How Well Did We Keep Students in Computing Programs, Pre-COVID and COVID?

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Has the COVID pandemic had noticeable effects on retention of students in computing disciplines? Are those not retained leaving academia in different ways than they did in pre-COVID years? Are program graduates staying in academia at the next degree level similarly to pre-COVID times? This study by the ACM Retention Committee explores the answers to these questions with respect to U.S. students in bachelor's and associate's level degree programs. Data from the academic years immediately preceding COVID (2018-19, 2019-20), is compared with that from academic years 2020-21 and 2021-22.

INTRODUCTION

For the past three years, the ACM Education Board has supported the "Actionable Computing Enrollment and Retention" (ACER) Task Force. The task force has gathered national-level data about enrollment, degree completions, and retention of students in bachelor's and associate's level degree programs in the United States, in order to study how the various computing disciplines are doing with respect to retention of these students. The task force's creation was motivated by the observed lack of prior comprehensive data from which to assess aspects of retention [13]. By compiling and publishing such data, the task force hoped to provide useful points of comparison for those doing such work at more local levels, as well as to offer observations that might motivate and direct future retention-related projects. The computing disciplines of interest for investigation are those in which ACM has published curricular guidelines [2,5] and in which ABET accredits programs [1]. At the bachelor's level, there are six such disciplines: computer science (CS), computer engineering (CE), information systems (IS), information technology (IT), software engineering (SE), and cybersecurity (CY)[1]. At the associate's level, there are three such disciplines: CS, IT, and CY.

With funding from the ACM Education Board and ACM's Committee for Computing Education in Community Colleges (CCECC), the task force has obtained data annually from the National Student Clearinghouse Research Center (NSC) [9]. The data thus obtained included, for each of four academic year enrollment cohorts beginning with 2017-18, enrollment, degree completions, and students who remained in the same program the following year, each disaggregated by gender, race/ethnicity, and institutional characteristics for each discipline of interest at a given degree level. Bachelor's data also was disaggregated by class rank. Additional data obtained from NSC for the CS enrollment cohorts provided information about students who were not retained but stayed in academia during the following year, and about students who graduated from their computing program and studied at the next degree level during the following year. We have similar data for the IT enrollment cohorts from 2018-19, 2019-20, and 2020-21.

To date, analyses of the data have been published in various reports [6,12,14,16,17]. Three of these [6,12,14] focused on the 2017-18 cohort year with significant emphasis on retention, while the NDC reports collectively focused on the enrollment and completion data in non-doctoral-granting programs across the first three cohort years. A forthcoming NDC report [15] does likewise for the 2020-21 cohort year.

[1] ACM recently approved curricular guidelines in Data Science (DS) and ABET is piloting accreditation criteria for this area. However, insufficient data about DS programs is available to do the kind of analysis desired in this paper.

Although simple enrollment investigations for a given academic year's cohort require only data from that academic year, investigations of retention, unretained students, or students studying at the next level each require enrollment data from two consecutive academic years. Thus, all of the data from two enrollment cohorts (2017-18 and 2018-19) covers the period prior to the onset of the COVID pandemic. Enrollment data from the 2019-20 enrollment cohort also is pre-COVID, but data from that cohort about retention, unretained students and students studying at the next level each require information from the first COVID academic year (2020-21). All data from the 2020-21 enrollment cohort is from the COVID period. We therefore can begin 1) to assess which results seemed to vary from year to year and which appeared to hold consistently for each of the four enrollment cohorts, as well as 2) see how results requiring data from the 2020-21 and 2021-22 COVID years differ from the corresponding results in pre-COVID years. This report focuses on these two assessments. We first summarize the enrollment data for each academic year's cohort and discipline, emphasizing gender and race/ethnicity representation trends that were observed. We then assess the differences over the four years, respectively for retained students, non-retained students remaining in academia, and graduates studying at the next level.

PROFILE OF THE DATA BY DISCIPLINE

The student data reported to the NSC by an institution includes the student's area of study, captured through the program's CIP code [7]. The ACER task force mapped CIP codes to the various computing disciplines. Initially, we used codes from the 2010 CIP code suite. However, in 2020 there was the decennial update of CIP codes. For the 2020-21 enrollment cohort, we modified our mapping to reflect pertinent new and changed codes in the 2020 CIP code suite. Table 1 details the mappings for each discipline; the entries that are asterisked are new or changed codes from the 2020 code suite. The pre-2020-21 mappings are the same mapping used in most previous reports from the ACER task force [6,12,14,16,17], and the modified mapping for 2020-21 is used in its most recent report [15]. Because of the timing of the code changes, students from the 2019-20 enrollment cohort who were reported in 2020-21 under any new or changed codes may not be properly counted with respect to retention, non-retained students, and graduates studying at the next level. This applies to IS, IT and CY students from the 2019-20 enrollment cohort.

Table 1: Mapping of CIP Codes to Computing Disciplines

Discipline	CIP Codes
CE	14.0901, 14.0902
CS	11.0101, 11.0701
CY	11.1003, 43.0116, 43.0403*, 43.0404*
IS	11.0401, 11.0501, 11.0902*, 52.1201, 52.1206, 52.1299
IT	11.0103, 11.0105*, 11.0201, 11.0202, 11.0204*, 11.0205*, 11.0301, 11.0801, 11.0802, 110804, 11.0899, 11.0901, 11.1001, 11.1002, 11.1004, 11.1005
SE	14.0903

*denotes codes introduced from the 2020 CIP code suite

The NSC data affords very comprehensive coverage of the bachelor's and associate's programs in the United States. Table 2 summarizes the extent of this coverage, with respect to institutions providing data and the total number of students enrolled in the various computing degree programs.

Each institution included in one of the counts must have at least one program in the given discipline, though it is possible that the institution has multiple programs in the same discipline (perhaps within different academic units at the institution). Thus, the sum of the number of institutions across the set of disciplines represents a lower bound on the number of computing programs for which we have data. As the table

Table 2: Number of Institutions and Enrolled Students

		2017-18		2018-19		2019-20		2020-21	
		Institutions	Enrollment	Institutions	Enrollment	Institutions	Enrollment	Institutions	Enrollment
Bachelor's	CS	925	283,080	935	304,137	945	320,959	952	338,636
	CE	229	52,010	238	54,439	241	55,040	239	55,160
	IS	432	91,355	426	91,324	420	88,642	385	79,887
	IT	308	104,016	312	109,387	337	117,281	344	113,551
	SE	55	9,416	56	9,899	59	11,359	65	12,017
	CY	99	28,888	111	35,175	147	42,962	161	49,936
	Sum	2,048	568,765	2,078	604,361	2,149	636,243	2,146	649,187
Associate's	CS	381	106,356	403	110,833	384	109,406	373	103,149
	IT	657	136,083	655	133,694	654	129,080	628	118,724
	CY	158	18,246	176	20,998	212	24,510	207	26,926
	Sum	1,196	260,685	1,234	265,525	1,250	262,996	1,208	248,799

illustrates, in each cohort year our data set comprises over 2,000 bachelor's programs and over 1,100 associate's programs, and includes data for well over half a million bachelor's students and roughly a quarter million associate's students.

Among bachelor's programs, total institutions and total enrollment increased each year in all disciplines with the following exceptions: IS, where both number of institutions and total enrollment decreased each year; CE, where number of institutions decreased slightly in 2020-21; and IT, where the total enrollment decreased in 2020-21. Among associate's programs, the CY area experienced increased total enrollment each year, with a slight decrease in the number of institutions in the 2020-21 year. The IT number of institutions and total enrollment decreased each year, and the CS counts increased from 2017-18 to 2018-19 but decreased from 2018-19 to 2019-20 and from 2019-20 to 2020-21. Table 2 shows that total enrollment across the six bachelor's computing disciplines increased by over 14% during this four-year period, while total enrollment across the three associate's disciplines declined by 4.6%, due to the drop-off in 2020-21. Compared to overall enrollment trends in the United States, computing fares quite well at both the bachelor's and associate's level. For example, an NSC report indicates that overall bachelor's-degree seeking enrollment during this period declined by approximately 4% during this period, while associate's-degree seeking enrollment declined by about 13% during this period [10].

INSTITUTIONAL PROFILE DISAGGREGATION

The institutions reported in Table 2 can be further disaggregated by institutional control (public, private not-for-profit, or for-profit), Minority Serving (MSI or non-MSI), and Carnegie classification [4]. We divided Carnegie classifications for bachelor's institutions into Doctoral-Very High Research Activity (aka R1 institutions), Doctoral-High Research Activity (aka R2 institutions), and non-R1/R2 institutions. We divided Carnegie classifications for Associate's institutions into Associate's-High Transfer, Bachelor/Associate Institutions, and Other. Since there typically are only small changes in the institutions reporting from one year to another, Table 3 shows, for each discipline, the percentage breakdown of the institutions into these categories as a range over the 4-year period.

Among the institutions with bachelor's programs, CE has the most distinct institutional profile. It has the largest percentages of public, MSI, R1, and R2 institutions, and the smallest percentages of private nonprofit, for-profit, non-MSI and non-R1/R2 institutions, among all disciplines. CS has the largest percentage of private nonprofit institutions, and the smallest percentage of R2 institutions, among all disciplines. CY has the smallest percentage of public and R1 institutions, and the largest percentage of for-profit (though the range overlaps somewhat with that of IT) and non-R1/R2 institutions, among all disciplines.

Among the institutions with associate's programs, over 90% are public. The IT and CY disciplines have very similar ratios of MSI to non-MSI, with CS having a somewhat higher proportion of MSI than the other two disciplines. CS also has the highest proportion of institutions in the High Transfer Carnegie class, with the lowest proportions in the other two Carnegie classes.

ENROLLMENT PROFILE DISAGGREGATIONS

We disaggregated the enrollments from Table 2 by gender and race/ethnicity for both bachelor's and associate's programs. The bachelor's programs also were disaggregated by class rank. 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 one fourth of the total degree credits, with the sophomore, junior and senior levels denoting each successive quartile of credits earned. The results for gender are shown in Table 4; the entries are, for each year within each discipline, the percentage of the total enrollment that was Male, Female, and Unreported gender (U).

The percentages of students with unreported gender vary by discipline for both bachelor's and associate's programs. CE

Table 3: Profile of Institutions by Discipline (%)

		Institutional Control			Minority Serving		Carnegie Classification		
		Public	Private NP	For-Profit	MSI	Non-MSI	R1	R2	Non-R1/R2
Bachelor's	CS	45.8-46.4	52.5-53.5	0.7-1.1	19.0-19.5	80.5-81.0	13.4-13.7	11.7-12.0	74.3-74.8
	CE	66.4-67.8	31.8-33.2	0.4	20.9-22.3	77.7-79.1	38.5-40.6	24.5-25.5	34.5-36.1
	IS	57.5-61.6	36.6-40.0	1.8-2.5	18.3-19.2	80.8-81.7	14.3-15.1	14.6-15.8	69.1-70.9
	IT	50.6-54.1	41.5-42.9	4.4-6.5	17.9-18.6	81.4-82.1	12.0-12.5	13.6-14.2	73.4-74.2
	SE	49.2-53.6	44.1-47.7	1.8-3.4	12.5-15.4	84.6-87.5	14.5-17.9	15.4-20.0	65.5-69.2
	CY	39.6-43.5	49.5-52.4	5.6-9.1	10.6-14.4	85.6-89.4	5.4-8.1	12.4-14.4	77.8-80.2
		Public	Private NP	For-Profit	MSI	Non-MSI	High Transfer	Bach/Assoc	Other
Associate's	CS	93.4-95.6	3.6-5.0	0.5-1.6	35.7-37.7	62.3-64.3	44.4-45.8	6.6-8.3	46.1-48.0
	IT	93.6-94.4	4.1	1.4-2.3	26.8-28.4	71.6-73.2	30.6-31.5	13.1-14.2	55.1-56.2
	CY	96.1-96.8	2.5-3.9	0-0.6	27.2-27.5	72.5-72.8	33.3-36.4	11.3-13.3	50.0-53.6

and CS have the highest percentages of bachelor's students of unreported gender and CS has the highest percentage of associate's students of unreported gender. CY has the lowest percentage of both bachelor's students and associate's students of unreported gender. To factor out the effect of students of unreported gender, Figure 1a plots the trend of representation of female bachelor's students as a percentage of those for whom gender was reported. Figure 1b has the corresponding trends for associate's students. IS and IT have the highest representation of female students among bachelor's programs, while CE has the lowest. CS has the lowest representation of female students among associate's programs, while the representation in IT and CY associate's programs is very similar. The representation of female students increased each year in each discipline, with the exception of CY bachelor's students between 2017-18 and 2018-19 (after which it has fully recovered), and IT bachelor's students between 2019-20 and 2020-21 (which declined by 0.2%).

Table 5a disaggregates the enrollments by race/ethnicity, for the two groups that historically are well-represented in computing—Asian (AS) and White (WH), two groups that historically have been poorly represented in computing—Black (BL) and Hispanic (HI), and Non-resident Aliens (NR). While the Non-resident Alien category is much smaller than the other four, it is a category that is quite vulnerable to changes in U.S. immigration practices, and therefore was of particular interest to our study of pre-COVID and COVID years. The entries in this table factor out the effects of unreported races/ethnicities, so they represent the percentage of students for whom race/ethnicity was known. They still do not total to 100% since they do not contain the smaller races/ethnicities (Native American, Native Hawaiian, and Two or More Races). The fraction of unreported race/ethnicity in the NSC data was much higher than the fraction of unreported gender. For CS, CE, and SE bachelor's students and for associate's students in each of the three disciplines, it was in the high teens to low twenties as a percentage of total enrollment. For bachelor's students in IS, it was about one

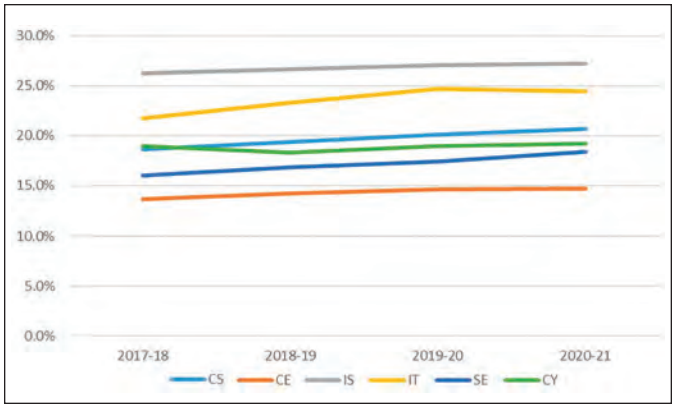

Figure 1a: Representation of Female Bachelor's Students by Discipline*
*as a percentage of students for whom gender was reported

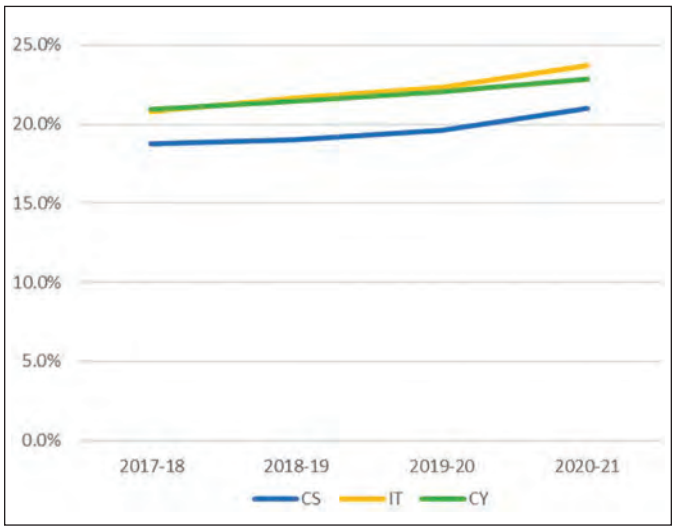

Figure 1b: Representation of Female Associate's Students by Discipline*
*as a percentage of students for whom gender was reported

Table 4: Percentage of Total Enrollment by Gender

		2017-18			2018-19			2019-20			2020-21		
		Male	Female	U	Male	Female	U	Male	Female	U	Male	Female	U
Bachelor's	CS	76.4	17.5	6.1	75.7	18.2	6.1	75.0	18.9	6.1	74.7	19.5	5.8
	CE	80.5	12.7	6.8	80.1	13.2	6.7	79.5	13.6	6.9	79.8	13.8	6.4
	IS	70.1	24.9	5.0	69.8	25.3	4.9	69.5	25.8	4.7	69.5	26.1	4.4
	IT	75.4	20.9	3.7	73.8	22.4	3.8	72.3	23.7	4.0	72.9	23.6	3.5
	SE	80.2	15.3	4.4	79.6	16.1	4.3	79.2	16.7	4.1	78.3	17.6	4.1
	CY	79.7	18.7	1.6	80.5	18.0	1.4	79.9	18.7	1.4	79.7	19.0	1.3
	All	**75.8**	**18.9**	**5.3**	**75.2**	**19.5**	**5.2**	**74.5**	**20.2**	**5.2**	**74.6**	**20.5**	**4.9**
Associate's	CS	77.3	17.8	4.8	77.2	18.1	4.7	76.5	18.6	4.9	75.2	20.0	4.7
	IT	76.2	20.0	3.8	75.3	20.8	3.9	74.5	21.4	4.1	73.3	22.8	3.9
	CY	76.6	20.3	3.1	75.9	20.8	3.3	75.6	21.4	3.0	74.7	22.1	3.1
	All	**76.7**	**19.2**	**4.2**	**76.1**	**19.7**	**4.2**	**75.4**	**20.2**	**4.3**	**74.3**	**21.6**	**4.2**

fourth of the total enrollment, and for bachelor's students in IT and CY, it ranged from about 33% to 40% of total enrollment. While there still is a very large number of students for whom race/ethnicity is known in each discipline each year, the validity of the percentages reported in Table 5a is more questionable than those reported for gender in Table 4.

Among bachelor's students, the percentage of White students decreased each year in every discipline. With the exception of SE from 2018-19 to 2019-20, the percentage of Hispanic students increased each year. With the exceptions of SE and CY, the percentage of Asian students increased each year. CY was the only discipline in which the percentage of Black students increased each year. There were no discernable trends for Non-resident Alien students.

Among associate's students, the percentage of Hispanic students increased each year in each discipline, while the percentage of White students decreased each year in each discipline. Each of these results is analogous to those for bachelor's students in the three disciplines tracked for both degree levels. In CS and IT, the percentage of Asian students increased each year until 2020-21. The percentage of Black associate's students declined in each year until 2020-21 within CS, but increased or remained steady each year in IT. The percentage of Non-resident Alien students also declined in each year until 2020-21 within CS, and while it did not decline in each year for IT and CY, there were no occasions where the percentage increased.

When analyzing the enrollment data for diversity characteristics, it is important to not only look at the absolute representation of each diversity category, but also to assess its representation against overall representation of that category within academia [3]. For gender diversity, we know that any of the gains described above with respect to representation of female students, while helpful, pales by comparison with the overall representation of female students in academia (over 50%) [8]. For racial/ethnic diversity, however, the situation is less obvious. For example, NCES [8] disaggregates enrollment by race/ethnicity category across all undergraduate programs (i.e., aggregating bachelor's and associate's programs across all disciplines). The data also disaggregate 2-year institutions. If we use the 2-year institution data to approximate associate's program enrollment, and non-2-year data to represent bachelor's program enrollment, we obtain the entries in Table 5b. The NCES rows can now be compared with the NSC data aggregating across all disciplines.

Table 5a: Enrollment Percentages by Race/Ethnicity*

		2017-18					2018-19					2019-20					2020-21				
		AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR
Bachelors	CS	18.4	9.6	11.6	52.6	2.9	19.0	9.6	12.2	50.7	3.2	19.9	9.4	12.8	49.0	3.4	20.4	9.8	13.6	47.1	3.2
	CE	20.7	7.3	14.3	49.8	3.4	20.9	7.4	14.7	48.6	3.5	21.4	7.3	14.8	47.8	3.5	21.3	7.9	15.2	47.0	3.2
	IS	12.8	17.6	10.7	51.9	1.8	12.9	17.9	11.3	50.2	1.6	13.6	17.1	11.8	49.3	1.6	13.9	17.1	12.2	48.5	1.6
	IT	11.1	16.7	12.6	52.7	1.7	12.3	16.4	12.9	51.2	1.7	13.1	16.4	13.7	49.0	1.9	14.0	15.7	14.1	48.4	2.0
	SE	14.9	5.9	12.1	60.6	2.3	14.9	5.4	12.8	60.1	2.5	14.6	7.3	12.2	59.0	2.1	14.7	7.8	13.3	57.5	1.9
	CY	6.2	16.1	11.3	58.9	1.9	6.0	16.2	11.6	57.6	2.0	5.6	16.4	12.6	56.7	2.0	5.7	16.9	13.7	55.0	1.8
	All	**16.0**	**11.9**	**11.9**	**52.6**	**2.6**	**16.5**	**11.9**	**12.4**	**51.0**	**2.7**	**17.1**	**11.8**	**13.0**	**49.6**	**2.8**	**17.6**	**11.9**	**13.7**	**48.2**	**2.7**
Associates	CS	14.5	13.1	22.9	41.2	2.1	15.4	12.4	25.0	39.1	1.6	16.3	12.1	26.2	38.0	1.2	15.6	12.2	26.9	37.6	1.3
	IT	9.3	16.4	17.5	50.0	1.5	9.6	16.6	18.0	48.6	1.5	9.9	16.6	19.7	46.7	1.4	9.5	16.9	20.5	45.9	1.3
	CY	8.4	21.4	13.2	49.5	1.1	8.4	21.5	14.6	48.2	0.9	8.2	21.1	16.4	47.2	0.9	8.1	21.0	17.4	45.7	0.8
	All	**11.4**	**15.4**	**19.4**	**46.4**	**1.7**	**11.9**	**15.3**	**20.6**	**44.7**	**1.5**	**12.3**	**15.2**	**22.0**	**43.2**	**1.2**	**11.8**	**15.5**	**22.7**	**42.6**	**1.3**

*as a percentage of students for whom race/ethnicity is known

Table 5b: Comparison of NSC Race/Ethnicity Data with NCES Data Across All Disciplines

	2017-18					2018-19					2019-20					2020-21				
	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR
NSC Bach	16.0	11.9	11.9	52.6	2.6	16.5	11.9	12.4	51.0	2.7	17.1	11.8	13.0	49.6	2.8	17.6	11.9	13.7	48.2	2.7
NCES non-2yr	6.6	12.4	16.3	55.5	4.5	6.8	12.2	17.1	54.7	4.4	6.9	12.1	17.7	53.9	4.3	7.3	12.1	18.1	53.4	3.8
NSC Assoc	11.4	15.4	19.4	46.4	1.7	11.9	15.3	20.6	44.7	1.5	12.3	15.2	22.0	43.2	1.2	11.8	15.5	22.7	42.6	1.3
NCES 2yr	5.9	14.2	25.3	48.4	1.5	6.1	14.0	26.1	47.5	1.5	6.1	14.0	27.3	46.2	1.4	6.3	13.4	27.1	46.9	1.3

At the bachelor's level, we note that Asian students have steadily increased representation both in all disciplines and in computing. In addition, the representation of Asian students in computing surpassed the representation of Asian students across all disciplines by a steadily increasing margin ranging from 9.4% in 2017-18 to 10.3% in 2020-21. Hispanic student representation also showed steadily increased representation both in all disciplines and in computing, but the representation of Hispanic students in computing consistently lagged the representation of Hispanic students across all disciplines, with the 4.4% spread in 2020-21 equaling that in 2017-18 though it had risen to 4.7% in the two intervening years. By contrast, the representation of White students steadily decreased both in all disciplines and in computing, with the representation in computing trailing that across all disciplines by a steadily increasing margin (2.9% in 2017-18 to 5.2% in 2020-21). The representation of Non-resident Aliens also steadily decreased across all disciplines, but increased in computing until 2020-21. The representation of Non-resident Aliens in computing lagged that across all disciplines, but by a steadily decreasing spread from 1.9% in 2017-18 to 1.1% in 2020-21. Finally, the representation of Black students across all disciplines showed a slight decline until becoming flat in 2020-21, while the representation in computing was approximately unchanged throughout the four-year period. While the representation of Black students in computing lagged that across all disciplines, the spread declined from 0.5% in 2017-18 to 0.2% in 2020-21. Thus, the overall representation of Black students in computing has been fairly close to the representation of Black students across all disciplines throughout the four-year period.

At the associate's level, the representation of Asian students increased each year in computing and was non-decreasing each year across all disciplines. Representation in computing exceeds that across all disciplines, as was the case for Asian bachelor's students, but the spread is lower. The spread increased between 2017-18 through 2019-20, but declined in 2020-21 and is now at 5.5%, the same as it was in 2017-18. Representation of Hispanic students steadily increased in computing, and increased across all disciplines until 2020-21, when it fell slightly. Representation of Hispanic students in computing is less than that across all disciplines, but the margin has steadily decreased from 5.9% in 2017-18 to 4.4% in 2020-21. Representation of White students steadily declined in computing, and did so across all disciplines until 2020-21. Representation of White students in computing is below that across all disciplines, by a steadily increasing margin ranging from 2.0% to 4.3%. The representation of Non-resident Aliens has varied by a small amount across the four years both in computing and across disciplines, and each year the margins have been small. As of 2020-21, there is equal representation of Non-resident Aliens in computing and across all disciplines. The representation of Black students across all disciplines has been non-decreasing over the four years, while the representation in computing declined until 2020-21. The representation in computing has consistently surpassed that across all disciplines, and the spread in 2020-21 is at its highest level of the four-year period, 2.1%.

Table 6 shows the bachelor's enrollment disaggregated by class rank. Unreported class rank among the bachelor's programs was comparable to unreported race/ethnicity for the bachelor's programs. Thus, the same caution discussed earlier applies about relying on the specific values in the table.

For each discipline and each year, there typically is a greater percentage of the total enrollment as class rank progresses from freshman (FR) to sophomore (SO) to junior (JR) to senior (SR). Factors contributing to this observation include admission-to-program requirements, transfers from other institutions, and the tendency for students to be seniors for multiple years [14]. Exceptions are in IT beginning with the 2018-19 academic year, CY for the 2018-19 and 2019-20 academic years, and for SE for the 2019-20 academic year. Also note that, with the exception of IT, and SE and CY between 2018-19 and 2019-20, the freshman class in each discipline has been a declining percentage of the overall student body. In CS, this also has been true with respect to the sophomore class.

RETENTION COMPARISONS

Our investigations of retention for a given student is from one year to the next. A student in a given year's enrollment cohort is considered retained if that student either graduates from the program by the end of the academic year or is still in the program in the following academic year. Table 7 shows, by

Table 6: Bachelor's Enrollment Percentages by Class Rank*

	2017-18				2018-19				2019-20				2020-21			
	FR	SO	JR	SR	FR	SO	JR	SR	FR	SO	JR	SR	FR	SO	JR	SR
CS	20.6	21.4	25.4	32.6	20.1	21.2	25.8	33.0	19.7	20.7	25.7	33.8	19.0	20.1	25.9	35.0
CE	21.3	21.6	23.1	34.0	20.4	21.9	22.8	34.8	18.6	21.9	23.5	36.0	18.0	20.5	24.1	37.5
IS	13.7	17.1	30.4	38.7	12.6	17.1	30.6	39.6	11.9	17.5	30.7	39.9	9.9	16.6	31.1	42.4
IT	18.5	19.3	26.3	35.8	19.5	19.0	26.3	35.2	21.0	18.7	25.5	34.8	21.0	18.2	25.3	35.5
SE	18.6	20.8	24.2	36.4	18.1	19.1	24.8	37.9	19.5	19.0	23.9	37.5	17.4	18.4	24.7	39.6
CY	22.9	23.4	25.4	28.3	22.5	21.6	25.7	30.2	24.5	21.5	24.5	29.5	20.7	22.7	25.5	31.0
All	**19.3**	**20.6**	**26.1**	**34.0**	**19.0**	**20.3**	**26.3**	**34.4**	**18.9**	**20.1**	**26.1**	**34.9**	**18.1**	**19.5**	**26.3**	**36.1**

*as a percentage of students for whom class rank is known

discipline for each enrollment year, the percentage of enrolled students completing their degrees during that enrollment year (Grad), and the percentage of enrolled students who were still in the program the following year ('Still in pgm'). For a given discipline in a given enrollment year, total retention is the sum of these two percentages.

Table 7: Percentages of Enrolled Students Who Graduated and Who Were Still in the Program in the Following Year

		2017-18		2018-19		2019-20		2020-21	
		Grad	Still in pgm	Grad	Still in pgm	Grad	Still in pgm	Grad	Still in pgm
Bachelors	CS	14.0	61.8	14.7	61.9	15.5	62.1	14.9	57.8
	CE	13.6	63.6	14.2	63.0	15.5	63.9	15.7	59.5
	IS	16.3	57.2	17.0	56.1	18.0	55.7	17.6	52.0
	IT	11.7	58.0	12.2	57.0	12.4	58.5	12.4	50.2
	SE	12.1	62.0	13.1	63.0	12.6	64.1	13.3	60.0
	CY	8.8	60.5	8.9	59.3	9.4	60.0	8.1	47.7
Associates	CS	6.0	43.3	6.2	41.6	6.1	41.3	5.5	39.4
	IT	9.0	43.3	9.2	42.7	9.1	43.0	8.3	39.4
	CY	9.0	46.0	9.1	45.5	8.8	46.8	8.6	41.0

Figure 2a depicts the overall retention trend lines for each bachelor's discipline. For CS, we added a fifth data point from 2016-17 [18]. Figure 2b shows the data for associate's programs in each of the three disciplines; there is no associate's data for 2016-17.

From these charts, we can observe the following six points.

a. Each associate's discipline program retention is considerably lower than the discipline's bachelor's program retention. This is consistent with other retention comparisons by NSC [11] although the two definitions of retention are not identical. We will comment further about this later in the paper.

b. Retention in CS programs has been decreasing at the associate's level; until 2020-21 it was increasing at the bachelor's level. The associate's decrease may reflect CS associate's students increasingly moving to bachelor's programs without completing the associate degree. This, too, will be explored further in subsequent sections.

c. The pattern of year-to-year retention change in bachelor's and associate's CY programs is similar.

d. CY has the highest retention among the three associate's disciplines but the lowest among the six bachelor's disciplines.

e. Retention within the 2020-21 enrollment cohort decreased compared to the previous year in each discipline at each degree level; it is now the lowest it has been over the four-year period that we studied (or 5-year period for CS bachelor's students).

f. CS retention in associate's programs is the only case where retention declined between 2018-19 and 2019-20. Since 2019-20 retention reflects the COVID period, COVID did not appear to have an adverse effect on student retention within computing programs during the first COVID academic year, but from item e above, it was a different story during the second COVID academic year.

Retention Comparisons by Institution Type

We disaggregated the overall retention data by type of institution, to see if observations made for the 2017-18 cohort [6] continued to hold in subsequent years. Table 8 contains the results for various institution type comparisons. If a test was not significant, it is denoted by "NS." Otherwise, the entry shows which institution type had significantly higher retention and at what level of significance (1% or 5%). These tests are each 2-tailed z-tests.

While many of the significance tests were consistent from year to year, there are some cases that merit comment. In both

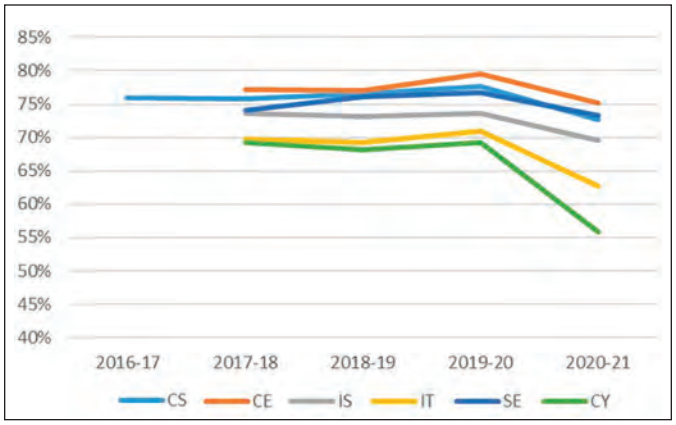

Figure 2a: Overall Bachelor's Retention by Discipline (all institutions)

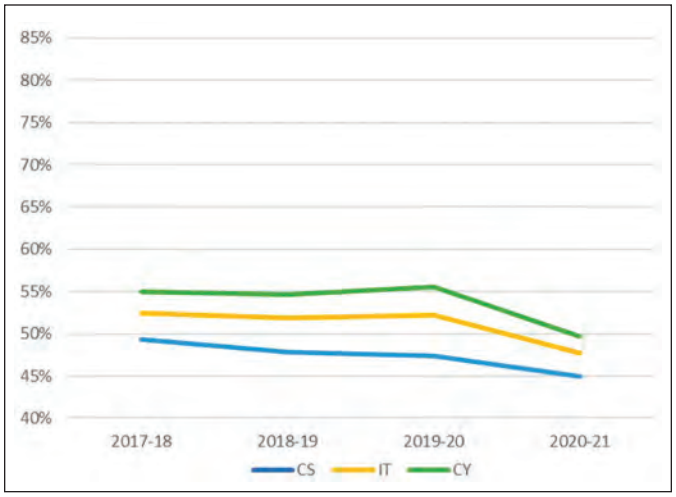

Figure 2b: Overall Associate's Retention by Discipline (all institutions)

Table 8: Retention Comparisons by Type of Institution

		Comparison	2017-18	2018-19	2019-20	2020-21
Bachelors	CS	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	Pri(1%) MSI(1%) R1(1%)	NS MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)
	CE	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	Pri(5%) NS R1(1%)	NS MSI(1%) R1(1%)	Pri(5%) MSI(5%) R1(1%)	Pri(1%) MSI(1%) R1(1%)
	IS	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)
	IT	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	NS MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)
	SE	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	Pri(1%) MSI(1%) nonR1R2(1%)	Pri(1%) NonMSI(1%) nonR1R2(1%)	Pri(1%) NonMSI(1%) NS	Pri(1%) NS R1(1%)
	CY	Public-PrivateNP MSI-nonMSI R1-nonR1/R2	Pri(1%) MSI(1%) R1(1%)	NS MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)	Pub(1%) MSI(1%) R1(1%)
Associates	CS	Public-PrivateNP MSI-nonMSI	Pri(1%) MSI(1%)	Pri(1%) NS	NS NS	Pub(1%) MSI(1%)
	IT	Public-Private NPMSI-nonMSI	NonMSI(1%) NS	Pri(1%) NonMSI(1%)	Pri(1%) NonMSI(1%)	NS Non-MSI(1%)
	CY	Public-PrivateNP MSI-nonMSI	NS NS	Pub(1%) NS	Pub(5%) NS	NS Non-MSI(1%)

CS and CY, bachelor's retention shifted from being significantly higher at private non-profits in 2017-18 to being significantly higher at publics in 2019-20 and 2020-21. Neither discipline also showed significant difference in 2018-19. Associate's program retention in these disciplines showed less dramatic changes than their bachelor's counterparts. In CS, associate's retention shifted away from private non-profits in 2019-20, but was not significantly greater for publics until 2020-21. Associate's CY programs went from no significant difference in 2017-18 to a significant difference in both 2018-19 and 2019-20, but back to no significant difference in 2020-21.

Retention in IT programs favored public institutions at the bachelor's level beginning in 2018-19, but private non-profits at the associate's level in 2028-19 and 2019-20. Furthermore, retention favored MSI institutions at the bachelor's level but favored non-MSI institutions at the associate's level.

Retention differences for bachelor's programs among Carnegie classes consistently favored R1 institutions over non-R1/R2 institutions at the 1% level in all disciplines except SE. The SE retention comparison favored non-R1/R2 institutions in 2017-18 and 2018-19, but became not significant in 2019-20 and favored R1 institutions in 2020-21.

Although the second COVID year brought widespread declines in retention, we find no systematic evidence that the two COVID years had a differential impact on computing program retention based on institution types.

RETENTION COMPARISONS WITH RESPECT TO DIVERSITY

We were interested in examining gender retention differences between male and female students. Figures 3a and 3b show, for bachelor's and associate's programs respectively, these differences by year and discipline. Once again, the CS bachelor's trend line is augmented by 2016-17 data [18]. The y-axis indicates the percentage point difference in retention between male and female students. A positive difference indicates that retention of male students was higher than that of female students. An example of this is in software engineering bachelor's programs in 2017-18, where the data point is 2.0%; male student retention was 74.1% and female student retention was 72.1%. Conversely, a negative percentage difference means that retention of female students was greater than that of male students. This existed in CE in 2019-20, where the data point is -0.2%; retention of female students was 79.4% and that of male students was 79.2%, and in CE and IS in 2020-21 where the data points are -0.3%.

If the retention difference between male and female students is improving within a discipline, its trend line should be moving toward a zero percent difference. While there are clear differences in the patterns among the various disciplines, the most recent data appear to have indicated improvement in several disciplines. For the 2020-21 enrollment cohort, four of the six bachelor's disciplines and two of the three associate's disci-

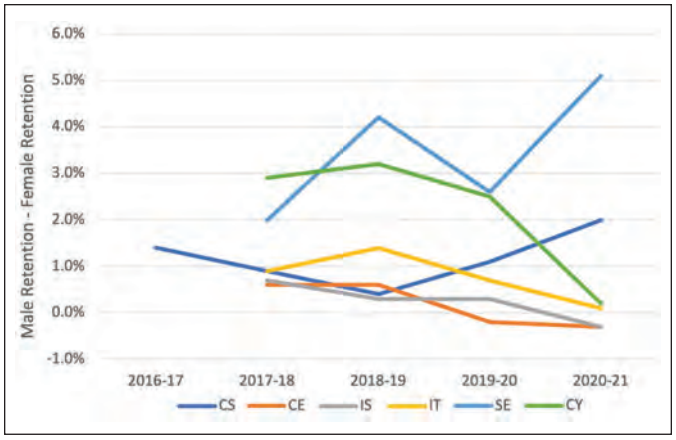

Figure 3a: Difference Between Male and Female Retention by Year and Discipline – Bachelor's Programs

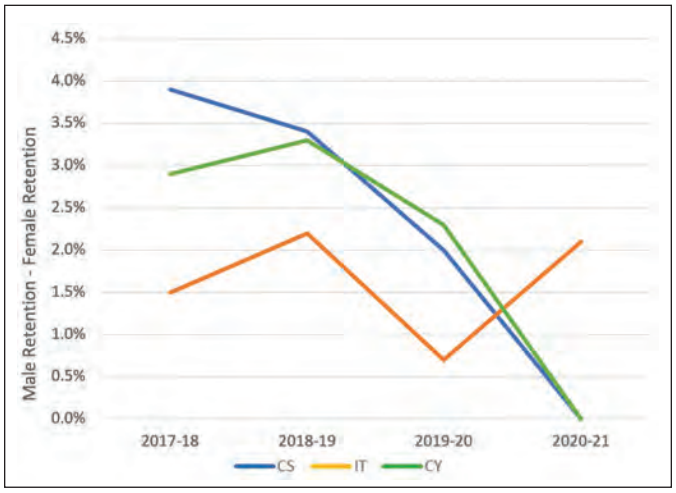

Figure 3b: Difference Between Male and Female Retention by Year and Discipline – Associate's Programs

plines are quite close to the zero-difference line. Of these six instances, only three had no year in which the spread got worse. These observations will need more data to provide evidence of sustained changes in retention over time.

Our earlier observation about the absolute declines in overall retention for the 2020-21 cohort made it important that we also investigate whether the genders were equally prone to retention decline in 2020-21. We found that each gender in each discipline at each degree level experienced a decline in retention from the 2019-20 cohort to the 2020-21 cohort. The magnitude of the respective changes in percentage of students retained is illustrated in Figure 4.

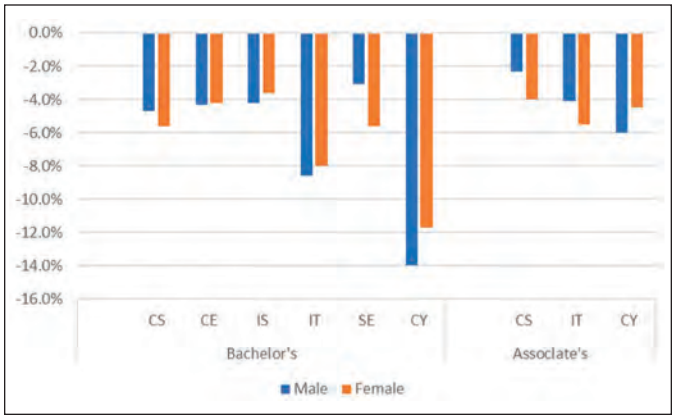

Figure 4: Retention Change from 2019-20 to 2020-21 by Gender and Discipline

Among bachelor's disciplines, the magnitude of the change was greater for male students in four of the six disciplines. The magnitude of the change was greatest for each gender in CY programs and second greatest in IT programs. Among associate's disciplines, the magnitude of the change was greater for female students in two of the three disciplines. CY and IT also experienced the two greatest changes for each gender among the three associate's disciplines.

Table 9: Retention in Selected Race/Ethnicity Categories.

		2017-18					2018-19					2019-20					2020-21				
		AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR	AS	BL	HI	WH	NR
Bachelors	CS	83.1	64.0	71.8	76.1	79.5	83.9	64.9	73.5	76.5	82.3	84.2	68.1	75.2	77.4	82.7	81.9	64.9	70.2	73.7	78.2
	CE	81.2	68.5	73.5	78.0	79.5	80.7	67.6	74.2	77.6	79.0	82.6	75.1	76.1	79.4	81.1	80.7	68.4	71.4	74.4	80.9
	IS	80.3	67.7	72.5	76.0	78.8	80.0	65.3	72.8	75.1	81.6	80.7	66.6	73.5	75.0	74.6	76.4	64.4	70.3	70.0	72.6
	IT	81.7	64.3	71.8	72.5	75.7	81.9	63.7	70.0	71.1	81.2	82.4	65.2	72.1	72.9	79.0	77.5	59.5	66.1	67.2	72.6
	SE	79.5	64.0	73.3	73.3	80.9	81.9	67.8	70.9	76.2	77.0	83.8	59.0	76.1	77.1	82.0	82.2	57.8	71.8	74.0	79.1
	CY	73.1	63.4	65.8	71.1	83.3	73.5	61.4	68.6	70.2	80.3	74.5	62.6	70.3	71.4	84.2	69.6	52.7	64.0	65.3	72.2
Associates	CS	49.7	43.8	51.0	49.5	51.9	46.5	44.0	49.4	48.5	43.5	46.0	43.6	49.0	48.0	46.2	43.8	41.9	45.9	45.1	50.9
	IT	52.4	47.2	50.8	54.4	58.3	50.8	46.3	51.3	54.1	57.0	52.0	48.2	51.7	54.1	56.4	46.3	42.8	45.9	50.1	54.6
	CY	60.3	53.3	51.0	57.0	58.2	61.2	51.3	52.3	56.3	64.8	58.5	52.3	55.1	56.5	60.1	49.9	47.2	47.0	51.7	59.7

Table 9 shows retention changes with respect to the major race/ethnicity categories. The format of and abbreviations used in this table are similar to those in Table 5.

Among bachelor's programs, either Asian or Non-resident Alien students had the highest retention in every discipline in each year, and whichever was not highest was second highest. Black students had the lowest retention in each year in each discipline. In CS, retention increased year-to-year in each of the five race/ethnicity categories until 2020-21, when it decreased in each of the five categories. There was no such consistent trend for any of the other disciplines prior to 2020-21, although there were disciplines where retention for students of a particular race/ethnicity increased each year. In 2020-21, retention in each of the race/ethnicity categories in each discipline decreased from its value the previous year. This is a more dramatic illustration of our earlier statement about widespread declines in retention during the second COVID year.

Among associate's students, there were few consistent trends. Black students had the lowest or second lowest retention in each year in each discipline. Non-resident Alien students had the highest or second highest retention in IT and CY each year; in CS their retention dropped off after 2017-18 relative to the other race/ethnicity categories but recovered in 2020-21. In fact, Non-resident Alien students in CS associate's programs were the only major race/ethnicity group in either bachelor's or associate's programs to experience an increase in retention between 2019-20 and 2020-21.We were particularly interested if COVID may have had an effect on the retention of Non-resident Alien students. However, there was no evidence of any systematic pattern of decreased retention in either the 2019-20 or the 2020-21 cohort that was more dramatic for Non-resident Alien students than it was for other race/ethnicity categories.

In a previous report [6], we investigated differences by gender within selected race/ethnicity categories for bachelor's students in the 2017-18 cohort, to see which were significant. Some of these significant differences favored retention of female students over that of male students. Now that we have four years of data, it is of interest to see whether these relationships continued to hold over time. Table 10 shows the results for not only the bachelor's students, but also the associate's students who were not investigated in the earlier study. The entries in each cell include four significance test results; the top is for the 2017-18 cohort, with each successive entry being for the next year's cohort. The row labeled "All races/ethnicities" includes not only the five selected races/ethnicities, but also Native American, Native Hawaiian/Pacific Islander, students of two or more races/ethnicities, and students whose race/ethnicity was not reported. If a test was not significant, it is denoted by "NS." If the test could not be performed because of lack of sufficient data, the cell entry is "NA." Otherwise, the entry shows which gender had significantly higher retention (M or F) and at what level of significance (1% or 5%). Once again, these tests are each 2-tailed z-tests.

Table 10: Retention Difference by Gender within Selected Race/Ethnicity Categories

	Bachelor's						Associate's		
	CS	CE	IS	IT	SE	CY	CS	IT	CY
Asian	NS F(5%) NS NS	NS NS NS NS	F(5%) NS NS NS	NS F(1%) F(1%) M(1%)	NS NS NS NS	NS NS NS NS	M(1%) M(1%) M(1%) M(1%)	NS NS NS NS	NS NS NS NS
Black	NS M(1%) NS NS	NS NS NS NS	M(1%) M(5%) M(1%) F(5%)	M(1%) M(1%) M(1%) M(1%)	NS NA NS NS	NS NS M(5%) NS	M(5%) M(1%) M(1%) NS	NS M(1%) NS NS	NS NS NS NS
Hispanic	M(1%) M(1%) M(1%) M(1%)	NS NS NS NS	NS NS NS NS	NS M(1%) NS M(1%)	M(1%) NS NS M(5%)	NS NS NS NS	M(1%) M(5%) NS M(1%)	M(1%) NS NS M(1%)	NS NS NS NS
White	M(1%) M(5%) NS M(1%)	NS NS NS NS	NS NS NS NS	M(5%) M(1%) NS M(1%)	NS M(1%) M(5%) M(1%)	NS M(1%) M(1%) M(1%)	M(1%) M(1%) M(5%) M(1%)	NS M(1%) NS M(1%)	M(5%) M(1%) NS NS
Non-resident. Alien	F(5%) F(5%) M(1%) NS	F(5%) NS NS NS	F(5%) NS F(5%) NS	F(5%) NS NS NS	NA NA NA NA	NS NS NS NS	NS NS NS NS	NS NS NS NS	NA NA NA NS
All races/ ethnicities	M(1%) M(5%) M(1%) M(1%)	NS NS NS NS	M(5%) NS NS NS	M(1%) M(1%) M(5%) NS	NS M(1%) M(5%) M(1%)	M(1%) M(1%) M(1%) NS	M(1%) M(1%) M(1%) M(1%)	M(1%) M(1%) NS M(1%)	M(1%) M(1%) M(1%) NS

Many of the significance results are consistent. The direction of significance changed in three cases. The first is Non-resident Alien CS bachelor's students, which changed from mildly significant in favor of female student retention in 2017-18 and 2018-19 to more highly significant in favor of male student retention in 2019-20 but then not significant in 2020-21. The second instance was for Black IS bachelor's students, which was significant in favor of male student retention from 2017-18 through 2019-20, and became mildly significant in favor of female retention in 2020-21. The third was Asian IT bachelor's students, which was highly significant in favor of female students in 2018-19 and 2019-20 but in 2020-21 was highly significant in favor of male students. The only other instance where retention was significantly higher for female students more than once was for Non-resident Alien IS bachelor's students, which was mildly significant in favor of female students in 2017-18 and again in 2019-20, but was not significant in each of the other two years. Six cases exist where all four years show a significant difference in favor of male student retention. Five of them are in CS programs, including for all races/ethnicities combined in both bachelor's and associate's programs; the other is for Black IT bachelor's students. However, 14 other cases exist where significant differences in favor of male students exist in some years, but no significant difference exists in other years. Associate's retention showed no instances where female retention significantly exceeded male retention, and few instances where a significant difference in early years became not significant by 2020-21. The bottom line is that, as was the case for gender retention, there was no clear evidence that COVID affected a change in the relative retention by race/ethnicity more than the differences observed in the pre-COVID period.

For bachelor's students, we are able to investigate retention by class rank. Table 11 shows the year-by year results for each discipline. Values that we were unable to calculate from the way the data was reported are noted by NA in the table.

Of note is that retention declined from 2019-20 to 2020-21 for each class rank in each discipline. In CS, the highest percentage decline was at the freshman rank. In IT the freshman and sophomore ranks experienced the highest percentage declines, and in CY the freshman, sophomore and junior ranks experienced equally large percentage declines. In contrast, in IS the decline was largest at the senior rank and smallest for the freshman rank.

STUDY IN THE FOLLOWING YEAR

Since the NSC data is capable of tracking individual students from year to year, we are able to study students who were not retained in their program but who remained in academia during the following year. Questions of interest for these students include whether they remained at the same institution and the area of study to which they went.

Similarly, the ability to track individual students from year to year affords the opportunity to study those students who graduated from their program but went on to study at the next level in the following year. For bachelor's graduates, "next level" means a graduate program, while for associate's students it means a bachelor's program. For these students we are interested in the percentage of graduates who studied at the next level in the year following graduation, and the area of study pursued at the next level.

For both non-retained students and graduates who were studying at the next level, we have data from the same four CS cohorts (2017-18, 2018-19, 2019-20, and 2020-21) for whom we studied retention. We also have data from three of the IT cohorts (2018-19, 2019-20, and 2020-21) used in our retention studies. In the analyses of this data, we will comment on the degree of consistency observed from year to year, and on differences between the pre-COVID period (those from the 2017-18 and 2018-19 cohorts) and COVID period data (from the 2019-20 and 2020-21 cohorts). Since there is only one pre-COVID cohort for the IT data, the influence of COVID on changes is less clear.

NON-RETAINED STUDENTS

For each of the four CS cohorts, we were able to obtain data about approximately 50% of the non-retained bachelor's students' academic whereabouts, and more than 40% of the non-retained associate's students' academic whereabouts. The tracking of students from the two IT cohorts was not as robust; for both bachelor's and associate's IT students, we had tracking information for approximately 30% of the non-retained students at each degree level from each cohort. Table

Table 11: Bachelor's Student Retention by Class Rank and Discipline

	2017-18				2018-19				2019-20				2020-21			
	FR	SO	JR	SR	FR	SO	JR	SR	FR	SO	JR	SR	FR	SO	JR	SR
CS	61.0	73.6	80.8	83.3	60.8	74.6	81.6	84.9	64.1	74.9	81.8	84.6	56.7	71.0	77.2	79.0
CE	62.5	71.6	80.9	86.8	NA	NA	81.2	87.2	NA	NA	82.7	87.6	NA	NA	78.2	84.6
IS	58.4	68.8	77.1	81.5	58.7	68.8	76.1	80.4	59.2	70.2	76.4	80.4	57.2	65.6	71.4	74.8
IT	55.1	69.8	76.1	79.0	54.5	68.3	75.2	76.5	57.1	71.8	76.7	79.9	49.0	63.8	70.4	73.6
SE	NA	NA	NA	80.3	NA	NA	79.3	82.2	62.3	73.6	79.8	83.8	NA	NA	76.3	81.2
CY	53.6	64.2	72.9	75.9	53.5	63.3	73.6	76.4	57.6	66.4	73.5	76.9	49.0	57.5	64.7	71.1

12 illustrates how these percentages varied by gender, major race/ethnicity categories and, for bachelor's students, class rank. In two of the cohorts, we were unable to compute the exact value of the percentage of Non-resident Alien bachelor's IT students who were tracked, due to some small cell values. But we were able to bound the range of these values within 3 percentage points.

Overall, the percentage of non-retained students who were tracked declined between the 2018-19 cohort and the 2019-20 cohort, in each discipline at each degree level. In CS, but not in IT, this decline continued in the 2020-21 cohort for both bachelor's and associate's students. Since the 2018-19 cohort year represents the last pre-COVID year and the other two cohorts represent COVID years, it is possible that the pandemic influenced the fraction of students who remained in academia in any capacity. If a student simply took time off because of the pandemic but fully intended to return to their former program when they came back to their studies, they are considered non-retained even though they are not (yet) lost to the program. We have no estimate of the fraction of students in this category.

The tracking declines between the 2018-19 pre-COVID cohort and the two COVID cohorts affected each gender, race/ethnicity category, and class rank to some degree. With respect to gender, there was a slightly larger percentage drop-off for male students than for female students in each discipline at each degree level. In fact, there was a slight increase in the percentage of female CS associate's students tracked between the 2018-19 and 2019-20 cohorts, but that was followed by a larger decline among female students than male students for the 2020-21 cohort. With respect to race/ethnicity, Hispanic CS students at both degree levels, and Hispanic IT students at the associate's level, each showed larger than average drop-offs in percentage tracked between the 2018-19 and 2019-20 cohorts. In CS, the declines continued into the 2020-21 cohort. Non-resident Alien CS bachelor's students also showed higher than average drop-offs in both COVID years, but this was not the case with either CS associate's students or IT students at either degree level. With respect to class rank for bachelor's students, there were tracking declines at each class rank in CS in both COVID years, and the second COVID year decline in the freshman class was even greater than in the first COVID year. In IT the tracking declines were just in the first COVID year, with the freshman and sophomore classes being hit the hardest. We note that the percentage of non-retained IT students whose class rank was unreported was considerably higher than the percentage of non-retained CS students whose class rank was unreported. This may be a factor in the different impact on class rank percentage drop-offs within these two disciplines.

Among those non-retained students who were tracked, we are interested in a) whether or not these students continued their studies at the same institution or went to a different institution, and b) the area of study they chose. Previously, we reported results from the 2017-18 CS bachelor's and CS associate's enrollment cohorts [14]. We are now interested in any differences observed in the behavior of the three subsequent cohorts, as well as differences between the CS and IT cohorts. Figure 5 contains the results of this investigation for the CS Bachelor's cohorts with respect to where the non-retained students continued their studies. The three options were "at the same institution," "at a different institution but still in a bachelor's program," and "at a different institution in an associate's program."

The figure illustrates separate trends aggregated over all non-retained students who were tracked, as well as disaggre-

Table 12: Percentage of Non-retained Students Tracked

	Bachelor's							Associate's						
	2017-18	2018-19		2019-20		2020-21		2017-18	2018-19		2019-20		2020-21	
	CS	CS	IT	CS	IT	CS	IT	CS	CS	IT	CS	IT	CS	IT
Overall	54.3	56.6	33.3	51.4	29.5	48.5	29.7	43.3	43.6	31.6	41.7	28.9	40.6	30.0
Male	52.9	54.6	32.1	49.4	28.2	46.4	28.3	42.8	43.0	30.9	40.2	27.8	39.8	29.1
Female	61.8	63.1	37.3	58.5	34.0	55.5	33.9	47.2	46.8	34.4	47.9	33.1	43.9	33.0
Asian	57.0	64.3	46.8	60.9	40.8	58.9	46.9	56.9	59.0	46.3	59.2	44.5	57.1	43.3
Black	56.2	55.1	34.7	52.0	30.7	49.6	28.8	37.5	38.7	28.4	37.9	25.5	38.5	27.1
Hispanic	59.6	56.1	36.6	50.0	33.0	47.6	34.1	45.0	43.0	35.4	39.7	30.3	38.2	30.6
Non-res	51.5	63.8	39-42	56.8	40-43	50.7	37.9	46.1	51.4	33.2	51.5	29.9	53.0	37.1
White	53.8	55.8	39.7	52.3	34.2	50.7	36.1	41.3	40.9	29.6	39.7	27.1	37.1	27.2
Freshman	63.1	60.8	36.2	56.1	28.5	50.5	28.9	NA	NA	NA	NA	NA	NA	NA
Sophomore	68.3	70.0	47.5	64.7	42.3	62.6	45.3	NA	NA	NA	NA	NA	NA	NA
Junior	57.8	62.1	41.7	56.3	38.6	53.2	42.8	NA	NA	NA	NA	NA	NA	NA
Senior	28.7	36.0	25.5	31.0	21.7	29.3	23.5	NA	NA	NA	NA	NA	NA	NA

gated by gender and by race/ethnicity. Each has a set of four bars (one bar for each year's enrollment cohort). Each bar totals 100% of the tracked students for the category and year in question, and is split into three components: the first shows the percentage, of that year's tracked non-retained students of the indicated gender or race/ethnicity, who stayed at the same institution; the second shows the percentage who went to a different institution's bachelor's program, and the third shows the percentage who went to a different institution's associate's program.

It is obvious that most students stay at the same institution, regardless of cohort, gender, or race/ethnicity. Except among Hispanic students in 2017-18 and 2018-19, most of the remaining non-retained students who stayed in academia chose bachelor's rather than associate's programs at another institution.

Between the pre-COVID 2018-19 and COVID-year 2019-20 enrollment cohorts, there was little overall change overall, for both genders, and for White students in the percentage staying at the same institution. However, all genders and race/ethnicities showed some decline in the percentage staying at the same institution between 2019-20 and 2020-21. All categories of students showed a noticeable drop between 2018-19 and 2019-20 in the percentage who went to a different institution's associate's program, and an increase in the percentage who went to a different institution's bachelor's program. The percentage who went to a different institution's bachelor's program continued to rise, even if slightly, for the 2020-21 cohort, and all categories except Non-resident Alien students showed a slight increase between 2019-20 and 2020-21 in the percentage going to a different institution's associate's program. Non-resident Alien students in fact showed some decline in each successive cohort with respect to the percentage going to a different institution's associate program.

Figure 6 disaggregates the location that non-retained students chose based on the type of institution in which they studied in the enrollment cohort year. Each set of bars depicts the location and enrollment cohort year in the same manner as in Figure 5: the first shows the percentage, of that year's tracked non-retained students from the indicated type of institution, who stayed at the same institution; the second shows the percentage who went to a different institution's bachelor's program, and the third shows the percentage who went to a different institution's associate's program.

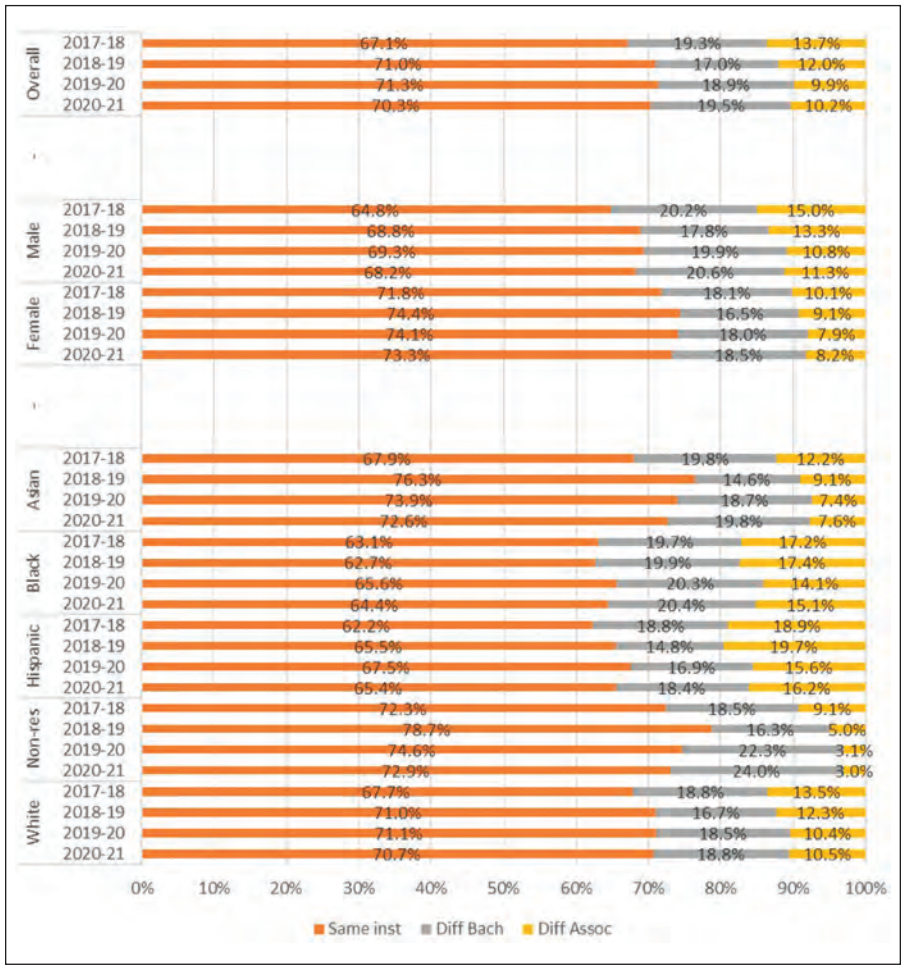

Figure 5: Location of Non-retained CS Bachelor's Students by Gender and Race/Ethnicity

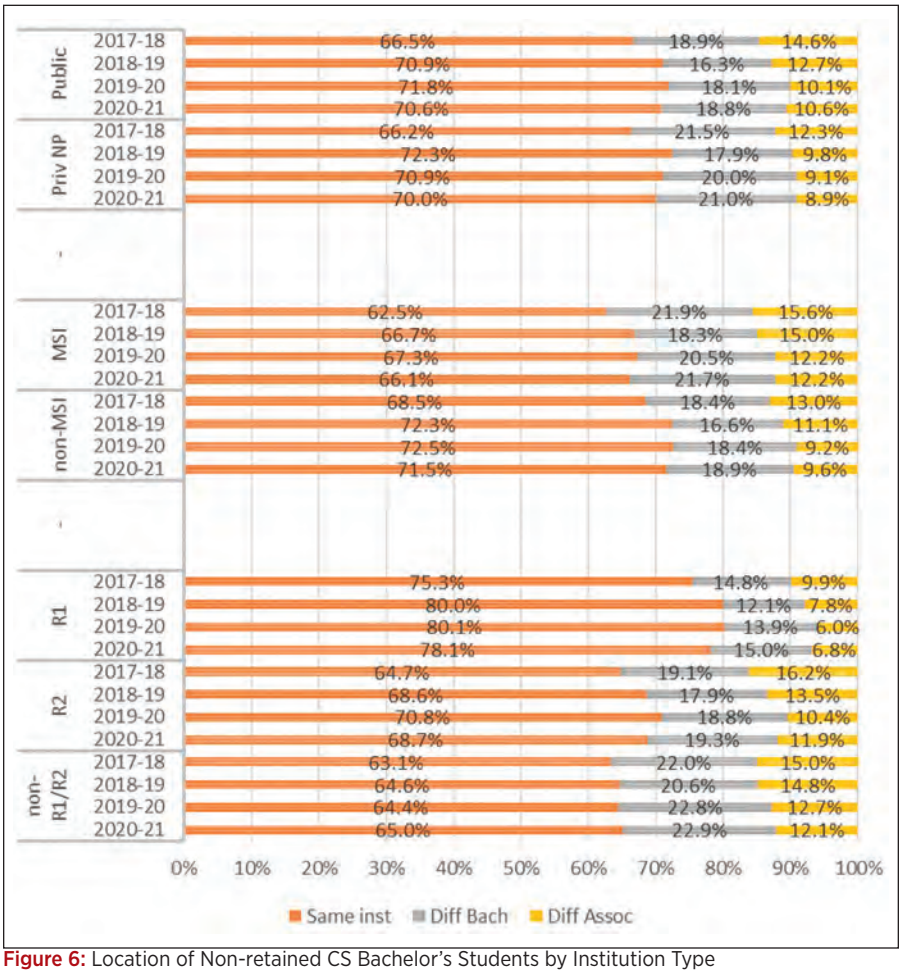

Figure 6: Location of Non-retained CS Bachelor's Students by Institution Type

As was the case with respect to gender and race/ethnicity, most non-retained students stayed at the same institution regardless of institution type, and if they didn't stay at the same institution, they were more likely to study in a bachelor's program than an associate's program. Figure 6 also shows, through 2019-20, a declining percentage from year to year of non-retained CS bachelor's students who went to study at the associate's level, regardless of the type of institution from which they came. But only non-R1/R2 institutions showed a decline from 2019-20 to 2020-21, and that decline was slight. R2 institutions, and to a smaller extent public and MSI institutions, showed an increase in the percentage of non-retained students remaining at the same institution between the 2018-19 enrollment cohort and the 2019-20 enrollment cohort.

Our results suggest that, except for the fact that a smaller percentage of non-retained CS bachelor's students could be tracked during the COVID years, the disruptions caused by COVID did not affect non-retained CS bachelor's student behavior very much.

Figures 7 and 8 show the analogous results for non-retained CS associate's students that Figures 5 and 6 show for non-retained CS bachelor's students.

Non-retained associate's students do not remain at the same institution with the same intensity that non-retained bachelor's students do. This is not surprising, since an objective of many students enrolled in associate's programs is to eventually earn a bachelor's degree. For these students, transferring to a bachelor's program before completing an associate's degree is consistent with their long-term academic goal. In fact, we note that, during the two COVID years, there was an increased percentage of non-retained students who transferred to a bachelor's program at another institution. This is in line with a possible explanation of the decreased retention trend among CS associate's students that we offered in our analysis of Figure 2b. Non-retained students at private institutions were the most likely to stay at their same institution, although private institutions account for less than 10% of the total institutions reporting associate's level enrollment.

Between pre-COVID 2018-19 and COVID year 2019-20, there was no consistent gender or race/ethnicity pattern relative to where non-retained associate's students decided to go. However, the 2020-21 cohort showed a smaller percentage of students staying at the same institution, and a larger percentage going to a bachelor's program at a different institution, compared with the 2019-20 cohort. This was true for all gender and race/ethnicity categories. It also was true for all institution

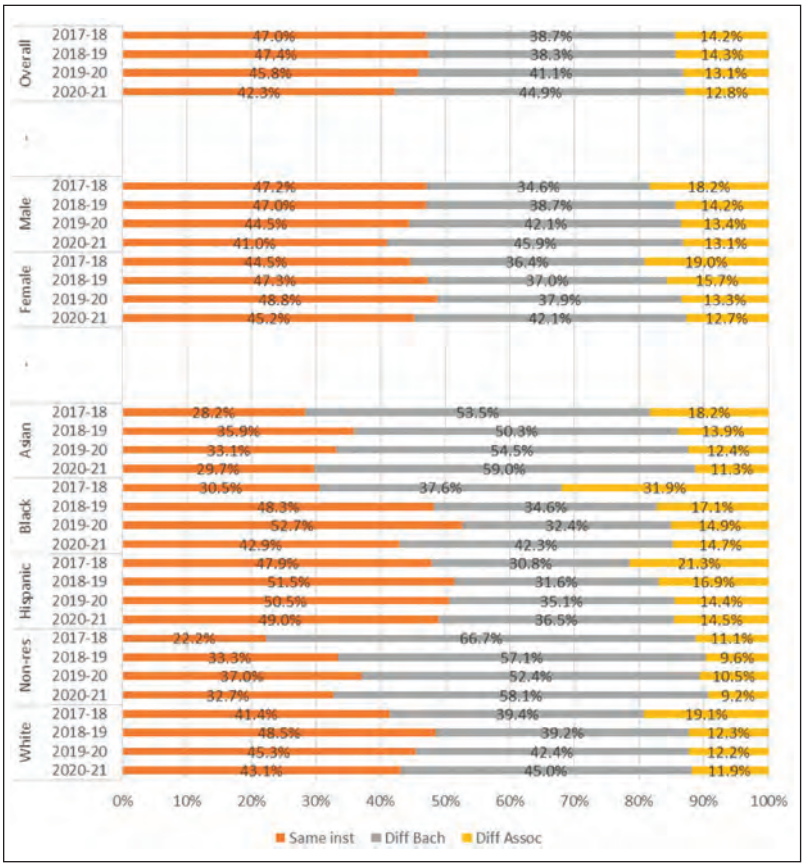

Figure 7: Location of Non-retained CS Associate's Students by Gender and Ethnicity

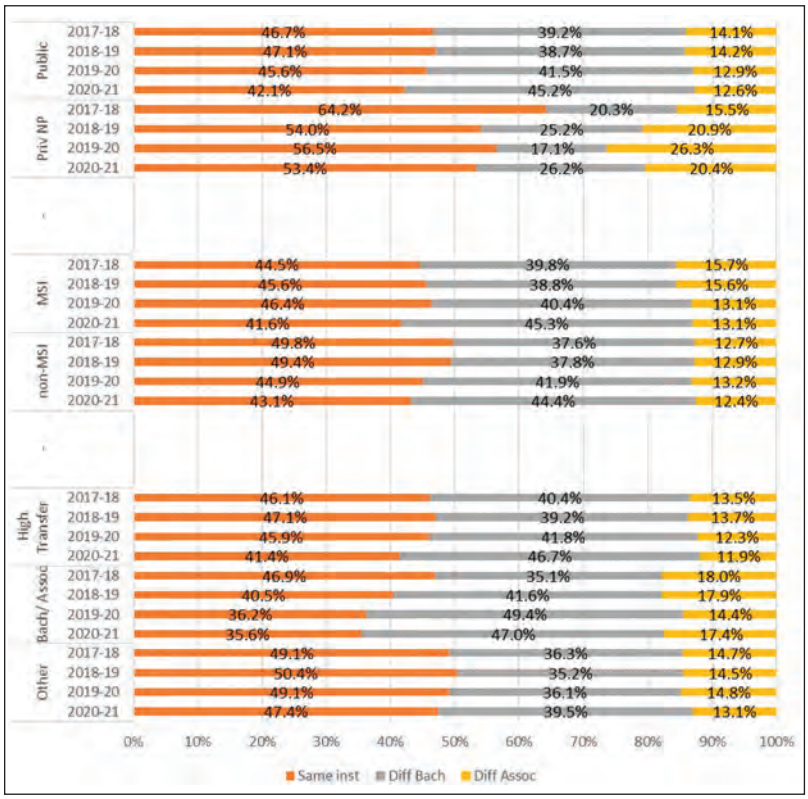

Figure 8: Location of Non-retained CS Associate's Students by Institution Type

types except for the bachelor/associate institutions, which showed smaller percentages in both those staying at the same institution and those going to bachelor's programs at a different institution. The instructional changes necessitated by COVID may have accelerated students' movement to bachelor's programs if that was their career goal,

Figures 9–12 show the locations to which non-retained IT students went for the three cohorts (2018-19, 2019-20, and 2020-21) for which we obtained such data. These figures correspond, respectively, to Figures 5–8 for the non-retained CS students. We could not display the distribution of non-retained IT Non-resident Alien students for the 2018-19 or 2019-20 cohorts since their computations are based on cells whose values were too small to allow NSC to provide us with exact values.

Among IT bachelor's students (Figures 9 and 10), students preferred to stay at the same institution and, if they went to another institution, it was primarily to study at the bachelor's level. This held for all three cohorts, both genders, all race/ethnicities, and all institution types. However, the IT cohorts experienced larger ups and downs than did their CS counterparts. Between the 2018-19 and 2019-20 cohorts, there was a noticeable decline in the percentage of non-retained IT students going to the same institution, with an even stronger rise in the 2020-21 cohort. The comparable CS cohorts showed much more narrow changes overall, and they went in different directions. The larger IT declines in the 2019-20 cohort were typically with respect to male students, white students, and students at public, MSI and non-R1/R2 institutions. However, the increases in the 2020-21 cohort were manifest in all genders and race/ethnicities, and in all institution types with the possible exception of private non-profits which saw a more modest increase.

For the most part, IT associate's students also typically preferred to stay at the same institution and, if they went elsewhere, it was to study at the bachelor's level (Figures 11 and 12). But there were exceptions among Asian students, and among students at Private Non-profit institutions. Asian students showed no difference in staying at the same institution and going to a bachelor's level program at another institution, while in two of the three cohort years, students at Private Non-profit institutions did not prefer bachelor's programs to associate's programs if they went elsewhere. The behavior of Asian associate's students also was seen in CS, and in fact was even more decidedly in favor of students going to a bachelor's level program at another institution, but the behavior of associate's students at Private Non-profit institutions was not.

Like their non-retained IT bachelor's counterparts, non-retained IT associate's students showed a decline between 2018-19 and 2019-20 in the percentage who went to the same institution. They had a recovery in the 2020-21 cohort to about the same level as in 2018-19.

What about the area studied by non-retained bachelor's and associate's students who remained in academia? Figure 13 shows the percentage of non-retained students from each cohort who went to other programs, either at the same institution or at different institutions. The choices of other programs are "same area" (i.e., other CS programs for CS students and other IT programs for IT students), computing programs in a

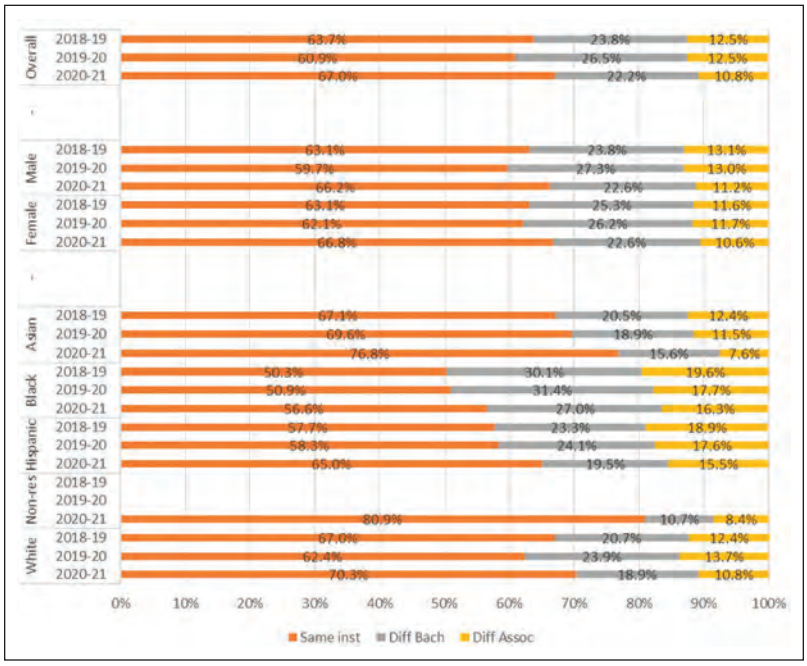

Figure 9: Location of Non-retained IT Bachelor's Students by Gender and Race/Ethnicity

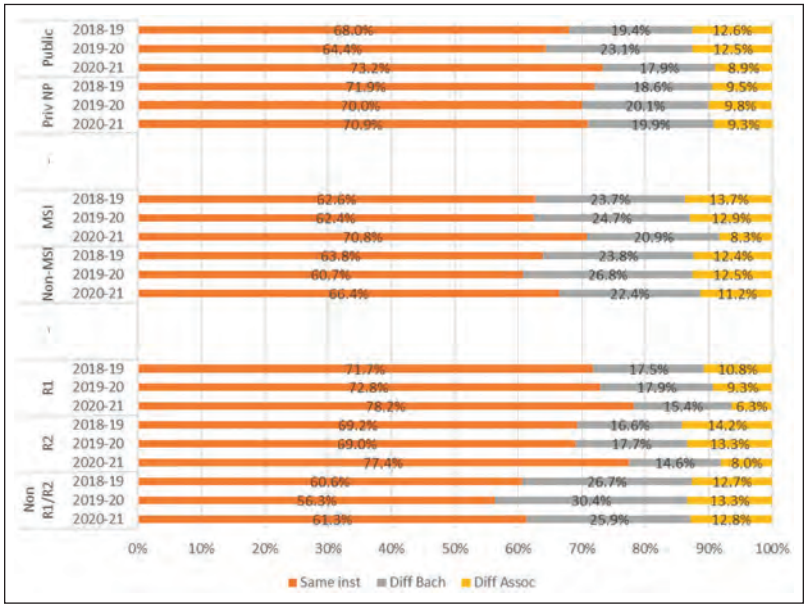

Figure 10: Location of Non-retained IT Bachelor's Students by Institution Type

different area (for CS students this can include IT, and for IT students it can include CS), non-computing programs in STEM areas, and all other types of programs. Using the topmost bar as an illustration, of the non-retained IT associate's students from the 2020-21 enrollment cohort who remained in academia, 7.8% continued their studies in IT, 34.8% studied in a different area of computing, 9.3% studied in a non-computing STEM area, and 48.0% studied in some other area.

As the figure illustrates, the largest group of students from each cohort, typically 40–50%, chose to study in a non-STEM area. The next largest group, typically 20–30% chose to move to a different area of computing. IT students were more apt to move to one of these options than were CS students. CS bachelor's students were more apt than IT bachelor's students to go to a different program in the same discipline (typically this would be at another institution, though this also includes students who stayed at the same institution to study in a program in the same area at a different degree level) or to a non-computing STEM program. CS associate's students initially were about equally likely to stay in CS as they were to study in a different area of computing, but the gap widened during the COVID period in favor of staying in CS. As was discussed earlier, this is consistent with the desire of many CS students who eventually are seeking a bachelor's degree in CS to begin their study in an associate's program, even if they do not attain an associate's degree before transferring to a CS bachelor's program. IT associate's students, but not CS associate's students, showed an increasing tendency to study a different area of computing during the COVID period.

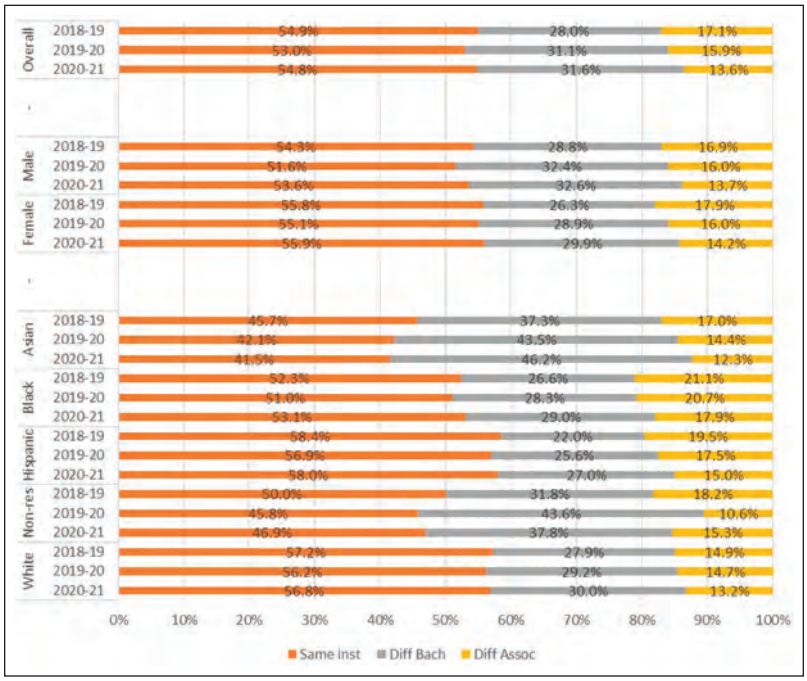

Figure 11: Location of Non-retained IT Associate's Students by Gender and Race/Ethnicity

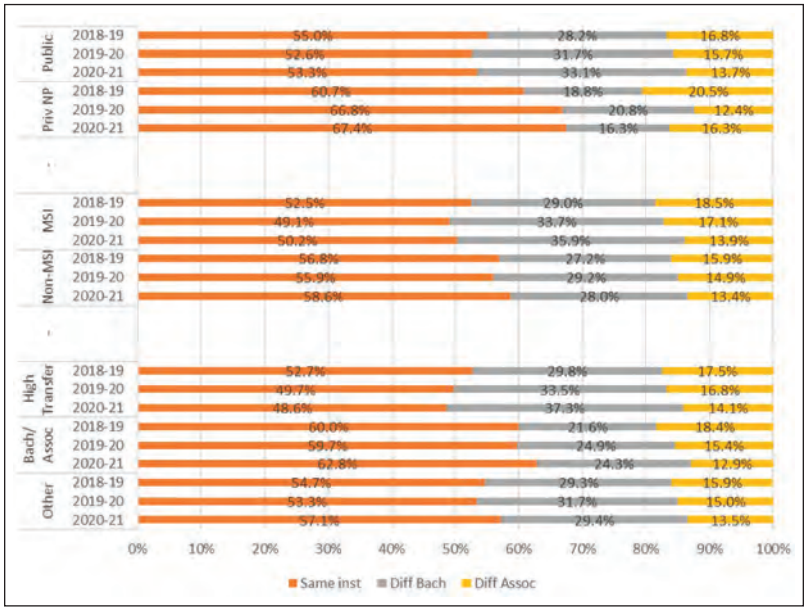

Figure 12: Location of Non-retained IT Associate's Students by Institution Type

GRADUATES STUDYING AT THE NEXT LEVEL

There only were slightly over 10% of the bachelor's graduates who went to graduate programs in the following year. This was true for both CS and IT bachelor's graduates. In CS, the percentage going to graduate programs increased in each year of the four-year period. For associate's graduates, the percentage studying at the next level was much higher in both areas, but especially in CS. This is consistent with the objective of many associate degree programs to prepare their students for bachelor's degree programs. Table 13 summarizes the data for both bachelor's and associate's students, and also disaggregates the overall percentages by gender and race/ethnicity.

Female bachelor's graduates were more likely to go to graduate programs than were male bachelor's graduates. Female IT associate's graduates also were more likely to go to bachelor's programs than were male IT associate's graduates; however, in CS, it was the male associate's graduates who were more likely to go to bachelor's programs.

Among the various race/ethnicity categories, the highest percentage of CS bachelor's graduates going to graduate programs was, by far, among Non-resident Aliens. The lowest CS percentages were among Hispanic and White graduates. In IT, Black and Non-resident Alien graduates had the two highest percentages. Hispanic and Asian graduates had much lower percentages. White IT graduates were comparable to Non-resident Aliens

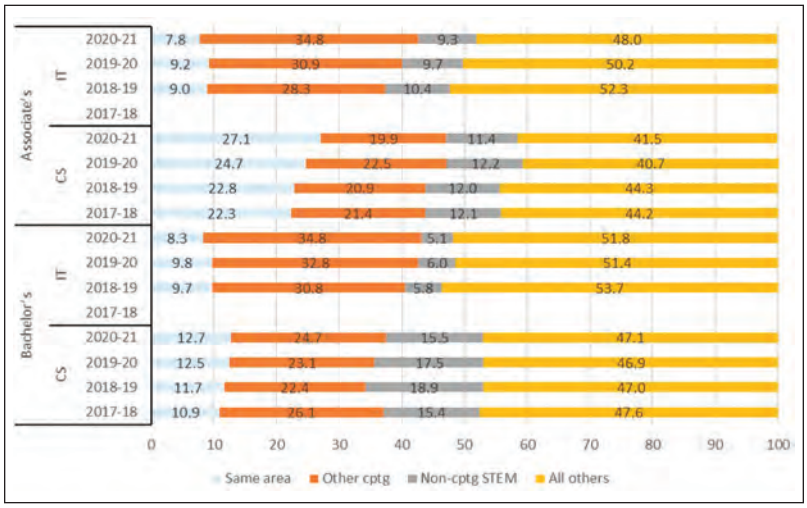

Figure 13: Area Studied by Non-retained Students Who Remained in Academia (%)

Table 13: Percentage of Graduates Studying at the Next Level

	Bachelor's							Associate's						
	2017-18	2018-19		2019-20		2020-21		2017-18	2018-19		2019-20		2020-21	
	CS	CS	IT	CS	IT	CS	IT	CS	CS	IT	CS	IT	CS	IT
Overall	10.4	10.9	10.5	12.3	11.8	13.0	11.3	44.4	50.5	29.6	52.9	31.1	50.1	31.3
Male	9.9	10.1	10.1	11.7	11.4	12.3	10.9	45.4	51.1	29.1	53.1	30.9	51.0	31.1
Female	12.7	13.1	12.6	13.5	12.8	14.3	12.2	40.7	47.9	32.1	51.7	31.9	47.4	32.9
Asian	10.7	11.6	8.5	13.5	11.0	14.4	10.5	59.6	68.2	41.7	71.2	42.0	67.1	45.2
Black	13.3	11.2	14.6	11.4	16.0	11.6	13.5	41.4	51.6	32.6	55.5	35.1	52.4	35.4
Hispanic	8.1	8.9	9.0	8.4	9.6	9.5	8.4	49.8	53.8	36.3	55.5	35.1	50.4	34.2
Non-res	25.5	26.9	13.1	27.9	16.4	28.8	18.8	45.7	60.3	33.1	61.9	38.1	54.2	29.8
White	9.0	8.4	13.0	10.2	8.4	10.4	9.1	37.7	43.5	23.8	45.0	24.0	42.5	24.0

in the 2018-19 cohort, but then dropped considerably to rank lowest among the race/ethnicity categories in the 2019-20 cohort and second lowest in the 2020-21 cohort. Among associate's graduates, Asian students had the highest percentage going to bachelor's programs in both CS and IT, while White students had the lowest percentage in both disciplines.

Figure 14 shows the areas studied by graduates in their next level of study. More than half of the CS graduates, whether bachelor's or associate's graduates, continued their study in CS at the next level. More than 75% of them stayed in some computing area for their study. In IT, by contrast, only about 20% of the bachelor's and 30% of the associate's graduates continued their study in IT. However, about two thirds of the bachelor's IT graduates and about 70% of the associate's graduates stayed in some area of computing.

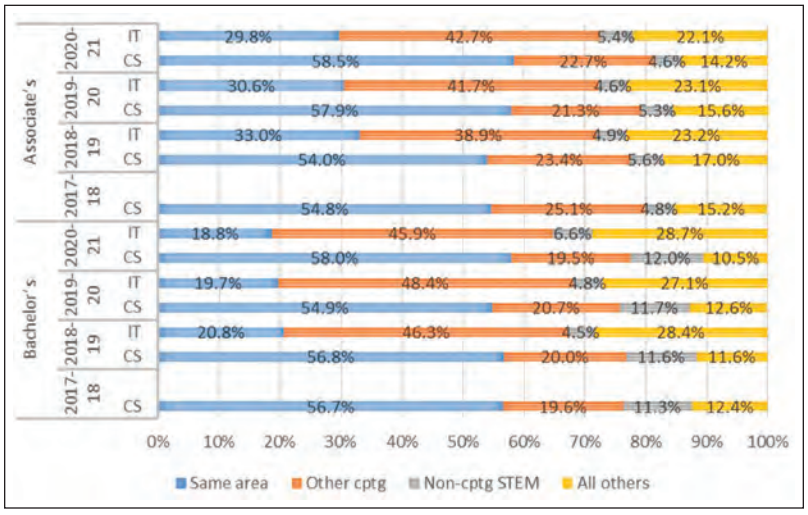

Figure 14: Area Studied at the Next Level by Graduates Who Remained in Academia the Year Following Graduation.

SUMMARY AND CONCLUSION

Our study provided comprehensive data about undergraduate enrollments and retention in U.S. computing programs covering four enrollment cohorts. The enrollment cohorts included two from pre-COVID times, one from the academic year during which COVID first hit, and the first academic year after COVID hit. The enrollment results showed that, in each year-over-year period, aggregate enrollment in the six bachelor's computing disciplines did better than aggregate enrollment across all bachelor's disciplines. In addition, aggregate enrollment across the three associate's computing disciplines did better than aggregate enrollment across all associate's disciplines. When the results are compared over the entire four-year period, enrollment increased by double-digit percentage across the six computing bachelor's disciplines, while aggregate bachelor's enrollments across all disciplines declined during this period. Furthermore, while declining enrollments at the associate's level were present both in computing and across all disciplines, the decline across the three computing associate's disciplines that we studied was only 36% of what took place across all disciplines (Figure 15).

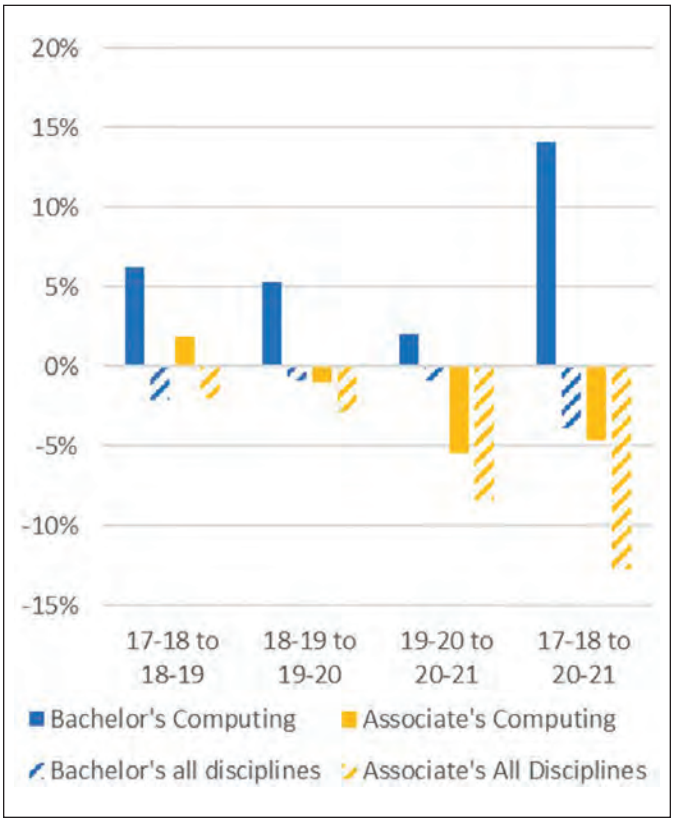

Figure 15: Enrollment Changes in Computing vs All Disciplines (%)

The enrollment results also indicate that the year-over-year results were worst for the period that was affected by COVID (2019-20 to 2020-21) in all cases except for bachelor's enrollment in all disciplines. However, all three cases that were worst for 2019-20 to 2020-21 continued a decline in year-over-year enrollment change evidenced by comparing the previous two periods. Therefore, it is not clear whether COVID really made a difference in the overall enrollment patterns we observed.

We observed slowly increasing representation of female students during the four-year period, at both the bachelor's and associate's levels. We also observed increasing representation of Asian and Hispanic students at both degree levels, and a decreasing representation of White students. Each of these results generally held for every computing discipline that we studied.

We investigated the gap between representation of various race/ethnicity categories in computing and that in all disciplines combined. We learned that the representation of Black bachelor's students is higher across all disciplines than in computing, but the gap has been at most one-half of one percentage point over the four years. At the associate's level, the representation of Black students in computing exceeds that at associate's programs across all disciplines. This calls into question statements about the overall underrepresentation of Black students in computing, though clearly there are differences in representation across the various computing disciplines.

With respect to retention, the COVID period seemed to have a noticeable effect, but not in retention from the 2019-20 cohort (the cohort that was enrolled when COVID first hit). The effect was pervasive for the 2020-21 enrollment cohort, affecting each discipline we studied, each gender, each race/ethnicity we studied, and each degree level. We observed only one instance, for Non-resident Alien students in CS associate's programs, where retention increased from the 2019-20 enrollment cohort to the 2020-21 enrollment cohort.

During the four-year period, male students were retained in greater percentages than female students in most, but not all cases. Furthermore, many disciplines exhibited a decreasing gap in these retention differences during this period. For most disciplines, Asian and Non-resident Alien students exhibited the highest retention among the race/ethnicities, while Black students tended to exhibit low retention relative to the other race/ethnicity categories.

We examined retention differences across various institution types, and between genders within specific race/ethnicity categories, to see which significant differences were present across the different enrollment cohorts. We observed a large degree of consistency in these results across the different cohorts. Those results that were not consistent from year to year may be of interest to researchers for future study.

There is a limited amount of comparison that we can make of our retention results with those of other studies. NSC provides reports of retention of first-year students [11]. For associate degree programs, the computing area's overall first-year retention levels are reported, suggesting a "sanity check" of our associate's retention results against theirs. However, there are three important differences in these computations that diminish our ability to accurately compare our retention data with that in the NSC report. First, NSC reports the computing area as "Computer and Information Sciences and Support Services" programs, which comprises all programs using any CIP codes of the form 11.xxxx. As Table 1 illustrates, there are

several CIP codes that we mapped to computing from outside of area 11. Furthermore, there are some CIP codes within area 11 that we did not map to the specific computing disciplines that we studied, although these codes are included in our calculations of non-retained students and students studying at the next level who studied in another computing area. The second important difference is the definition of retention used by NSC. Our definition of retention counts students studying in the same program of study at the same institution during the following year or graduating during the base year. NSC's definition counts students studying at the same institution in the following year in any program of study, or completing their degree in the original program of study during the base year. We can correct for this as will be explained below. The third difference is that our retention is not computed only for first-year students. With these caveats, we offer an approximate comparison of our computing retention results for associate's students to those of NSC's first-year retention in two-year programs. While we would expect our results to not coincide, we are interested to see if they are in the same ballpark.

NSC reports retention for first-year associate's students as 57.1% for the 2020-21 cohort. For the same cohort, we reported associate's retention of 44.9% for CS, 47.7% for IT, and 49.7% for CY (Table 7 and Figure 2b). To correct for the differences in the definition of retention, we need to account for students who remained at their same institution, but were in other programs of study. We can do this for the CS and IT students, but not for the CY students, using our data about non-retained students. The computation multiplies the percentage of non-retained students from the enrollment cohort (i.e., 100% minus the percentage of retained students) by the percentage of those non-retained students who were tracked, and then by the percentage of those tracked who remained at the same institution. For CS, these values are, respectively, 55.1%, 40.6% and 42.3% (Table 12 and Figure 7). For IT, the respective values are 52.3%, 30.0% and 54.8% (Table 12 and Figure 11). Adding these products to our reported retention values gives totals of 54.4% for CS and 56.3% for IT as points of comparison with the 57.1% value in the NSC report. Indeed, our results are in the same ballpark.

The NSC report also contains overall retention rates across all disciplines, and disaggregates the retention data by gender and certain race/ethnicity groups within different categories of institutional control. For associate's programs, the most approximate data given in the NSC report is for Public Two-Year Institutions. As Table 3 indicates, public institutions comprise well over 90% of the associate's institutions in our computing data set. For the 2020-21 enrollment cohort, overall retention was 52.4%. Thus, computing retention, whether measured by the set of computing programs we studied or the set of programs using CIP Codes from area 11, exceeded retention across all disciplines. With respect to diversity, the NSC disaggregated data for all disciplines shows highest retention rates for Asian students and lowest for Black students, and higher retention for female than for male students. Our study did not show consistent race/ethnicity rankings across the three computing disciplines at the associate's level; it also showed that, for two of the disciplines, there was virtually no difference in gender retention but for the third (IT) there was a clear edge in retention of male students (Table 9 and Figure 3b).

While the NSC retention reports do not single out bachelor's data for computing programs, we can provide some approximate comparison of first-year bachelor's retention in computing by looking at retention of freshman students in CS and IT. NSC reports first-year retention separately for public 4-year institutions, private non-profit 4-year institutions, and private for-profit 4-year institutions. The 2020-21 retention values are 75.4%, 75.5%, and 42.5%, respectively. More than 95% of the bachelor's institutions offering the computing programs that we studied were either public or private non-profit. Overall freshman retention rates for CS and IT bachelor's students in 2020-21 were 56.7% and 49.0%, respectively (Table 11). Using a similar approach as for the associate's students to correct for the differences in the definition of retention, the modified retention computation for CS is 56.7% + (43.3%*50.5%*64.8%) = 70.9%. For IT the modified value is 49.0% + (51.0%*28.9%*59.6%) = 57.8%. The middle values in the parenthetic expressions come from Table 12; the third values were not discussed in the body of this paper, but were available from the raw NSC data. Both modified retention values compare unfavorably to the NSC reported values for all disciplines. It should be noted that IT and private non-profit CS institutions reported a high fraction of enrolled students without a specific class rank. Furthermore, in IT, only 28.9% of non-retained bachelor's students were tracked at all in 2020-21, although this was not much lower than the percentage of non-retained IT associate's students who were tracked. Even with the caveats in comparing the all-disciplines and computing data, it appears that first-year retention in both CS and IT was lower than that across all disciplines in 2020-21. However, for public CS institutions, the modified CS retention is computed as 60.8% + (39.2%*57.5%*65.6%) = 75.6%, which is quite close to the 75.4% reported by NSC for 4-year public institutions in all disciplines. With respect to diversity across all disciplines, both 4-year public and 4-year private non-profit institutions were shown to have highest retention for Asian students and lowest for Black students among the common race/ethnicity groups that we studied (White and Hispanic/Latinx were the others), exactly what our bachelor's computing data showed (Table 9). Female students had slightly higher retention than male students across all disciplines; our study showed small differences in four of the six bachelor's computing disciplines, with two slightly favoring male students and two slightly favoring female students, while the other two bachelor's disciplines (CS and SE) clearly favored male students (Figure 3a).

During the pandemic years, there was a decrease in the fraction of non-retained students who were tracked (Table 12). These are students who neither completed their degree nor returned to academia in the following year. In other words, there appeared to be a decrease in what is called "persistence" of enrolled students (we say "appeared to be" because, where there was increased retention during this period, there would

be a smaller percentage of non-retained students, so even if there was a smaller fraction of students tracked, there still may not have been a smaller fraction of originally-enrolled students tracked). This change was most noticeable in the 2019-20 cohort, the first cohort affected by the pandemic. The change affected both computing disciplines that we studied, CS and IT. It was present among both bachelor's and associate's students, although to a greater extent for bachelor's students. Hispanic students were the hardest hit among the race/ethnicity classes, while in CS, Non-resident Alien students also showed greater than average change. This decrease in persistence among computing students cannot readily be compared with persistence across all disciplines. However, the NSC report mentioned above also contains persistence rates for students across all disciplines in their first year of study [11]. Their report found that, aggregated across all institution types, first year persistence dropped between the 2018-19 and 2019-20 enrollment cohorts. It increased for the 2020-21 cohort, though not to the pre-pandemic level. The all-disciplines report also mentions that, in 2019-20, there was a large persistence drop among Latinx students, which partially recovered in 2020-21. Freshman bachelor's students in the IT cohorts that we studied behaved similarly to the overall NSC first year persistence results, while CS freshman bachelor's students showed declines in both COVID-affected cohorts (Table 12).

When students in computing programs were not retained by their program but continued in academia, our data showed that more often than not they left computing altogether as their selected area of study. In fact, more than 40% of former CS students and more than 50% of former IT students did not even pursue another STEM area. We did not identify any noteworthy COVID-related changes in this pattern. However, in both disciplines, non-retained associate's students who remained in academia went to different bachelor's programs in increasing percentages during the COVID period (see Figures 7 and 11). In CS, but not in IT, this was coupled with an increased tendency to continue their studies in the same area.

CS bachelor's graduates showed an increasing tendency over the four-year period to pursue graduate work during the year after graduation. We could not relate this to the pandemic since there was an increase in the year prior to the pandemic. Nor were we able to identify any other year to year changes in the data on graduates studying at the next level that appeared to be attributable to the pandemic.

The extensive amount of data we presented here is intended to serve as a baseline for ongoing annual updates about enrollment and retention in computing programs, as well as providing multiple years' worth of data against which other researchers and academic leaders can benchmark their work and local environment. With this four-year period as a baseline, we are in a better position to assess a subsequent year's data as a departure from previous patterns. Where we identified differences between pre-COVID and COVID-year data, we also will look for any rebounding to pre-COVID years. ❖

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