM area (10.6%) among those staying at the same institution; both significance levels also are .01. Hispanic students were the only major race/ethnicity category more likely to select programs of study in the “Other” category than in the “Other Computing” category (28.6% to 26.0%). Non-residents were more likely than students of other major race/ethnicity categories to go into other STEM areas (29.8%) and less likely than those of other major race/ethnicity categories to go into another computing program (24.1%), a business program (12.8%), or a program in the “Other” category (17.4%).

Table 5: Selected Programs of Study for Non-retained 2017-2018 Bachelor’s Students Staying at Same Institution, by Gender and Major Race/Ethnicity Categories

	Other Computing	Non-Computing STEM	Business	None of Defined Areas
Male	30.2%	17.8%	15.9%	24.4%
Female	22.8%	18.4%	14.6%	29.9%
Asian	29.1%	22.1%	16.6%	20.1%
Black	35.4%	10.6%	14.9%	25.8%
Hispanic	26.0%	16.5%	16.8%	28.6%
Non-resident Alien	24.1%	29.8%	12.8%	17.4%
White	29.5%	17.9%	15.0%	26.0%

Figures 3a and 3b respectively show the distribution of programs of study for students who went to other institutions. Among those who went elsewhere to a bachelor’s program, 42.1% stayed in computer science and nearly 65% were in computer science or another STEM computing program; another 17% went into some other STEM area or business. Among those going into an associate’s program, only 20.3% stayed in computer science and slightly over 40% stayed in computer science or another computing program, with 18.1% going to

some other STEM area or business (similar to those going to bachelor’s programs at another institution), but with another 18.1% pursuing a liberal arts and sciences program. The liberal arts results could reflect the types of programs available at institutions with associate’s degrees, or might reflect students who felt it best to pursue a more broad-based program to help them make later decisions about a possible specialization. Approximately 44% of the non-retained students who went to associate’s degree programs came from the freshman rank, and when those of unreported rank are included, the fraction is approximately 2/3.

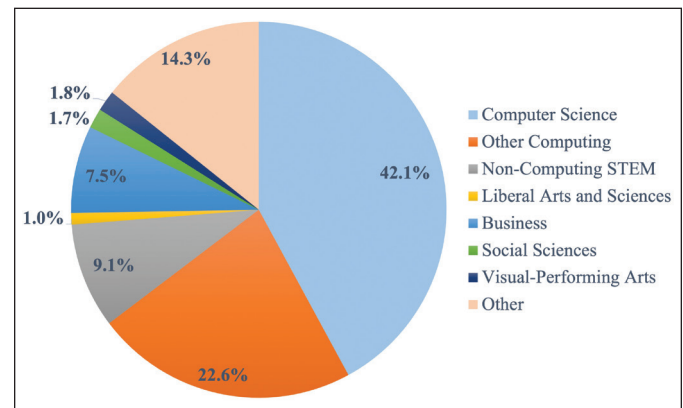


Figure 3a: Students at a Different Institution in a Bachelor’s Program in 2018-2019

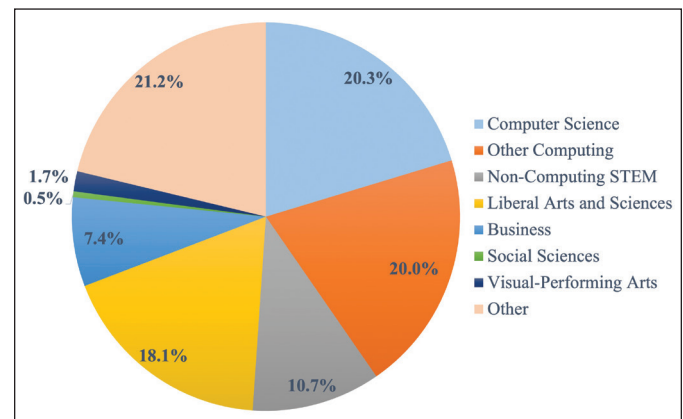


Figure 3b: Students at a Different Institution in an Associate’s Program in 2018-2019

Tables 6a and 6b disaggregate by gender and the major race/ethnicity categories the major program areas of study for students who went to other institutions. The Non-resident Alien category is not included since it is not a major category among those going to other institutions. Table 6a shows the breakdown for students going to bachelor’s programs and Table 6b does likewise for students going to associate’s programs.

Regardless of the level of program, male students were more likely than female students to stay in computer science, and were more likely to go into another computing program. Conversely, female students were more likely than male students to go into programs outside of our defined areas.

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Also, regardless of level of program, Asian students were much more likely than the other race/ethnicity categories to continue in computer science. Black students were much more likely than the other race/ethnicity categories to go into other computing areas and less likely to go into non-computing STEM in bachelor's programs, but neither of these was true for associate's programs. Instead, Black students were the most likely to go into Liberal Arts and Sciences associate's programs and Asian students were least likely to go into such programs.

NON-RETAINED ASSOCIATE'S STUDENTS

Figure 4 shows that, for the non-retained CS associate's students still in academia in the U.S., close to half of those were enrolled in some other program at the same institution in 2018-2019, while just over half went elsewhere, including 14.2% in another associate's program and 38.7% moving to a bachelor's program. It is interesting that the same fraction of non-retained associate's students as non-retained bachelor's students went to an associate's program at a different institution.

It is not surprising that a much larger fraction of non-retained associate's students went to bachelor's programs. Some associate's institutions do not allow students to select a major for their transfer degree. CS students at these institutions complete general education courses and take CS courses as electives. It is not unusual for some students to transfer to a bachelor's program before completing an associate's degree. Even if a CS major can be selected at an associate's institution,

some CS students enroll to complete prerequisites for their intended bachelor's degree and transfer once the prerequisites are complete. In both scenarios, the students are considered non-retained by our definition even though they are on track to meet their academic goal of completing a CS degree.

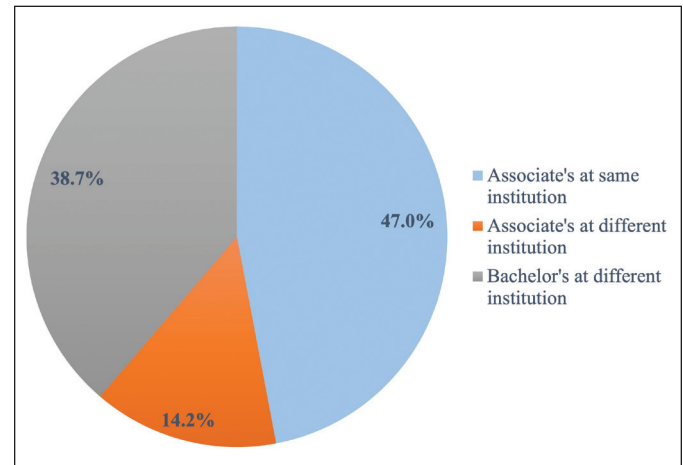


Figure 4: Non-retained Associate's Students Still in Academia in 2018-2019

Table 7 disaggregates the movement of the associate's students to other programs by gender and race/ethnicity. There was no significant difference in the percentage of male and female students staying at the same institution (46.6% and 46.4%, respectively). There also was no significant difference in the percentage of students of each gender going to a bachelor's

Table 6a: Selected Programs of Study for Non-retained 2017-2018 Bachelor's Students Going to Bachelor's Programs at Other Institutions, by Gender and Major Race/Ethnicity Categories

	Computer Science	Other Computing	Non-Computing STEM	None of Defined Areas
Male	43.2%	23.3%	8.6%	13.3%
Female	37.4%	20.7%	9.8%	18.5%
Asian	54.5%	15.8%	9.8%	11.5%
Black	38.3%	29.1%	5.1%	16.1%
Hispanic	39.9%	19.2%	10.9%	17.0%
White	40.9%	21.4%	9.7%	15.2%

Table 6b: Selected Programs of Study for Non-retained 2017-2018 Bachelor's Students Going to Associate's Programs at Other Institutions, by Gender and Major Race/Ethnicity Categories

	Computer Science	Other Computing	Non-Computing STEM	Liberal Arts and Science	None of Defined Areas
Male	20.8%	20.7%	10.4%	18.5%	19.9%
Female	17.1%	16.8%	11.8%	17.5%	27.6%
Asian	26.4%	19.1%	9.0%	12.5%	21.5%
Black	19.9%	19.4%	9.5%	21.4%	21.7%
Hispanic	20.7%	17.6%	13.9%	17.6%	22.1%
White	18.3%	22.0%	10.3%	19.4%	20.8%

program; however, female students were significantly more likely than male students to go to an associate's program at another institution, at the .05 level. Among the major race/ethnicity categories, we analyzed only Asian, Black, Hispanic, and White students since fewer than 400 Nonresident Alien associate's students were tracked. Asian students had the lowest percentage of students remaining at the same institution (34.6%) and the highest percentage pursuing a bachelor's program (52.5%). Hispanic students had the highest percentage remaining at the same institution (49.8%) and the lowest percentage pursuing a bachelor's program (33.0%). Black students had the highest percentage of students pursuing an associate's program at a different institution (18.8%), while White students had the lowest (12.9%).

Table 7: 2017-2018 Non-retained Associate's Students Still in Academia, by Gender and Race/Ethnicity

	% at Same Institution	% in Bachelor's at Different Institution	% in Associate's at Different Institution
Male	46.6%	39.2%	14.2%
Female	46.4%	38.1%	15.4%
Asian	34.6%	52.5%	12.9%
Black	45.2%	36.0%	18.8%
Hispanic	49.8%	33.0%	17.1%
White	46.1%	40.9%	12.9%

Table 8 disaggregates the movement of the associate's students by institution type. Non-retained CS associate's students at Minority Serving Institutions and at Associate-High Transfer institutions are more likely than students at other institution types to go to a Bachelor's program (39.8% and 40.4%, respectively). Students at Bachelor-Associate institutions are more likely than students at other institution types to go to a different associate's program (18.0%). Students at Non-MSIs and CTE-Mixed institutions are most likely to stay at the same institution (49.8% and 49.1%, respectively).

As we did for the bachelor's students, we computed the proportion of non-retained associate's students pursuing each of the program areas identified in Table 4, using the data aggregated across all institution types. Figure 5 shows the results for students staying at the same institution.

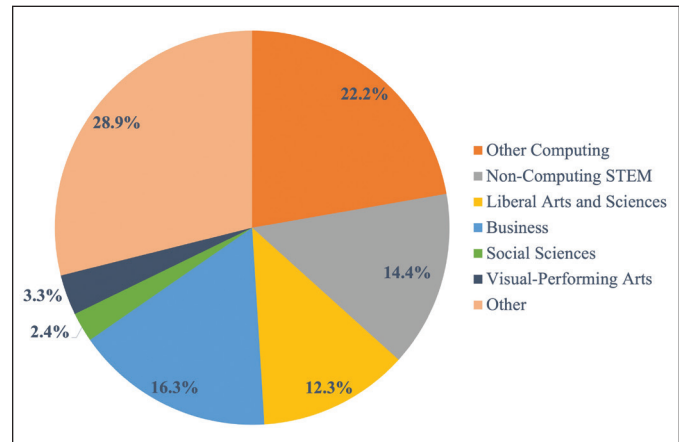


Figure 5: Non-retained CS Associate's Students at the Same Institution in 2018-2019

Among the non-retained CS associate's students who stayed at the same institution, 22.2% went to another computing program, 16.3% to a business program, 14.4% to a non-computing STEM program, and 12.3% to a liberal arts and science program. An additional 28.9% went to none of the defined areas. Table 9 illustrates how students of each gender and major race/ethnicity category are distributed among these program areas.

A significantly greater percentage of male than female students went to another computing program (23.4% of male students vs. 18.2% of female students) or a non-computing STEM program (14.7% of male students vs. 12.2% of female students), while a significantly greater percentage of female than male students went to a business program (18.5% of female students vs. 15.6% of male students) and to programs outside of the defined areas (31.3% of female students vs. 28.4% of male students). All significance levels are .01.

As with bachelor's students, among the major race/ethnicity categories, Black associate's students staying at the same institution were significantly more likely than students from other race/ethnicity categories to go to another computing program (26.0%), and significantly less likely to go to a non-computing STEM program (9.8%). Both of these significance levels are .05. Hispanic students were significantly less likely (at the .01 level) than students from other race/ethnicity categories to go to

Table 8: 2017-2018 Non-retained Associate's Students Still in Academia, by Type of Institution

Institution Type	% at Same Institution	% in Bachelor's at Different Institution	% in Associate's at Different Institution
Minority Serving	44.5%	15.7%	39.8%
Non-MSI	49.8%	12.7%	37.6%
Associate-High Transfer	46.1%	13.5%	40.4%
Bachelor-Associate	46.9%	18.0%	35.1%
CTE-Mixed	49.1%	14.7%	36.3%

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other computing programs (14.5%). Asian students were more likely to go into a non-computing STEM program (18.1%), but not significantly more so than Hispanic students, and were significantly more likely (at the .05 level) to go into a Business program (20.2%) than were students from the other major race/ethnicity categories.

Figures 6a and 6b illustrate the program areas that the non-retained associate's students entered when they moved to another institution. Among those students who went to a different institution in a bachelor's program (Figure 6a), 46.5% went to computer science and 20.8% to other computer programs. Compared to the non-retained bachelor's students who went to a bachelor's program at another institution, a greater percentage of non-retained associate's students stayed in CS, while a greater percentage of bachelor's students pursued programs in the "other" category. In other respects, the respective distributions were very similar.

Among those CS associate's students who went to a different institution in an associate's program (Figure 6b), 29.8% went to computer science and 20.5% to other computer programs. Compared with non-retained bachelor's students who went to an associate's program, a greater percentage of non-retained associate's students stayed in CS, while a smaller percentage pursued programs in the liberal arts and sciences and programs in the "other" category.

Tables 10a and 10b show, by gender and by major race/ethnicity

category, the percentage of unretained associate's students who went to the most highly selected program areas at other institutions. Table 10a contains the percentages relative to those students who went to other bachelor's programs, and Table 10b does likewise relative to those students who went to associate's programs.

As was the case for bachelor's students going to other institutions, regardless of the level of program, male students were more likely than female students to stay in computer science, and were more likely to go into another computing program. Conversely, female students were more likely than male students to go into programs outside of our defined areas.

Asian students were more likely than the other race/ethnicity categories to continue in computer science, whether in bachelor's or associate's programs; this also is similar to what was found for bachelor's students going to other institutions. Black students were more likely than the other race/ethnicity categories to go into other computing areas and less likely to go into non-computing STEM, whether in bachelor's and associate's programs; this result held for bachelor's students going to other institutions' bachelor's programs but not for those going to other institution's associate's programs. White students were the most likely to go into Liberal Arts and Science associate's programs at other institutions, while Hispanic students were least likely to do so. This also differs from the results for bachelor's students going to associate's programs at other institutions.

Table 9: Selected Programs of Study for 2017-2018 Non-retained Associate's Students Staying at Same Institution, by Gender and Major Race/Ethnicity Categories

	Other Computing	Non-Computing STEM	Liberal Arts and Science	Business	None of Defined Areas
Male	23.4%	14.7%	12.5%	15.6%	28.4%
Female	18.2%	12.2%	12.9%	18.5%	31.3%
Asian	18.8%	18.1%	11.6%	20.2%	25.4%
Black	26.0%	9.8%	12.6%	13.1%	32.7%
Hispanic	14.5%	17.5%	12.1%	16.7%	32.1%
White	22.7%	12.5%	14.0%	15.8%	29.9%

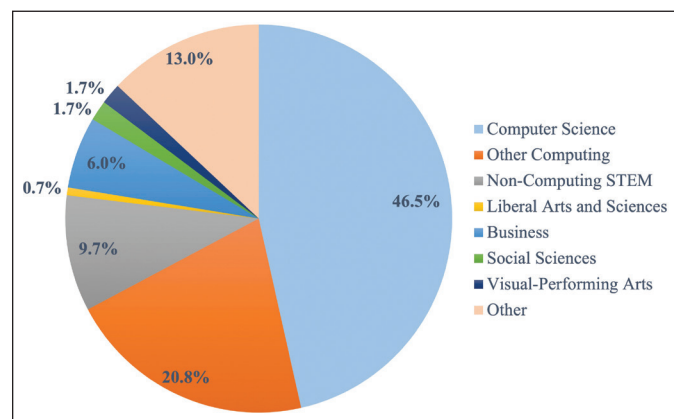


Figure 6a: Non-retained CS Associate's Students at a Different Institution in a Bachelor's Program in 2018-2019

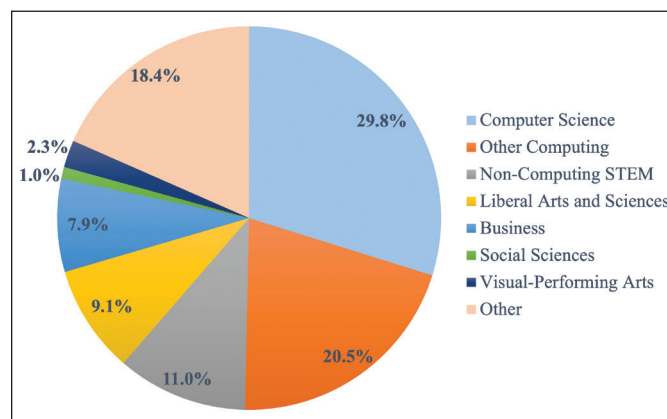


Figure 6b: Non-retained CS Associate's Students at a Different Institution in an Associate's Program in 2018-2019

Table 10a: Selected Programs of Study for 2017-2018 Non-retained Associate's Students Going to Bachelor's Programs at Other Institutions, by Gender and Major Race/Ethnicity Categories

	Computer Science	Other Computing	Non-Computing STEM	None of Defined Areas
Male	48.4%	21.3%	9.4%	11.5%
Female	38.2%	19.6%	10.2%	19.1%
Asian	50.7%	18.3%	10.2%	12.1%
Black	35.9%	25.2%	7.2%	16.3%
Hispanic	45.6%	20.7%	9.7%	14.8%
White	47.9%	19.4%	9.3%	12.8%

Table 10b: Selected Programs of Study for Non-retained 2017-2018 Associate's Students Going to Associate's Programs at Other Institutions, by Gender and Major Race/Ethnicity Categories

	Computer Science	Other Computing	Non-Computing STEM	Liberal Arts and Science	None of Defined Areas
Male	30.0%	21.2%	11.9%	8.9%	17.5%
Female	28.2%	18.8%	7.9%	10.1%	22.0%
Asian	33.9%	18.5%	13.4%	9.1%	14.3%
Black	21.7%	24.4%	8.1%	9.0%	22.4%
Hispanic	31.3%	18.7%	11.2%	7.1%	19.6%
White	26.0%	20.7%	11.8%	11.7%	20.5%

CS DEGREE RECIPIENTS GOING TO PROGRAMS AT THE NEXT LEVEL

Students who graduated from their bachelor's or associate's program in 2017-2018 are part of the set of students considered retained by their program. We were interested to know how many of them were enrolled in the following year (2018-2019) in academic programs at the next level. For bachelor's graduates, the next level would be a graduate program, and for associate's graduates it would be a bachelor's program. In addition to knowing that students were enrolled in such programs, we investigated the program area in which they were enrolled.

BACHELOR'S GRADUATES

The data we obtained from NSC showed that, in 2017-2018, there were 39,982 bachelor's graduates. This is slightly higher than the 39,631 CS graduates included in 2017-2018 NSC data used in a study of retention from that year [1]. We attribute this discrepancy (<1%) to timing of the receipt of the data. The enrollment and retention data were obtained earlier than the data on graduates going to the next level. This enabled the NSC database to include additional degree completions from that academic year if institutions updated these data.

Of these 39,982 graduates, 4,178 (10.4%) were enrolled in a graduate program in 2018-

2019. A significantly greater percentage (at the 1% level) of female graduates (12.7%) than male graduates (9.9%) were in graduate programs. Within the five major race/ethnicity categories (Figure 7), Non-resident Alien students were most likely to go on to graduate school (25.5%), followed by Black students (13.1%), Asian students (10.7%), White students (9.0%), and Hispanic students (8.1%).

Table 11 shows the specific areas studied by those bachelor's graduates who went to graduate school, both overall and for each gender and the five major race/ethnicity categories.

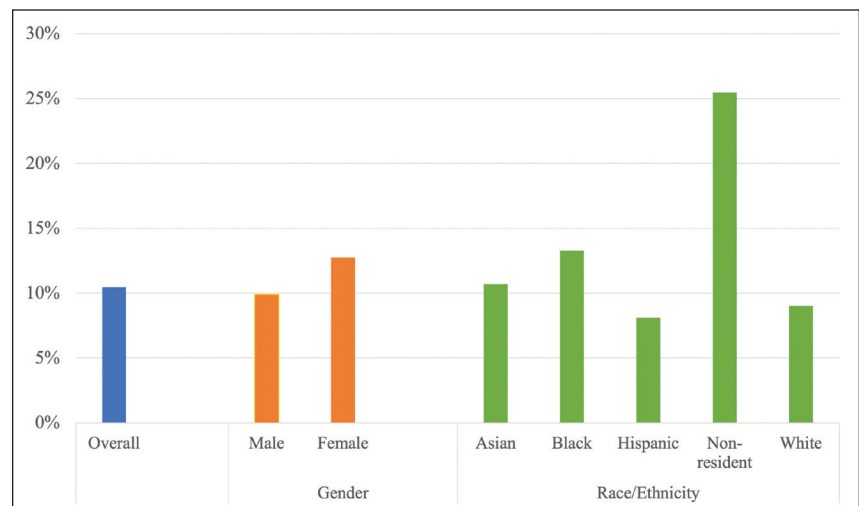


Figure 7: Percent of 2017-2018 Bachelor's Graduates in Graduate Programs in 2018-2019

Tracking CS Graduates and Non-Retained Students to the Following Year's Academic Programs

Computer science, not surprisingly, was the most likely choice of program of study for both genders and all five major race/ethnicity categories. In aggregate, 56.7% of those going to graduate school went to CS graduate programs. However, 58.7% of the male students in graduate school were in CS programs, while only 48.2% of the female students chose CS programs; this difference is significant at the 1% level. With respect to the major race/ethnicity categories, only Black students chose CS less than 50% of the time (36.7%). Non-resident Alien students selected computer science with the highest percentage (68.2%).

The next most popular area was “other computing programs,” chosen by 19.6% of the graduates. This area was the second most popular for each gender and each major race/ethnicity. In fact, 33.9% of Black students chose this area, which was fairly close to the fraction who chose computer science. Black students also had the largest percentage of those in graduate school who studied in areas other than computer science, other computing, or non-computing STEM (20.2%). Asian students had the highest percentage choosing non-computing STEM (15.1%).

ASSOCIATE'S GRADUATES

The data from NSC showed 6,476 associate's graduates in 2017-2018. As was the case with the bachelor's data, this value is greater than the number of graduates reported when we obtained enrollment and retention data from NSC at an earlier time (6,367). The discrepancy in this case is 1.7%.

A greater percentage of male graduates than female graduates were in bachelor's programs after receiving their associate's degrees (45.4% of male graduates vs 40.7% of female graduates, significant at the 1% level). Among the major race/ethnicity categories, Asian students had the greatest fraction of graduates who went to bachelor's programs (59.6%) and White students had the smallest fraction (37.7%). These gender and race/ethnicity comparisons are different from those for bachelor's graduates going to graduate school (Figure 8).

Of the 6,476 associate's graduates, 2,877 (44.4%) were enrolled in a bachelor's program in 2018-2019. The majority of these students (54.8%) were in a computer science bachelor's program, with another 25.1% in another type of computing program. Another 4.8% went to a non-computing STEM program, and the remaining 15.2% went to various other bachelor's programs (Table 12).

Table 11: Percent of 2017-2018 Bachelor's Graduates in Graduate Programs Who Studied Specific Area

	Computer Science	Other Computing	Non-Computing STEM	None of Defined Areas
Overall	56.7%	19.6%	11.3%	12.4%
Male	48.4%	21.3%	9.4%	11.5%
Female	38.2%	19.6%	10.2%	19.1%
Asian	63.2%	12.5%	15.1%	9.1%
Black	36.7%	33.9%	9.3%	20.2%
Hispanic	50.4%	26.7%	7.6%	15.3%
Non-resident Alien	68.2%	15.7%	10.9%	5.1%
White	58.2%	17.4%	9.5%	14.9%

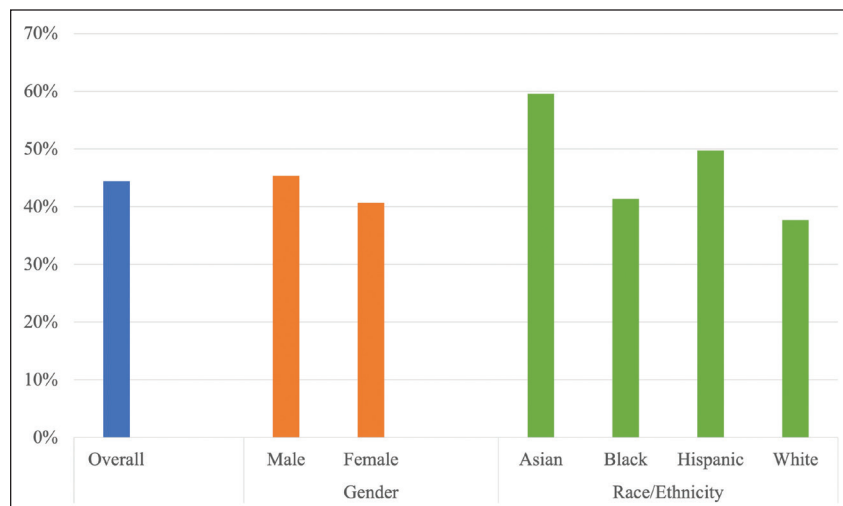


Figure 8: Percent of 2017-2018 Associate's Graduates in Bachelor's Programs in 2018-2019

Table 12: Percent of 2017-2018 Associate's Graduates in Bachelor's Programs Who Studied Specific Area

	Computer Science	Other Computing	Non-Computing STEM	None of Defined Areas
Overall	54.8%	25.1%	4.8%	15.2%
Male	56.8%	25.0%	4.5%	13.7%
Female	45.1%	26.5%	5.1%	23.3%
Asian	58.9%	20.6%	5.1%	15.4%
Black	42.0%	32.9%	NA	25.1%
Hispanic	58.3%	18.8%	6.1%	16.8%
White	57.3%	23.5%	3.9%	15.3%

A greater percentage of male than female associate's graduates (56.8% vs 45.1%) who went to a bachelor's program in 2018-2019 chose computer science. This difference is significant at the 1% level and is the same result that was observed for bachelor's graduates who went to graduate school. Among the four major race/ethnicity categories, Asian, Hispanic and White students had similar percentages choosing computer science (ranging from 57.3% to 58.9%). Black students had the lowest percentage choosing computer science (42.0%) and a correspondingly higher percentage (32.9%) choosing other computing areas for bachelor's study, as was the case for Black bachelor's graduates going to graduate school.

COMPARISON WITH OTHER DISCIPLINES

The data we examined in this study naturally lend themselves to questions about how CS compares with other disciplines. Here, we present one possible approach to answering this question, making use of our data about non-retained students.

The data on non-retained students lend themselves to a further understanding of the concepts of retention and persistence. An earlier paper [1] examined what was referred to as "one-year retention at the program level" for 2017-2018, defining it as the percentage of students who were enrolled in 2017-2018 and either graduated from the program in 2017-2018 or were still in the same *program of study* in 2018-2019. The CS retention thus obtained was 75.8% for bachelor's students and 49.3% for associate's students. The NSC produces annual reports of retention, and defines retention as the percentage of students enrolled at a given degree level in a base year who either graduated that year or were still in the same *institution* (regardless of program of study) in the following year [5].

To get the institution-level retention percentage from the program-level retention percentage, we need to add the percentage of what we referred to as "non-retained" students who stayed at the same institution. For the bachelor's students, this is 67.1% of the non-retained students who were still in academia (see Figure 1). But as noted earlier in this paper, the non-retained students who still were in academia comprise 54.3% of all non-retained students, and the non-retained stu-

dents are 24.2% of the 2017-2018 enrolled students (see Table 1). Therefore, the institution-level retention percentage is $75.8\% + (67.1\% \times 54.3\% \times 24.2\%) = 84.6\%$. A similar computation for the associate's students (using data from Table 1 and Figure 4) yields an institution-based retention percentage of $49.3\% + (47.0\% \times 43.3\% \times 50.7\%) = 59.6\%$.

Persistence is defined as the percentage of students who are enrolled in a degree program in the base year and are still enrolled at the degree level in *any institution, in any program area*, in the following year. Bachelor's CS persistence for 2017-2018 is therefore $75.8\% + 54.3\% \times 24.2\% = 88.9\%$, while associate's persistence is $49.3\% + 43.3\% \times 50.7\% = 71.3\%$.

How do these retention and persistence values for CS compare against other types of programs? NSC reports only what it refers to as "first year" retention and persistence, which restricts attention to students whose base year is their first year of study at the degree level at the institution. Unfortunately, this makes it impossible to assess our bachelor's retention and persistence values against their data, since our retention and persistence includes many students for whom the base year is not their first year of study at the institution. If we expect retention and persistence to be stronger the longer a student has been at an institution, our retention and persistence values should exceed those reported by NSC. NSC's report shows 2017-2018 bachelor's program values for the top five areas of study, which do not include computing. The retention values for first-year students from these top five areas range from 77.1%-85.3% compared with our 84.6% value for CS. The persistence values range from 87.5%-92.8% compared with our 88.9% value for CS. In each case the lower value in the NSC range is for business-management programs and the higher value is for engineering programs.

Associate's programs tend to be two years long. Therefore, the concept of first-year retention and persistence for associate's students may be expected to more closely approximate our institution-based retention and persistence computations. For 2017-2018 associate's programs, the first-year retention values in NSC's top five areas' range from 51.5%-57.0%, with the lower value from security protective services programs and the higher value from computer information sciences and support services programs. The latter area comprises much more than CS;

it includes all CIP codes of the form 11.xxxx [4], of which CS has only two (see Table 4). The persistence range for the top five areas is from 57.3% (again in the security protective services area) to 66.0% in the liberal arts and humanities area. The computer information sciences and support services persistence is 63.1%. Our CS associate's level institution retention and persistence values compare favorably to these NSC-reported first-year retention and persistence values.

SUMMARY AND CONCLUSION

This paper investigated the next steps taken by students who were in a CS bachelor's or associate's degree program in 2017-2018 but were no longer in that program by 2018-2019. Specifically, we tracked those students who, in the year after they left their computer science program, were in another academic program. The students fell into two groups: those who stayed in academia upon leaving their CS program without completing their degree, and those who stayed in academia after completing their degree, but were enrolled at the next level of academic study (the graduate level for those who completed their bachelor's degree and the bachelor's level for those who completed their associate's degree).

Tables 13a and 13b summarize the results for the first group, respectively the bachelor's students who did not complete their degree and the associate's students who did not complete their degree. The columns of the tables indicate whether these so-called non-retained students stayed at the same institution, or went elsewhere to either a bachelor's program or an associate's program. The rows show the most likely areas of study they undertook.

Of particular interest in future studies will be data about the 2018-2019 graduates, who also would have made decisions about the following academic year prior to the onset of the COVID-19 pandemic. The two years of data prior to COVID can then be compared with data about 2019-2020 graduates to understand how the COVID-related disruptions to both the educational system and the general workforce may have altered the behavior of these graduates.

Table 13a: Percentage Breakdown of Non-retained 2017-2018 Bachelor's Students Remaining in Academia

	Stayed at Same Institution	Bachelor's Program at Another Institution	Associate's Program at Another Institution	Total for Area of Study
CS	NA	8.1%	2.8%	10.9%
Other Computing	19.0%	4.4%	2.7%	26.1%
Non-computing STEM	12.2%	1.7%	1.5%	15.4%
Business	10.4%	1.4%	1.0%	12.9%
All Other Areas	25.5%	3.6%	5.7%	34.8%
Total for Where They Studied	67.1%	19.3%	13.7%	100.0%

Based on 54.3% of all non-retained bachelor's students

Table 13b: Percentage Breakdown of Non-retained 2017-2018 Associate's Students Remaining in Academia

	Stayed at Same Institution	Bachelor's Program at Another Institution	Associate's Program at Another Institution	Total for Area of Study
CS	NA	18.0%	4.3%	22.3%
Other Computing	10.5%	8.0%	2.9%	21.4%
Non-computing STEM	6.8%	3.7%	1.6%	12.1%
Business	7.7%	2.3%	1.1%	11.1%
All Other Areas	22.1%	6.6%	4.4%	33.1%
Total for Where They Studied	47.0%	38.7%	14.2%	100.0%

Based on 54.3% of all non-retained bachelor's students

Among the non-retained bachelor's students, the most likely area was in another computing discipline, followed by a non-computing STEM program. Only 10.9% of those non-retained bachelor's students whom we found in another academic program actually were in a CS program at another institution. Among the non-retained associate's students, the most likely area of study was another CS program, mainly at the bachelor's level. This was followed closely by a program in another computing discipline. For both the non-retained bachelor's and associate's students, the business area was a popular choice outside of computing and STEM programs. Computing, STEM, and business programs accounted for approximately 2/3 of all the non-retained students who stayed in academia. Non-retained bachelor's and associate's students who went to other associate's level programs also frequently chose liberal arts and science as their area of study.

For the second group of students, those who stayed in academia after getting their degree, there are similarities between bachelor's and associate's graduates in the choices of areas of study at the next degree level. For both sets of graduates, more than half did their next academic work in CS, followed by some other computing discipline and a non-computing STEM program. These three categories of programs accounted for 87.6% of the bachelor's graduates who stayed in academic and 84.8% of the associate's graduates who stayed in academia. The computing categories alone accounted for over ¾ of the bachelor's graduates and over ¾ of the associate's graduates (see Tables 11 and 12). Male graduates from both bachelor's and associate's programs who went to study at the next level in 2018-2019 were more likely than female graduates to study CS. Black graduates from both bachelor's and associate's programs were least likely among the major race/ethnicity categories to study CS.

We also showed how data from this paper and data from an earlier paper on CS retention might be used to compare CS with other disciplines. Academic departments and administrators also can compare CS data from their own institution against our national level results, and evaluate the comparisons with respect to institutional goals and mission. We caution that, with only one year of such data, the generality of our observations is not yet apparent. Additional data are anticipated in future reports by the ACM Education Advisory Committee subgroup studying Actionable Computing Enrollment and Retention data.

Of particular interest in future studies will be data about the 2018-2019 graduates, who also would have made decisions about the following academic year prior to the onset of the COVID-19 pandemic. The two years of data prior to COVID can then be compared with data about 2019-2020 graduates to understand how the COVID-related disruptions to both the educational system and the general workforce may have altered the behavior of these graduates. ♦

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