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AP[®] Computer Science Principles and the STEM and Computer Science Pipelines

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Executive Summary

For decades, Black, Hispanic, and female students have been underrepresented in computer science, including college majors, introductory programming courses, and the “AP[®] Computer Science A” Java-based programming course designed to award high school students college credit and placement into more advanced college computer science courses. This lack of representation stands to leave underrepresented students less prepared to capitalize on high paying opportunities in the science, technology, engineering, and math (STEM) fields that are expanding more rapidly than opportunities in non-STEM fields.

To address these issues, the College Board, with significant support from the National Science Foundation, launched a new AP Computer Science Principles (CSP) course and exam in the 2016-17 academic year designed to foster a wider appeal and attract more underrepresented students to computer science while still providing college-level rigor and college credit for those who demonstrate proficiency. The AP CSP course teaches the foundational concepts of computer science and includes programming skills that explore computing principles that cut across many areas of computer science, but unlike AP Computer Science A (CSA), CSP is not focused primarily on programming. The first year of CSP attracted more students than any other AP course debut. Now that the high school graduating class of 2019 has had both the opportunity to take CSP throughout high school and the opportunity to enroll in college, we examine whether CSP students who enroll in college are more likely to major in computer science or STEM and whether they are more likely to take CSA or another AP STEM in high school.

Data for our analyses come from the College Board database of students who graduated high school in either 2019 or 2016 and the National Student Clearinghouse (NSC). NSC tracks students’ college enrollment, choice of major, and degree attainment for students enrolled in more than 3,100 colleges and universities in the United States. Our analyses compare CSP takers in the 2019 graduating class in terms of declared major in college and AP STEM and AP CSA taking in high school to a similar group of students in the 2016 graduating class who attended high school prior to the launch of CSP.

In the class of 2019, we find the AP CSP course attracts more diverse students than AP CSA, with a greater proportion of female, Hispanic, Black, and first-generation students taking CSP than CSA.

Our analyses demonstrate that CSP participation is positively associated with students’ college major choice, with CSP students considerably more likely to declare a computer science major at the start of their first year in college, and also more likely to declare STEM majors. Specifically, CSP students are more than three times as likely to major in computer science than similar students who did not take CSP (16.9% vs. 5.2%), and differences are even larger for female and Hispanic students. The increases in college computer science majors are evident both for students who take AP CSP as their only AP STEM course in high school as well as for students who take CSP and another AP

STEM including CSA in high school. This result is significant given that CSP was designed to be more accessible than CSA and reach students who previously may have not participated in computing.

When we examine CSA taking by CSP and non-CSP students with similar prior achievement, we find that gaps in CSA enrollment by race/ethnicity are greatly reduced. Black students who take CSP enroll in CSA at virtually the same share as Asian CSP students, who have long led CSA participation. Altogether, CSP students are nearly twice as likely to enroll in CSA compared to similar non-CSP students (32.5% vs. 18.2%). This result holds for female, Hispanic, and first-generation students, and is even larger for Black CSP students, who are three times more likely to later enroll in CSA if they take CSP.

Finally, our analyses suggest that CSP serves as a stepping-stone to other advanced AP STEM coursework for most CSP students. In the class of 2019, CSP was the first AP STEM course for more than half of CSP students, and more so for Black students (68%), Hispanic students (59%), and first-generation students (60%).

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Introduction

Computer science enables the development of new technology and innovations in every field and has far-reaching applications for the workforce of tomorrow. Opportunities in high paying STEM jobs are expanding and the number of jobs for computer science and research scientists is expected to grow 15% between 2019 and 2029, compared to 11% for all computer occupations and just 4% for all occupations (Occupational Outlook Handbook 2020). Despite this projected growth, few students, especially underrepresented students, have historically enrolled in advanced high school computer science courses (e.g., AP Computer Science A) or declared a major in computer science in college (U.S. Department of Education 2012).

Limited enrollment in computer science courses in high school is problematic given research finds most decisions to pursue a degree in computer science, especially among young women, begin before college (Cheryan, Ziegler, and Montoya 2017; Google 2014). Furthermore, the opportunity to participate in computer science courses and other computing-related activities in high school is related to an increased interest in a computer science major (Google 2014). In response, the College Board, with significant support from the Nation Science Foundation, embarked on a major effort in late 2009 to develop a new course called AP Computer Science Principles (CSP). This new course aims to foster a wider appeal, particularly among students traditionally underrepresented in computer science, by teaching the foundational concepts of computer science. While the new course includes programming skills to explore computing and principles that cut across many areas of computer science, this is not the primary focus as it is in the Java-based AP Computer Science A (CSA) course.

The end of course assessment for AP CSP is also unique. In addition to traditional multiple-choice items, students complete a performance task over the course of the school year where they create a program to solve a problem, enable innovation, explore personal interests, or express creativity. Students can collaborate with their partner(s) during aspects of this task, including development of program code. The emphasis on programming as a collaborative and creative process is thought to especially appeal to students who traditionally may have felt they did not belong in computer science. As Cheryan, Ziegler, and Montoya (2017) put it, “Efforts to increase women’s participation in computer science, engineering, and physics may benefit from changing masculine cultures and providing students with early experiences that signal equally to both girls and boys that they belong and can succeed in these fields.” Research suggests that one of the main benefits of a collaborative environment is the impact on students’ beliefs about themselves (Johnson and Johnson 1989). Through working in groups or using pair programming strategies, students are given the opportunity to discuss their ideas freely and tend to be more comfortable expressing their ideas during the problem-solving process (Braught, Wahls, and Eby 2011).

The first year of CSP attracted more students than any other AP course debut. Now that the high school graduating class of 2019 has had the opportunity to take CSP as sophomores, juniors, or seniors, we have ample data to generate early evidence on the relationship between AP CSP participation and subsequent STEM and computer science interest and

participation in high school and college. Prior AP research demonstrates a positive relationship between AP participation and STEM outcomes in college (Tai, Liu, Almarode, and Fan 2010; Mattern, Shaw, Ewing 2011; Smith, Jagesic, Wyatt, and Ewing 2017). The most recent study finds that AP STEM students are 13 percentage points more likely to complete a STEM major than similar non-AP STEM peers and that positive results hold for female, underrepresented minority students, and first-generation students (Smith, Jagesic, Wyatt, and Ewing 2018). However, CSP had not yet launched at the time of these studies and, thus, has not yet been examined. One exception is research by Sax et al. (2020) who surveyed first-time college students in fall 2017 attending approximately 170 institutions to find that students who take AP CSP are more representative of groups historically underrepresented in computing with a greater proportion of women, Hispanic, Black, and first-generation students reporting enrollment in CSP compared to CSA during high school. The survey also finds that nearly 17% of students who take CSP select a computing major at the start of their first year in college and are also likely to select other STEM-focused and business-related majors. Students who take CSA only or take both CSP and CSA are even more likely to select a computing major. The Sax et al. (2020) survey was conducted just one year after the CSP course launched, capturing only those students who took AP CSP as high school seniors, and did not attempt to isolate the effect of CSP on student outcomes by controlling for other factors that are related to course taking and college major choice decisions.

In this study, we build on prior work by investigating three specific research questions:

- 1) Is CSP diversifying the pipeline of students taking AP computer science?
- 2) After taking CSP and enrolling in college, are students more likely to major in computer science or, more broadly, in STEM?
- 3) After taking CSP, are students more likely to go on to take AP CSA or another AP STEM course? Is CSP serving as the introduction to AP STEM coursework for those who take it?

Data and Methodology

Data for our analyses come from the College Board database of students who graduated from high school in either 2019 or 2016 and the National Student Clearinghouse (NSC). NSC tracks students' postsecondary enrollment and degree attainment for over 3,100 two-year and four-year colleges and universities in the United States.¹ Students in the high school class of 2019 had the opportunity to take CSP in 10th grade, when AP CSP Exam was administered for the first time in May 2017, or later in 11th grade or 12th grade. Approximately 65,000 students in the class of 2019 took the Computer Science Principles (CSP) Exam at some point during high school.

¹ A list of participating institutions is provided here: <https://www.studentclearinghouse.org/colleges/enrollment-reporting/enrollment-reporting-institutions/>.

To address our first research question, we analyze the AP Exam taking patterns of students in the class of 2019 to understand if CSP attracts a more diverse group of students than the traditional CSA course. While the number of Black and Hispanic students taking CSA has increased by almost 40% in the three years between 2016 and 2019, the composition of CSA nonetheless reflects the gender and racial disparities that we see in computer science in general. We compare the composition of CSP takers in the 2019 graduating class to those of CSA takers in that same graduating class to further explore whether CSP is diversifying the AP computer science pipeline.

For our second research question, we compare CSP takers in the 2019 graduating class in terms of computer science (CS) and STEM majoring to a similar group of students in the 2016 graduating class. We analyze the high school graduating class of 2016 for this comparison as these students graduated high school the year prior to the launch of the CSP and, as a result, did not have CSP available to them. All students in our sample came from 2019 and 2016 graduating classes and also took the SAT[®] and self-reported their gender, ethnicity, parental education, and high school GPA (HSGPA), and immediately enrolled in a four-year college after high school. Additionally, to be included in our analysis for the second research question, students must have declared a major with a valid Classification of Instructional Programs (CIP) code, which is a six-digit number maintained by the National Center for Education Statistics (NCES) used to group similar fields of study.² CIP codes are used to categorize majors. Majors beginning with “11” were categorized as computer science and STEM majors were identified based largely on a taxonomy from the Department of Homeland Security.³

To account for many of the differences between CSP and non-CSP students that may be related to high school AP course taking decisions and choice of college major, we employ a matching methodology based on the Godfrey Exact Match (GEM) approach (Godfrey 2016). CSP students in the class of 2019 are matched to non-CSP students in the class of 2016 exactly on gender, race/ethnicity, parental education, self-reported HSGPA, and to within 20 points on both the ERW and math sections of the SAT. In other words, each CSP student from the 2019 graduating class is matched to a student from the 2016 graduating class who did not have the opportunity to take CSP and each resulting matched pair has the same gender, race/ethnicity, parental education level, and self-reported HSGPA, and very similar SAT scores.⁴ In our sample for both the second and third research questions, CSP students from the 2019 cohort are required to have attended a high school that continuously offered CSP from 2016-17 through 2018-19. Our methodology gives priority to students from the same high school to better control for differences across high schools. In our sample, approximately 35% of matched students attended the same high school. Even with this

2. Please see <https://nces.ed.gov/ipeds/cipcode/browse.aspx?y=55> for more information.

3. Please see <https://www.ice.gov/sites/default/files/documents/Document/2014/stem-list.pdf>

4. SAT scores from the 2016 were on the old scale and concorded to the current scale (<https://collegereadiness.collegeboard.org/pdf/higher-ed-brief-sat-concordance.pdf>). We used the students highest and lowest SAT scores, and both the CSP students and non-CSP students had to be within 20 points on any combination of scores (high-to-high, high-to-low, low-to-high, low-to-low).

approach and a robust set of matching variables, we are unable to control for all factors that may influence our outcomes of interest and the results do not support causal claims.

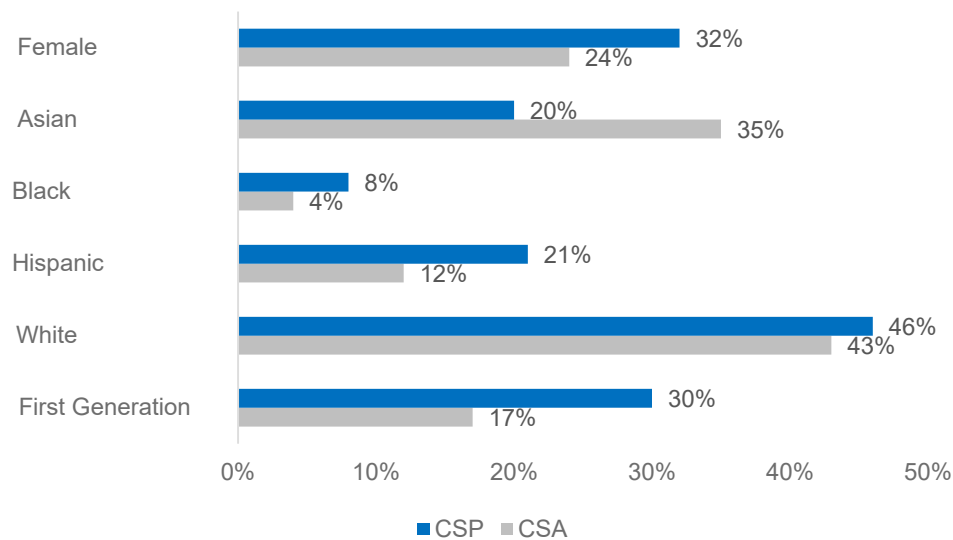
Our third research question investigates whether CSP students go on to take CSA or another AP STEM course in high school and relies on a similar data set to the one we utilize for the second research question, but is not limited to students who enroll in college. We use an identical matching methodology to the one described to address the second research question. Our final sample sizes differ for each analysis, ranging from 11,220 to 36,848 students depending on the sample criteria. Each sample is comprised of an equal number of both CSP and non-CSP students.

Results

AP CSP Participation

Figure 1 shows the characteristics of students in the class of 2019 who take CSP and CSA by gender, race/ethnicity, and first-generation status. First-generation status is derived from the parental education variable and represents students whose parents' combined highest education completed was at most a high school diploma. Results in Figure 1 indicate that students who take AP CSP are more representative of groups historically underrepresented in computing with a greater proportion of female, Hispanic, Black, and first-generation students taking CSP in the class of 2019 than AP CSA. Female students account for 32% of CSP students compared to just 24% of CSA students, while the proportion of Black, Hispanic, and first-generation students taking CSP is almost double that of CSA. Appendix Table A-1 provides more information on CSP participation among student subgroups.

Figure 1: Percentage Composition of AP CSP and AP CSA Students



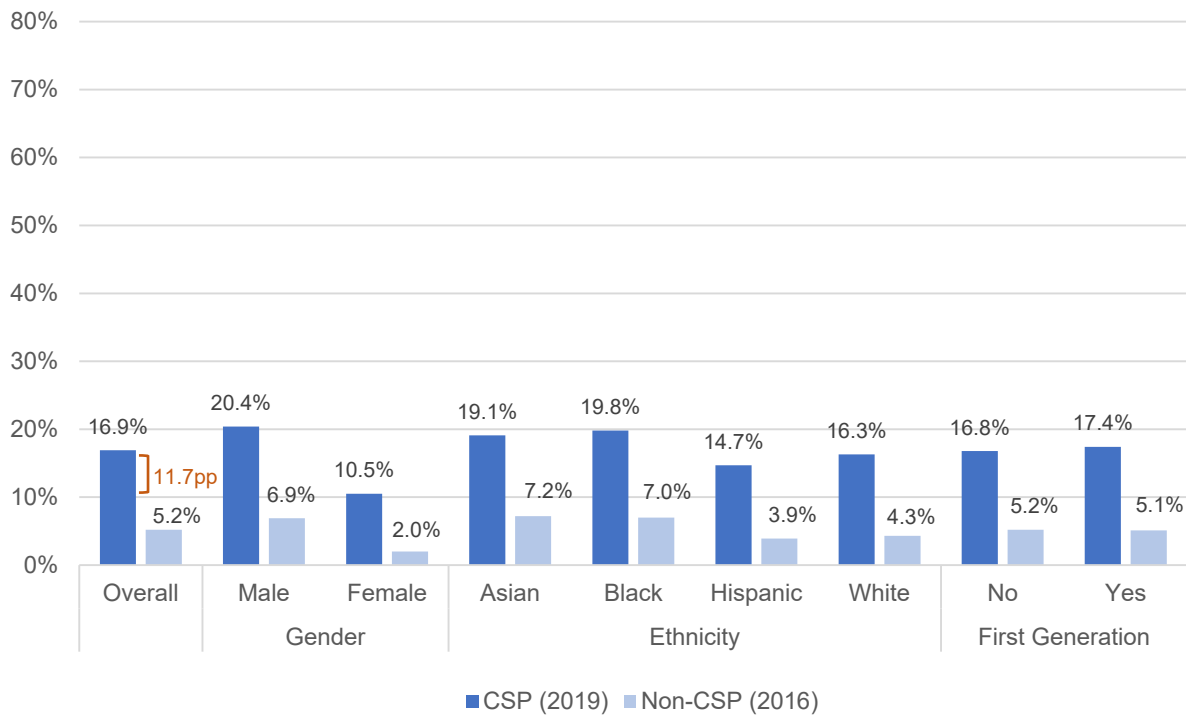
Note: In the graduating class of 2019, there are 65,639 students who took CSP and 64,474 students who took CSA.

AP CSP and Subsequent Computer Science and STEM Majoring in College

Figure 2 conveys the percentage of students who declare a CS major at the start of their first year in college for both CSP and non-CSP students. Students taking CSP are three times more likely to declare a major in computer science, 16.9% vs. 5.2%, with the rate of CS majoring among CSP students being 11.7 percentage points higher than that of non-CSP students.

Figure 2 also shows variation by student group. While CSP students consistently have higher rates of CS majoring than the non-CSP students, the magnitude of the difference varies by student group. Female CSP students are over five times as likely (10.5 vs. 2.0) to major in CS, Black students over two times as likely, Hispanic students over three times as likely, and first-generation students over three times as likely. Overall, 16.9% of CSP students in our matched sample declared a computer science major compared to 10.5% of female students, 19.1% of Asian students, 19.8% of Black students, 14.7% of Hispanic students, and 17.4% of first-generation students.

Figure 2: The Percentage of CSP and Non-CSP Students Who Major in CS



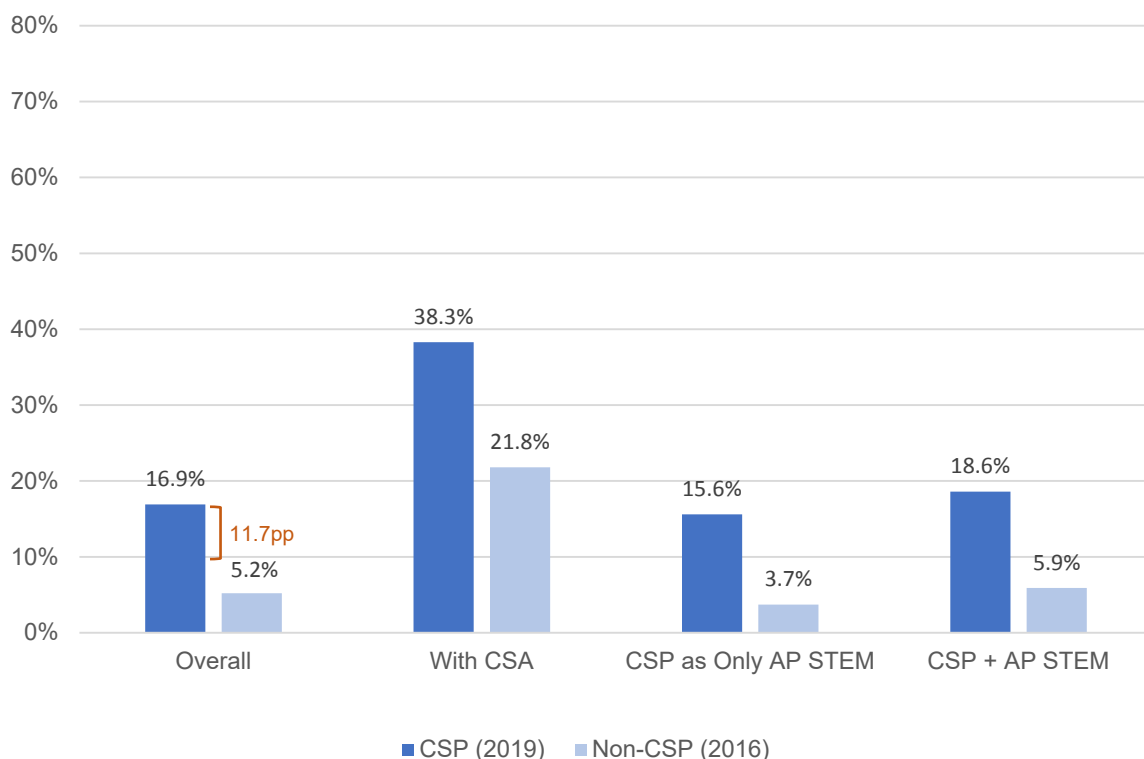
Note: This sample includes 36,848 students, 18,424 each of CSP and non-CSP students who are matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019, with all students enrolling in a four-year college and declared a major. The CSP students attended a high school that offered CSP continuously from 2017 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

We conduct additional analyses to understand if the likelihood of declaring a CS major for CSP students overall holds for students who take CSP as their only AP STEM course in high school. These analyses also address the extent to which the likelihood of declaring a CS major changes for students who take both CSP and CSA, or those who take CSP and another AP STEM. The “Overall” bar in Figure 3 corresponds to the same “Overall” result presented in Figure 2 and indicates as previously noted that CSP students overall are 11.7 percentage points more likely to major in computer science than non-CSP students. The other three bars in Figure 3 provide results for three subgroups of CSP takers: (1) those who take both CSP and CSA in high school (labeled “With CSA”), (2) those who take CSP as their only AP STEM in high school (labeled “CSP as Only AP STEM”) and (3) those who take CSP and one or more AP STEM Exam(s), either CSA and/or any other AP STEM Exam (labeled “CSP + AP STEM”).

Results in Figure 3 indicate that all CSP students, regardless of whether they take a subsequent AP CSA or AP STEM Exam in high school, are more likely to declare a CS

major once they enroll in college. Specifically, students who take CSP as their only AP STEM Exam in high school are 11.9 percentage points more likely to declare a CS major than students who take no AP STEM Exams (15.6% vs. 3.7%). Students who take CSP and another AP STEM are 12.7 percentage points more likely to major in CS than students who take an AP STEM other than CSP (18.6% vs. 5.9%). Finally, as expected, students who take CSP and CSA are even more likely (16.5 percentage points) to declare a major in computer science than similar students in the 2016 cohort who only take CSA, as CSP was not available to them.

Figure 3: The Percentage of CSP and Non-CSP Students Who Major in CS, by AP STEM and CSA Exposure

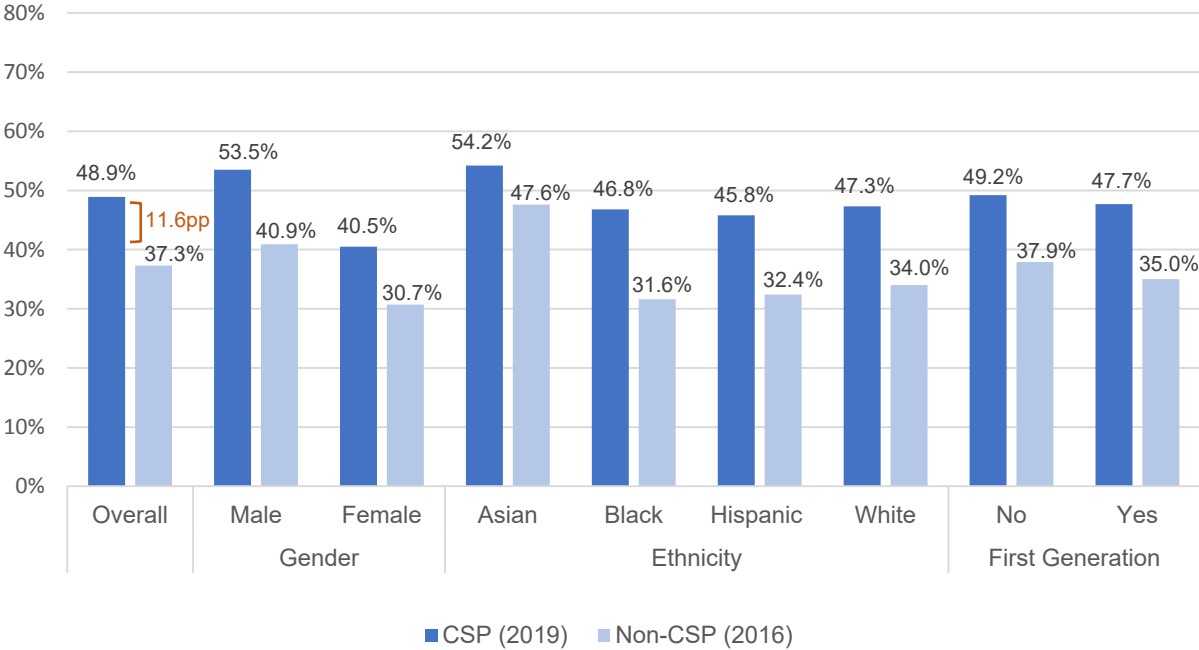


Note: This sample includes 36,848 students, 18,424 each of CSP and non-CSP students who were matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019, with all students enrolling in a four-year college and declared a major. The CSP students attended a high school that offered CSP continuously from 2017 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

Figure 4 displays the percentage of students who declare a STEM major at the start of their first year of college at a four-year institution. CSP students are 11.6 percentage points more likely to declare a STEM major in college than similar students who did not take CSP (48.9% vs. 37.3%). CSP students have higher rates of STEM majoring for all the subgroups studied, although the magnitude of the difference varies slightly by student group. For example, compared to similar students who do not take CSP, Black CSP students are 15.2

percentage points more likely to major in STEM and first-generation CSP students are 12.7 percentage points more likely to major in STEM in college.

Figure 4: The Percentage of CSP and Non-CSP Students Who Major in STEM

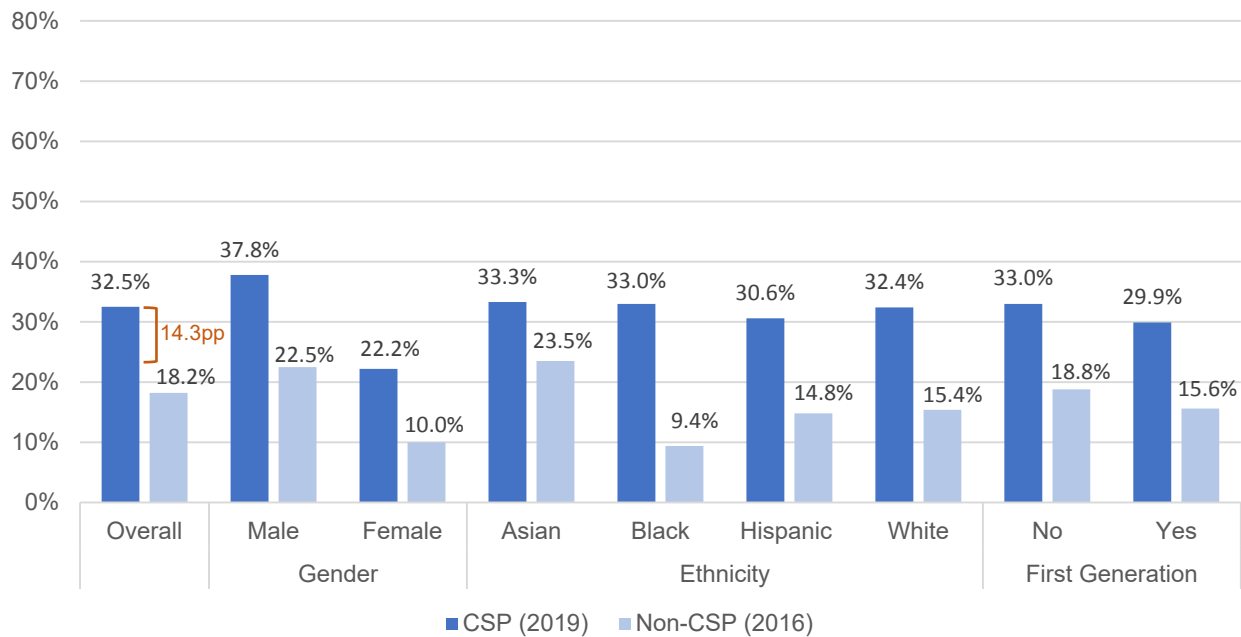


Note: This sample includes 36,848 students, 18,424 each of CSP and non-CSP students who are matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019, with all students enrolling in a four-year college and declared a major. The CSP students attended a high school that offered CSP continuously from 2017 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

AP CSP and Subsequent AP CSA and AP STEM Taking in High School

Next, we examine subsequent AP CSA and AP STEM taking for students who take CSP in either 10th or 11th grade. Figure 5 displays the percentage of students who take CSP and subsequently take CSA compared to the percentage of non-CSP students who take CSA. As can be seen in the overall sample, CSP students are nearly twice as likely (32.5% vs. 18.2%) to enroll in CSA compared to similar high school students before CSP was available. This result holds for female, Hispanic, and first-generation students, and is even larger for Black CSP students, who are three times more likely to later enroll in CSA if they have taken CSP (33.0% vs. 9.4%). As Figure 5 shows, gaps in CSA taking by race/ethnicity are substantially reduced among students taking CSP. Specifically, among those who did not take CSP because it was not yet available, 23.5% of Asian students, 9.4% of Black students, 14.8% of Hispanic students, and 15.4% of White students subsequently take CSA. By comparison, CSA participation among CSP students is very similar across racial/ethnic groups: 33.3% of Asian students, 33.0% of Black students, 30.6% of Hispanic students, and 32.4% of White students.

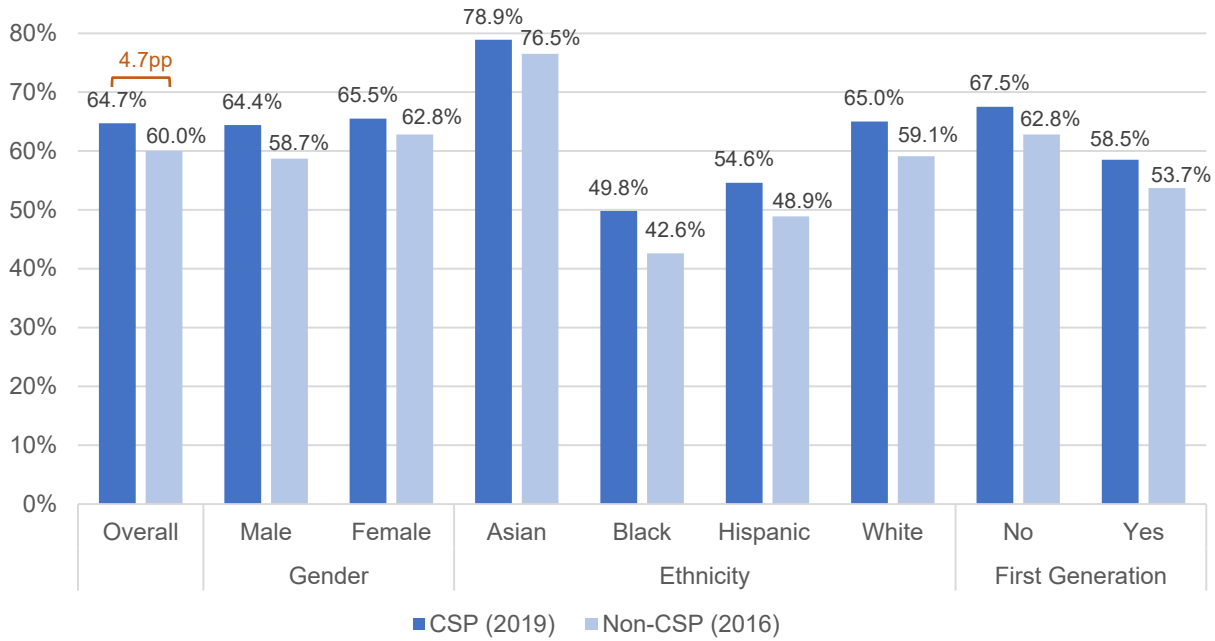
Figure 5: The Percentage of CSP and Non-CSP Students Who Subsequently Take CSA



Note: This sample includes 11,220 students, 5,610 each of CSP and non-CSP students who were matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019 and took the CSP Exam in either 10th grade or 11th grade as their first AP STEM Exam. The CSP students attended a high school that offered CSP continuously from 2017 through 2019 and continuously offered CSA from 2014 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

Figure 6 displays the percentage of CSP students in 10th or 11th grade who subsequently take another STEM AP Exam in 11th or 12th grade compared to the percentage of matched non-CSP students who take an AP STEM Exam. The CSP students have no prior or concurrent AP STEM Exams. In the overall group, 64.7% of CSP students take an AP STEM Exam compared to 60% of all non-CSP students, a difference of 4.7 percentage points. This positive difference for CSP takers is present across all student groups, although the magnitude of the difference varies by subgroup. The difference is about the same for first-generation students (4.8 percentage points), lower for Asian (2.4 percentage points) and female (2.7 percentage points) students, and higher for Black (7.2 percentage points) and Hispanic (5.7 percentage points) students.

Figure 6: The Percentage of CSP and Non-CSP Students Who Take a Subsequent AP STEM Exam

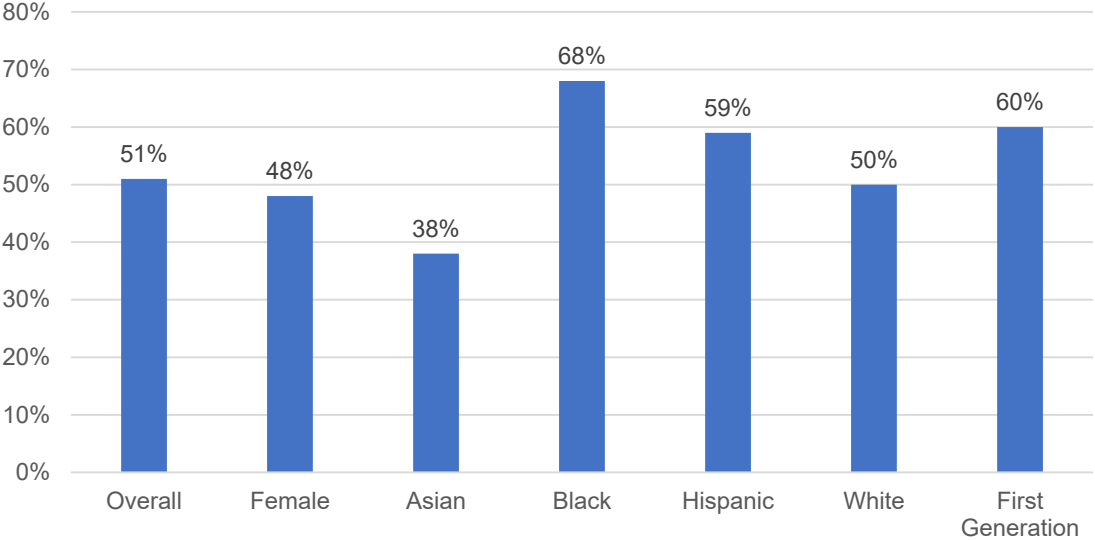


Note: This sample includes 22,916 students, 11,458 each of CSP and non-CSP students who are matched on academic performance and background characteristics. The non-CSP students graduated in 2016 while the CSP graduated in 2019 and took the CSP Exam in either 10th grade or 11th grade as their first AP STEM Exam. The CSP students attended a high school that offered CSP continuously from 2017 through 2019. All differences between the CSP students and the non-CSP students are significant at the .05 level. PP represents percentage point.

Finally, we investigate whether AP CSP is serving as an entryway into the STEM pipeline for those students who take CSP. Figure 7 displays the percentage of CSP students for whom CSP is their first AP STEM course. Half (51%) of all students who took AP CSP did so as their first AP STEM Exam.⁵ Students who have been traditionally underrepresented in STEM are even more likely to take CSP as their first AP STEM. CSP was the first AP STEM course for 68% of Black students, 59% of Hispanic students, and 60% of first-generation students taking CSP.

5. Other STEM AP Exams include AP Computer Science A, Calculus AB, Calculus BC, Statistics, Environmental Science, Biology, Chemistry, Physics B, Physics 1, Physics 2, Physics C: Mechanics, and Physics C: Electricity and Magnetism.

Figure 7: The Percentage of Students for Whom CSP Is the First AP STEM Taken, High School Graduating Class of 2019



Note: First AP STEM is defined as having no prior STEM AP's and having no concurrent STEM AP's.

Summary

This study provides compelling evidence that CSP students are more likely to participate in computing and STEM fields. The introduction of CSP diversified the population of students taking AP computer science coursework in high school, revealing higher proportions of female, Black, and Hispanic students in CSP than CSA. After taking CSP, students are more likely to declare a STEM major and considerably more likely to declare a computer science major. The increases in college computer science majoring are evident both for students who take AP CSP as their only AP STEM course in high school as well as for students who take CSP and another AP STEM, including CSA in high school. After taking CSP, students are also more likely to participate in additional AP STEM courses in high school and to take AP CSA compared to similar students who did not take CSP.

As students in the graduating class of 2019 progress through college and graduate, it will be important to study longer-term outcomes and investigate whether CSP students are more likely to persist in their computer science and STEM majors, earn better grades in college, graduate in a timely manner, and obtain gainful employment in their field of study. As more high schools offer CSP, it will also be important to understand how the results from this study, based on schools and districts that might be considered the “early adopters” of CSP, generalize to a broader group of schools and students who embrace the goal of diversifying the pipeline of students interested in computer science in the years to come.

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Appendix

Table A-1: Composition of Students Taking CSP and CSA: Graduating Class of 2019

		CSP		CSA	
		Number	Percent	Number	Percent
Gender	Female	20,845	31.8	15,693	24.3
	Male	44,794	68.2	48,781	75.7
Ethnicity	American Indian	149	0.2	93	0.1
	Asian	13,176	20.1	22,557	35.0
	Black	4,914	7.5	2,376	3.7
	Hispanic	13,639	20.8	7,622	11.8
	Native Hawaiian	105	0.2	73	0.1
	White	29,865	45.5	27,871	43.2
	Two or More Races	2,931	4.5	2,895	4.5
	No Response	860	1.3	987	1.5
First Generation	No	45,401	70.5	52,837	82.8
	Yes	19,042	29.5	10,965	17.2
Total		65,639		64,474	

Note: Small sample sizes of American Indian and Native Hawaiian preclude examination of these student subgroups in most analyses. In Figure 2, Figure 4, Figure 5, and Figure 6, the number of American Indian and Native Hawaiian students was between 1 and 15.

About College Board

College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success—including the SAT[®] and the Advanced Placement[®] Program. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. For further information, visit collegeboard.org.

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