Equity in High School Computer Science: Beyond Access

Paul Bruno[*]
Colleen M. Lewis
University of Illinois at Urbana-Champaign

Uncorrected Accepted Manuscript (*Policy Futures in Education*)

Abstract

Little is known about the extent to which expansions of K-12 computer science (CS) have been equitable for students of different racial backgrounds and gender identities. Using longitudinal course-level data from all high schools in California between the 2003-2004 and 2018-2019 school years we find that 79% of high school students in California, including majorities of all racial groups, are enrolled in schools that offer CS, up from 45% in 2003. However, while male and female students are equally likely to attend schools that offer CS courses, CS courses represent a much smaller share of course enrollments for female students than for male students. Non-Asian students enroll in relatively few CS courses, and this is particularly true for Black, Hispanic, and Native American students. Race gaps in CS participation are to a substantial degree explicable in terms of access gaps, but gender gaps in CS participation are not. Different groups of students have access to CS teachers with similar observable qualifications, but CS teachers remain predominantly white and male. Consequently, white and male CS students are much more likely than other students to have same-race or same-gender instructors. Our findings and the implications we draw for practice will be of interest to administrators and policymakers who, over and above needing to ensure equitable access to CS courses for students, need to attend carefully to equity-related course participation and staffing considerations.

Keywords: computer science education, high schools, California, equity, teacher quality, computer science

Notes and Acknowledgements

[*] Corresponding author; College of Education; 337 Education Building, 1310 S. 6th Street; Champaign, IL 61820; pbruno@illinois.edu

Equity in High School Computer Science: Beyond Access

Educational attainment around the world has increased, including for some groups historically marginalized from educational opportunities (e.g., women; Roser and Ortiz-Ospina, 2017). Accordingly, policymakers and educational advocates have increasingly turned their attention to ensuring that there is equitable access to high-quality educational experiences specifically in the subject areas thought to be of particular value to students or to society, such as science, technology, engineering, and math (STEM; e.g., UNESCO, 2017; United Nations, 2017). However, sizeable gaps in STEM educational opportunity remain, for example along gender lines (e.g., UNESCO, 2017), as do challenges to developing a STEM teaching force that is sufficiently qualified and diverse to promote equity objectives (e.g., UNESCO, 2015).

Moreover, the salience of specific STEM fields evolves, continuously raising new challenges of educational equity. Among the most notable of such recent evolutions is increasing advocacy for computer science (CS) coursework to be available to students in elementary and secondary schools (i.e., schools enrolling students in kindergarten through grade 12, K-12). Calls for greater CS access have diverse motivations, including meeting labor market demand for computer scientists, providing equitable access for students to coursework and lucrative career opportunities, and developing computational skills that may be of value to students even outside of CS. Yet the extent to which these calls have been successful is not obvious.

We consider this issue in the context of the United States, where a growing number of organizations have missions of providing CS to students in K-12 schools, and an estimated 45% of high school principals report offering CS at their schools (Code.org Advocacy Coalition, 2019). In particular, we use California as an illustrative example because, as we discuss below, it has been in some ways on the leading edge of K-12 CS education. It is also a large and diverse

state, and so may provide useful lessons for other jurisdictions concerned about equity as they

consider or attempt K-12 CS expansions.

Overall CS course taking trends in the United States are not as well documented at the

elementary and secondary levels as they are at the postsecondary level. Consequently, there is

limited evidence of the extent to which K-12 CS has expanded, and even less evidence about the

extent to which any such expansions have been equitable for students of different races and

gender identities. Moreover, even studies that have considered equity in student access to CS

coursework have often focused primarily on the most advanced CS courses or have not

considered within-school gaps in CS course participation or access to high-quality CS teachers.

We aim in this paper to focus attention on these often-understudied aspects of equity in

CS education. We hope to shift attention from school-level measures of CS course availability to

student-level measures of CS course participation and access to quality teaching. To that end, we

use statewide longitudinal data from California to answer the following research questions:

1. To what extent has secondary CS course taking expanded in California, both overall

    and for students of different gender identities and ethnic backgrounds?

2. Do students have equitable access to teachers as measured by certification, education,

    experience, or congruence in terms of race and gender?

We find that 79% of high school students in California, including majorities of students

from all administratively-defined racial groups, are enrolled in schools that offer CS, up from

45% in 2003. However, while they are equally likely to attend schools that offer CS courses, CS

courses represent a much smaller share of course enrollments for female students than for male

students. Non-Asian students enroll in relatively few CS courses, and this is particularly true for

Black, Hispanic, and Native American students. All student groups have mostly similar access to

high-quality CS teachers, at least in terms of teachers' observable experience, education, and credential status, but CS teachers remain predominantly White and male. Consequently, White and male CS students are much more likely than other students to have same-race or same-gender instructors, respectively. Our findings and their implications will be of interest to administrators and policymakers who, beyond needing to ensure equitable access to CS courses, need to attend carefully to equity-related course participation and staffing considerations.

Background
Equitable Access to Secondary Computer Science Courses

There is evidence that access to secondary CS courses is inequitable along race and gender lines. Test taking rates on the College Board's Advanced Placement Computer Science (AP CS) tests are a common measure of CS access in the US. AP exams can often be used to earn students college credit or course placement at colleges and universities, and are typically – though not necessarily – taken after completing a corresponding AP course. Even relative to other AP exams, AP CS exams have shown low rates of participation among women, Black students, Hispanic students, American Indian/Alaska Native students and Native Hawaiian/Other Pacific Islander students. For example, 55% of all AP exams in 2018 were taken by female-identified students, but female-identified students account for only 28% of AP CS exams in the same year. Black students are approximately 15% of the HS student population in the US (c. 2017), but only 6.3% of all AP exams in 2018 were taken by Black students and 5.6% of AP CS exams were. Approximately 25% of HS students in the US are Hispanic (c. 2017), but only 22.2% of all 2018 AP exams were taken by Hispanic students and only 16.3% of AP CS exams were taken by Hispanic students (Author, Year). These data do not capture students who opt not to take the AP exams, but who are nevertheless enrolled in an AP CS course or another (usually

less advanced) non-AP CS course, but they provide longitudinal information disaggregated by gender, and race.

Evidence on non-AP CS participation equity is scarce; existing work focuses primarily on whether CS courses are offered at students' schools rather than on the extent to which students enroll in them. In that work, too, inequity in terms of race and gender is apparent. For example, a 2019 report found that 45% of high schools offered CS across the 39 states from which they were able to collect complete public high school data (Code.org Advocacy Coalition, 2019).[1] However, they find that access is unequally distributed by race, ethnicity and income. Only 35% of schools in which 75%-100% of their student population is from a racial or ethnic group underrepresented in CS offer CS. Similarly, in a nationally representative sample of students Wang et al., (2016) report that "lower income students are less likely to report access to CS learning opportunities" (p. 648) and "Black students, regardless of income, are less likely than White or Hispanic students to report opportunities to learn computer science at school....Hispanic students are also less likely than White students to report having dedicated computer science classes, but after accounting for household income, this effect diminishes." (p. 648).

The results discussed above point to stark inequities in K-12 CS education, particularly in terms of access. Perhaps due to data limitations, we know considerably less about inequities in CS course participation, particularly outside of the AP academic track. We know even less about equities in students' experiences in the CS courses they take. As we discuss below, of particular concern is how the staffing challenges associated with CS course expansions have translated into inequitable access to high quality teachers.

---

[1] High schools are classified as offering CS if "students learn computer science during the school day (not in after school clubs) and spend [at least 20 hours] per semester applying learned concepts through programming" (page 88, Code.org Advocacy Coalition, 2019).

California Context for Secondary Computer Science Education

California is an interesting context to study equity in CS education, and not only because it is the home of Silicon Valley. California releases detailed course-level data on staffing and student enrollment. Additionally, California is a large and diverse state with a recent history of being at the front of efforts to expand CS education, while also facing a number of challenges to the equitable expansion of educational opportunities in CS. For example, the high school course Exploring Computer Science, which was designed to address the racial inequity documented in the book "Stuck in the Shallow End: Education, Race, and Computing" (Margolis et al., 2008), was launched in Los Angeles in 2008. Based on the data we use here, and describe below, by the fall of 2016 284 high schools in more than 140 districts in California were offering Exploring Computer Science courses with collective enrollments of more than 19,000 students. Similarly, in September of 2018 California adopted computer science standards for K-12 students to facilitate – though not to require – the implementation of L-12 CS curriculum (Lambert, 2018). In May of 2019, California adopted the California Computer Science Strategic Implementation Plan (CCSSIP; Lambert, 2019), which articulates strategies to expand access to CS instruction (e.g., integrating CS content into other courses) and preparation for teachers (e.g., adopting a dedicated CS teaching certification). This kind of attention and effort over many years may have created many of the conditions needed for equitable secondary CS opportunities for students, but there is little evidence of this to date and there are reasons to suspect challenges remain. For example, the CCSSIP does not include funding and makes implementation by districts optional.

Potential funding challenges notwithstanding, secondary CS access has expanded dramatically in California in recent years. Figure 1 shows the percentage of California high

school students who are enrolled in a school that offers a CS course.[2] The solid line in Figure 1

shows the percentage of students at a school that offers any CS course and the dotted and dashed

lines show percentages for students at schools offering CS courses with and without the College

Board's AP designation, respectively.

[insert Figure 1]

Figure 1 shows that access to any secondary CS - defined here as attending a high school

offering any CS course - has expanded considerably in California, more than doubling (to

79.1%) since a nadir in 2010-2011. These expansions in access have often been done with a

deliberate eye toward equity, for example in the expansion of the Exploring Computer Science

course and the development of a new AP CS course. As of the 2003-2004 school year there were

two AP CS exams: AP CS A, which focuses on Java programming, and AP CS AB, which

includes the content from AP CS A with additional topics related to data structures. The AP CS

A exam was last offered in 2009 after a period of decreased participation (Author, Year;

Computer Science Teachers Association, 2013). Beginning in 2017 a new, potentially more

accessible AP CS course was offered: "Computer Science Principles" (AP CS P), which focuses

on CS topics beyond programming and uses pseudocode on the exam rather than requiring

students to learn a particular programming language (Howard and Havard, 2019). However, it

remains unclear whether simply increasing the availability of CS courses has been sufficient to

increase equity in student participation.

Equitable Access to Teachers of Computer Science

The rapid expansion in CS course availability entails additional challenges for schools in

terms of staffing. In California, there are no programs for pre-service teacher preparation in CS

---

[2] For discussion of these data sources, including course classifications, see below.

specifically, and secondary teachers in related subjects (e.g., math and science) are often in short

supply (Darling-Hammond et al., 2018; Goldhaber et al., 2018). Perhaps relatedly, California has

relatively flexible CS teacher credentialing requirements:

> "Secondary teachers with single-subject credentials in Mathematics, Business, or
>
> Industrial and Technology Education (ITE) are currently authorized to teach CS courses
>
> that are coded as a core academic course. When a CS course is coded as Career Technical
>
> Education (CTE), then those with a Designated Subject CTE Teaching Credential in
>
> Information and Communication Technology are authorized to teach the course." (p. 15,
>
> California Department of Education Executive Office, 2019).

The prospect of CS teacher shortages poses challenges for secondary CS implementation[3] and a

2013 report by the Computer Science Teachers Association (CSTA) drew particular attention to

the potential of California's flexible credentialing system to result in CS teachers who possess

little CS content knowledge (CSTA, 2013). This raises additional questions about the extent to

which students from different backgrounds have access to high quality CS teachers.

   The available evidence, while limited, suggests that concerns about the supply of CS

teachers are well-founded. A 2013 report from interviews with teachers (N=19) and

administrators (N=8) described scarcity of CS teachers as a primary challenge (Century et al.,

2013). Similarly, Wang et al. (2016) report from a survey of principals and superintendents that

42% of principals and 73% of superintendents agreed with the statement "There are no teachers

available at my school/in my district with the necessary skills to teach computer science." These

findings all point to the possibility that many schools are likely to face shortages of highly-

---

[3] Even if teachers are available, startup costs and inertia may also make adopting new CS
programs challenging for schools (Parker and Guzdial, 2019).

qualified teachers to teach CS, limiting what CS courses they can offer. It may also mean that the CS courses they do offer are staffed by teachers with weak qualifications.

However, the existing work on this question, including the studies discussed here, rely on survey data; the actual qualifications of CS teachers are not well understood. Moreover, the statewide teacher supply problems discussed above are often particularly acute in communities of color (Darling-Hammond et al., 2018); this suggests that there may be inequities not only in terms of CS course access in high schools, but also in terms of access to well-qualified teachers.

A related concern is that, over and above the qualifications or credentials of their teachers, there is now a substantial body of evidence indicating that when students have teachers of the same race or gender, they enjoy benefits in terms of achievement (Egalite et al., 2015), attainment (Gershenson et al., 2018), attendance (Holt and Gershenson, 2019), disciplinary outcomes (Holt and Gershenson, 2019; Lindsay and Hart, 2017), and attitudes (Egalite and Kisida, 2018). While these studies do not consider CS classrooms specifically, similar findings appear to generalize at least to STEM education, and appear to indicate if anything that this kind of demographic congruence may be particularly beneficial for students from groups historically underrepresented in STEM fields (Bottia et al., 2015; Carrell et al., 2010; Lim and Meer, 2020). The short supply of teachers in communities of color and the underrepresentation of women and people of color in postsecondary CS (BPCnet, 2020) seem likely to translate into female students and students of color having inequitable access to demographically congruent CS teachers even when they have access to CS courses.

Data

To answer our aforementioned research questions, we use data made public by the California Department of Education (CDE) and spanning the school years from 2003-2004 through 2018-2019. We restrict our analyses to schools classified by the state as traditional

schools (which includes most charter schools), alternative schools of choice (e.g., magnet schools or schools blending high school and college coursework), and so-called "state special schools" overseen by the state and serving students who are deaf or blind. Because the course data released by the CDE provide little information on course content at lower grade levels, we additionally only include schools in our sample if they are classified by the CDE as high schools or K-12 schools, or if they are classified as offering instruction at the high-school level.

Course Data

The CDE releases data on student course taking at the course level as of a census day in the fall, though these data were not released for the 2009-2010 school year. Each course is linked to a teacher and school and is classified with a code indicating its curricular content.[4] We exclude course codes that do not provide information about the curricular content of the course, including courses that are classified only as self-contained or special education, or free periods for students (e.g., during which they may be able to leave campus). The full list of courses that we classify as CS courses is shown in Table 1, along with information about whether the CDE classifies the course an AP or career technical education (CTE, i.e., vocational) course.

Table 1 - *Courses Classified as Computer Science (CS)*

CDE Course Code	CDE Course Name	CDE Course Subject	CDE-Designated AP Course	CDE-Designated CTE Course
2451	Computer Programming	CE		
2452	Exploring Computer Science	CE		
2453	Computer Science	CE		

[4] For the CDE's purposes, in most cases a "course" represents a class section in which a teacher teaches a particular group of students in a particular location the content associated with a particular course. However, in some cases a single class section may be receiving instruction pertaining to multiple courses, and the CDE's course data includes multiple course entries for that class section. We treat each course as distinct, even if it is one of multiple courses within a class section, to capture all information about students' curricular experiences.

2455	Web design	CE		
2465	IB Computer Science	CE		
2466	IB Information Technology in a Global Society	CE		
2470	AP Computer science A	CE	X	
2471	AP Computer science AB	CE	X	
2472	AP Computer Science Principles	CE	X	
4604	Network Engineering	ICT		X
4616	Computer Programming and Game Design	ICT		X
4617	Game Design and Development	ICT		X
4619	Computer Programming for Solving Applied Problems	ICT		X
4631	Database Design and SQL Programming	ICT		X
4633	Computer Repair and Support	ICT		X
4634	Exploring Computer Science	ICT		X
4640	CTE AP Computer Science Principles	ICT		X
4641	CTE AP Computer science A	ICT		X
4646	Network Security	ICT		X
4647	Robotic Technologies	ICT		X
5612	Robotics	MPD		X
8100	Introduction to ICT	ICT		X
8110	Introduction to Information Support Services	ICT		X
8111	Intermediate Information Support Services	ICT		X
8112	Advanced Information Support Services	ICT		X
8120	Introduction to Networking	ICT		X
8121	Intermediate Networking	ICT		X
8122	Advanced Networking	ICT		X
8130	Introduction to Systems Programming	ICT		X
8131	Intermediate Systems Programming	ICT		X
8132	Advanced Systems Programming	ICT		X
8133	Introduction to Web and Social Media Programming and Design	ICT		X
8134	Intermediate Web and Social Media Programming and Design	ICT		X
8135	Advanced Web and Social Media Programming and Design	ICT		X
8140	Introduction to Games and Simulation	ICT		X
8141	Intermediate Games and Simulation	ICT		X
8142	Advanced Games and Simulation	ICT		X

Note: The two "CTE AP" courses above – course codes 4640 and 4641 – were used in the 2016-2017 school year. The CDE did not respond to requests for clarification on the difference between those courses and the analogous non-CTE courses, which have very similar descriptions in other CDE documentation. We do not include the "CTE AP" courses as AP courses because they are not officially designated as such by the CDE. AP = Advanced Placement; CDE = California Department of Education; CTE = Career Technical Education; CE = Computer Education; ICT = Information and Communication Technologies; MPD = Manufacturing and Product Development.

Ideally, we would be able to observe course taking behavior at the student level rather than enrollment data aggregated to the course level. For example, because we cannot distinguish individual students, we are unable to identify the number of unique pupils taking CS courses or the number of CS courses taken by individual students. However, having data on all courses offered in a school allows us to measure *CS access*, that is, the presence of *any* CS course in a school. Additionally, the aggregated course data provided by the CDE include the number of male and female students enrolled and, beginning in 2012-2013, enrollment by student race. This allows us to measure *CS participation* in a given school in a given year as the percentage of all course enrollments - by any students in all courses - that are in CS courses, and to measure participation separately for students for different genders or races.[5]

Staff Data

The CDE's public course data allow each course to be linked to staff data files. While these staff files do not allow individual staff members to be followed over time, they capture a variety of information about instructors. Though these variables do not include direct measures of teacher quality, they include several plausible proxies that have been used in previous research, including teacher experience (Goldhaber et al., 2018), education (Nguyen and Redding, 2018), and credential status (Carver-Thomas and Darling-Hammond, 2017). In addition to considering the previous experience of teachers of different courses, we distinguish teachers who have a full credential, indicating the completion of a teacher preparation program, from those

---

[5] The mean (median) school in our sample reports 5.6 (5.8) course enrollments per student. This most likely indicates that for many schools in our data, each course represents one class period with students taking 5 or 6 courses at a time. However, there is some variation between schools, making individual courses difficult to compare with one another. Since schools may account for courses in different ways or expect students to take different numbers of courses (e.g., because they use block period scheduling), we believe describing course enrollments in percentage terms allows for better comparisons across schools or over time than alternatives (e.g., numbers of unique courses offered).

who do not (e.g., teachers completing alternative certification programs or possessing only emergency certifications to teach in positions administrators had difficulty filling), and teachers with a master's degree (or more education) from those without. Also included in these files are teacher race and gender, which allows us to identify racial or gender congruence between the students in each course and their teacher. Summary statistics are presented in Table 2.

Table 2 - *Summary Statistics of Schools' Student Demographics and CS Course Enrollment*

	N	Mean	SD	Minimum	Maximum
School Characteristics					
%age Hispanic	23518	45.83	28.15	0.00	100
%age White	23518	32.91	26.70	0.00	100
%age Black	23518	7.19	10.86	0.00	100
%age Asian	23518	6.63	11.22	0.00	90.96
%age Multi-Race	23518	3.33	5.30	0.00	100
%age Filipino	23518	2.17	3.86	0.00	45.26
%age Native American	23518	1.40	4.77	0.00	100
%age Pacific Islander	23518	0.54	1.20	0.00	100
%age Male	23518	50.13	6.88	0.00	100
%age Female	23518	49.87	6.88	0.00	100
Percentage of Course Enrollments by Subject					
CS	23518	0.33	0.88	0.00	36.36
AP CS	23518	0.04	0.23	0.00	21.24
Other CS	23518	0.29	0.83	0.00	36.36

Note. Data in this table combines annual observations of 2208 unique schools from 2003-2004 through 2018-2019. AP = Advanced Placement.

Empirical Strategy

We rely on basic descriptive methods to answer our research questions, documenting trends in CS enrollment and CS teacher characteristics overall and for different groups of students.

Results

To what extent has secondary CS course taking expanded in California, both overall and for students of different gender identities and ethnic backgrounds?

As we show above (Figure 1), the share of California's high school students attending schools that offer CS coursework was substantially larger in 2018-2019 (79%) than in 2003-2004 (45%). Unsurprisingly, this growth in access to CS has been accompanied by substantial growth in CS participation. This can be seen in Figure 2, which shows the percentage of all high school course enrollments in California that were in CS courses. In 2018-2019 CS courses accounted for more than 0.8% of all high school enrollments reported by the CDE, more than tripling their 2003-2004 enrollment share. This growth was proportionally similar for both AP CS courses and non-AP CS courses, though only the latter have continued to expand in the most recent years.

[insert Figure 2]

Figure 3 shows that CS enrollment growth has occurred disproportionately among male students for both AP and non-AP CS courses. As a result, gender gaps in CS course taking have increased substantially. In 2003-2004, AP CS courses accounted for 0.06% of enrollments for male students, compared to slightly over 0.01% for female students. Female AP CS course taking subsequently expanded rapidly in proportional terms: to 0.08% in 2018-2019, a six-fold increase. However, over the same period the AP CS enrollment share for male students roughly tripled from a much higher starting point, to 0.18%. As a result, the gap between male and female students in the percentage of course enrollments that are in AP CS has more than doubled, from 0.04% in 2003-2004 to 0.09% in 2018-2019. The pattern is qualitatively similar for non-AP CS course taking, where the gap has increased from 0.14% to 0.54%. These gaps appear to be the result of different student course taking patterns within schools; male and female

high school students are equally likely to attend schools in which CS courses are offered (not

shown). Thus, simply comparing CS *access* for male and female high school students could

easily give a misleading impression of the equity with which secondary CS has expanded.

[insert Figure 3]

Figure 4 shows similar patterns of growing CS enrollment gaps by race since 2012-2013,

when the CDE began reporting enrollment by race. In that year, CS enrollment rates were higher

for Asian students than for other students, with non-AP CS courses accounting for 0.26% of

Asian student enrollments and AP CS courses accounting for another 0.18%. For all other racial

groups, those figures ranged from 0.13-0.19% (for non-AP CS) and 0.01-0.04% (for AP CS).

[insert Figure 4]

As was the case for gender groups, all racial groups saw participation increases in

subsequent years in both AP and non-AP CS courses, but gaps between groups increased

substantially. The greatest absolute growth was for the group that already had the highest

participation rate: by 2018-2019, non-AP CS courses accounted for 1.4% of Asian students' high

school course enrollments, and AP CS courses accounted for another 0.4%. These represented

increases of 1.10 and 0.22 percentage points, respectively. For the racial group with the next-

largest participation increases – Filipino students – those figures were at least 30% smaller: 0.64

and 0.15 percentage points.

Increases for other student groups were smaller still. For example, by 2018-2019, all CS

courses accounted for only 0.64% of Hispanic students' course enrollments, up from 0.20% in

2012-2013 but still nearly two-thirds less than the figure for Asian students. Other groups'

enrollment rates barely increased at all. For example, in 2018-2019 AP CS courses accounted for

less than 0.06% of Native American students' course enrollments, up only slightly (in absolute

terms) from their 2012-2013 levels (0.01%). Indeed, in 2018-2019, only Filipino students had

AP CS enrollment rates as high as those seen for Asian students in 2012-2013.

Unlike the case of gender gaps, however, racial gaps in CS participation appear to be

driven at least in part by access gaps between schools. As shown in Figure 5, Asian students are

more likely than other students to attend high schools that offer CS courses, and this is true for

both AP and non-AP CS courses. In some cases these gaps are substantial. For example, while

39% of Asian students attended high schools offering AP CS courses in 2018-2019, the same

was true for only 18% of Native American students. Similarly, 86% of Asian students attended

schools offering non-AP CS courses, compared to only 70% of Black students, 69% of Hispanic

students, and 64% of Native American students. These gaps have expanded somewhat over time

even as the availability of CS has grown for all racial groups. CS access gaps may therefore

explain not only enrollment gaps, but the growth in these gaps.[6] This also highlights that the

mechanisms driving racial CS equity gaps are likely to be different in practice than those driving

gender gaps, and that conflating the two is unlikely to be helpful from a policy perspective.

[insert Figure 5]

Do students have equitable access to teachers as measured by certifications, education,

experience, or congruence in terms of race and gender?

As shown in Figure 6, consistent with previous work finding teacher quality gaps

between students from different racial groups (Goldhaber et al., 2017), students of different races

do tend to have teachers with different qualifications in their CS courses. However, these

differences are generally small, at least in terms of teachers' observable qualifications. For

---

[6] Our finding that racial CS participation gaps - but not gender gaps - are explained to a
substantial extent by access gaps echoes similar findings for CTE-oriented courses generally in
Michigan (Jacob and Guardiola, 2020).

example, in 2018-2019 Asian students tended to have the most highly-qualified CS teachers, with their teachers having the highest credentialing and master's degree attainment rates of any racial group, and above-average experience levels. However, for no group of students did less than 97.2% of their CS teachers have a full credential. And in many cases, differences in teacher qualifications between groups of students are mixed. For example, the CS teachers of Native American students had relatively low rates of master's degree attainment - 44.4% vs. 53.8% statewide - but they had roughly average credentialing rates and were slightly more experienced on average.

[insert Figure 6]

At the same time, Hispanic, Pacific Islander, and Black students had CS teachers with consistently below-average credentials. This is particularly true for Black students, whose CS teachers were the least likely to be fully credentialed and the least experienced on average and were less likely to have a master's degree than the teachers of any other group except Native American students. While these differences are not always large, it is concerning that students in these groups are not only participating in CS courses at relatively low rates but appear to have access to somewhat less-qualified teachers.

As discussed above, apart from access to teachers who are more highly qualified, access to demographically-similar teachers may be important, especially for underrepresented students in STEM fields. However, as shown in Figure 7, at no time since 2003-2004 have female teachers accounted for even one third of CS course enrollments' instructors, even as they have always accounted for at least 47% of non-CS course enrollments' instructors. Female teachers' representation in CS courses has also grown more slowly than in other types of courses; from 2003-2004 the female teacher share increased by less than four percentage points - from 28.7%

to 32.2% - among CS course enrollments even as the female teacher share grew by more than

seven percentage points - from 47.1% to 54.3% - among other enrollments.

[insert Figure 7]

Accordingly, as shown in Figure 8, the share of female CS enrollments taught by a

female teacher has grown only gradually, from 27.4% in 2012-2013 to 34.5% in 2018-2019. By

comparison, male CS students were roughly twice as likely as female students to have a same-

gender teacher in 2018-2019: 68.8%. This may disadvantage female students in CS courses and

may discourage them from enrolling in those courses at all. Indeed, in every year for which

enrollment numbers are broken down by student gender, the percentage of female CS

enrollments taught by female teachers (the dashed line in Figure 8) exceeds the percentage of all

CS enrollments taught by female teachers (the solid line in Figure 7). This is consistent with

female students being more likely to enroll in CS courses when those courses are taught by a

female teacher. However, we cannot demonstrate the processes by which students choose to

enroll in CS courses with these data, nor can we observe why teachers of different genders

become responsible for teaching CS courses.

[insert Figure 8]

The CS teaching force in California has diversified slowly along racial lines as well.

Figure 9 shows trends since 2012-2013 in the representation of different racial groups among

statewide high-school enrollment (the solid lines), CS enrollments (the dashed lines), and CS

teachers (the dotted lines). For example, while White students accounted for 24.5% of statewide

high-school enrollment and a nearly identical share of CS enrollments in 2018-2019, 66.7% of

CS enrollments were taught by White teachers. At the same time, Hispanic students represented

52.6% of all high school students but only 42.2% of CS enrollments, and only 13.5% of CS

enrollments were taught by Hispanic teachers. Notably, the last two of those figures represented slight decreases from 2012-2013, indicating decreasing Hispanic representation in CS courses among both students and teachers, even as Hispanic students became a larger proportion of statewide enrollment.

[insert Figure 9]

Comparing the solid lines in each panel of Figure 9 to the corresponding dashed line shows that, consistent with the patterns of CS participation discussed above, students from many racial groups are underrepresented in CS courses relative to their share of statewide enrollment. Pacific Islander, Hispanic, Black, and Native American students have consistently represented smaller shares of CS enrollments (the dashed lines) than of statewide enrollment (the solid lines). Only Asian and, in recent years, Filipino students have been overrepresented in CS courses during this period, consistent with the evidence above that those groups of students have relatively high CS participation rates. Multi-race students' representation in CS courses has largely tracked their representation in the statewide student population. However, changes for this group are particularly difficult to interpret since the specific racial composition of these students may change over time and differ between students who enroll in CS courses and those who do not.

Additionally, comparing the dotted lines in each panel of Figure 9 to the corresponding dashed lines shows that several of the racial groups most underrepresented in CS courses are even more underrepresented among CS teachers. In addition to the wide gap between the Hispanic share of CS course enrollments and CS teachers discussed above, the share of Asian or Filipino CS teachers is smaller than the corresponding shares of CS enrollments, and the same is true in recent years for the Black and Native American shares. As was the case with gender,

these gaps in teacher representation suggest the possibility of inequitable access to same-race CS teachers for many students. Indeed, this is precisely what is observed in Figure 10, which shows the share of CS enrollments with a same-race teacher for each racial group defined by the CDE.

[insert Figure 10]

Only for White students are the majority of their CS course enrollments taught by a same-race teacher, reflecting the fact that the large majority of CS teachers are White (Figure 9). In contrast, for no other racial groups does the share of CS enrollments taught by a same-race teacher exceed 23% in any year. For Native American, Filipino, and Pacific Islander students, that share never reaches even 5%, and in some years is exactly zero. Given the apparent benefits of student-teacher racial alignment discussed above, the dearth of same-race teachers may help to explain the relatively low participation rates for many of these groups of students and may disadvantage those students who do participate.

Discussion

Expansions of K-12 CS curricula in California provide potentially important lessons for policymakers elsewhere pushing for equity STEM education, which is likely to increasingly focus on CS specifically. Like some previous work, we find in California that while access to CS courses has expanded rapidly in high schools, these expansions have not been equitable along race lines. Moreover, we also show that these race gaps in secondary CS access have translated into substantial CS participation gaps. Black, Hispanic, and Native American students in particular enroll in CS courses at much lower rates than other students, and this appears to be due at least in part to the fact that these students are less likely to attend schools offering CS courses. Additionally, female students enroll in CS courses at lower rates despite being as likely as male students to attend schools offering CS courses and the gaps between male and female students' enrollment have increased. We do not observe students' reasons for enrolling in CS courses

when they are available, but prior research has found that differences in such choices across racial and gender lines may be driven by stereotypes about computer scientists (Cheryan et al., 2013) or a misalignment between students' values and their perceptions of the usefulness of CS (Author, year).

Compounding - and perhaps contributing to - these gaps is the fact that many of these same groups of students are also relatively unlikely to have a same-race or same-gender CS teacher even if they are enrolled in CS courses. This is because high school CS teachers in California remain mostly White and mostly male. Thus, the documented benefits of racial and gender congruence with their teachers are enjoyed primarily by White and male students.

This points to the need to think about how the CS teacher workforce can be diversified, a challenge that has plagued STEM education globally (UNESCO, 2015; UNESCO, 2017). Additional authorization requirements may pose additional barriers to entry into teaching jobs where the supply of female teachers and teachers of color is already extremely low. For instance, given their low CS participation rates at the post-secondary level (BPCnet, 2020), a requirement that CS teachers have completed substantial college-level CS coursework could further reduce the supply of female CS teachers and CS teachers of color. Additional prerequisites for CS teachers should be established only with some clear justification for expecting that they will increase CS teacher quality. It may also be useful to couple additional entry requirements with policies with some promise to increase the supply and retention of teachers currently underrepresented in CS, such as tuition subsidies for prospective CS teachers of color (Landa, 2020), salary increases (Achinstein et al., 2010), or induction supports or "grow your own" preparation programs (Carver-Thomas, 2018). Additionally, researchers should explore the processes by which teachers choose to become CS teachers, particularly in contexts where

flexible authorization requirements would allow multiple existing teachers at a school to teach CS courses.

More generally, our results highlight the importance of not conflating different kinds of equity issues. For example, the fact that male and female high school students are similarly likely to attend schools offering CS could easily obscure gender inequities in terms of actual participation in CS or in terms of access to same-gender CS teachers. Similarly, our results underscore the importance of distinguishing the different dimensions of students' identities along which inequities might arise. For instance, we find that race gaps in CS participation are to a substantial degree explicable in terms of access gaps, but gender gaps in CS participation are not. Attempts by policymakers to address one type of inequity may therefore do little to address other types of inequity. Equity-oriented CS education policies should be motivated explicitly not only by data, but in terms of the specific dimensions of equity the policy is expected to promote.

Our analyses are limited in ways that point to important areas for future research. For example, we identify CS courses based on their titles and descriptions, but do not observe their content; in some of these courses students may learn computer literacy rather than computer science (Margolis et al., 2008). Additionally, the observable teacher characteristics in our data are at best rough proxies for teacher quality. Thus, we are limited in what we can say about true CS teacher quality gaps. This points to the need for better measures of CS teacher quality. However, even many commonly-used measures of teacher quality that seem appropriate for other subject areas - such as evaluation ratings by administrators or value-added measures (VAMs) of contributions to student test scores - may be unsuitable for use in CS courses. For example, administrators may choose to observe teachers when teaching courses other than CS (if they observe teachers at all), administrators may not know how to assess CS instructional

quality, and VAMs typically require sequential years of standardized student assessment data. As students spend more time in CS courses, it will be increasingly important to develop better measures of CS teacher quality that can be used to assess both the average strength of CS teachers and the prevalence of gaps in CS teacher quality between different groups of students.

In sum, effective CS implementation in schools requires more than enrolling ever-growing numbers of students in CS courses. In addition to attending to access and participation gaps between groups of students, administrators and policymakers need to attend to issues of teacher quality. Consequently, researchers should attend to these issues as well. The importance of these challenges, and thus the importance of understanding and meeting them, will likely continue to grow for the foreseeable future.

References

Achinstein B, Ogawa RT, Sexton D, et al. (2010) Retaining Teachers of Color: A Pressing Problem and a Potential Strategy for "Hard-to-Staff" Schools. *Review of Educational Research* 80(1). American Educational Research Association: 71–107. DOI: 10.3102/0034654309355994.

Bottia MC, Stearns E, Mickelson RA, et al. (2015) Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM. *Economics of Education Review* 45: 14–27. DOI: 10.1016/j.econedurev.2015.01.002.

BPCnet (2020) Statistics & Data Hub. Available at: https://bpcnet.org/statistics/ (accessed 23 November 2020).

Bruno P and Lewis CM (forthcoming) Computer Science Trends and Trade-offs in California High Schools. *Educational Administration Quarterly*. SAGE Publications Inc. DOI: 10.1177/0013161X211054801.

California Department of Education Executive Office (2019) *California State Board of Education May 2019 Agenda Item #03*. SBE-003, 18 May. Sacramento, CA.

Carrell SE, Page ME and West JE (2010) Sex and Science: How Professor Gender Perpetuates the Gender Gap. *The Quarterly Journal of Economics* 125(3). Oxford Academic: 1101–1144. DOI: 10.1162/qjec.2010.125.3.1101.

Carver-Thomas D (2018) *Diversifying the teaching profession: How to recruit and retain teachers of color.* Palo Alto, CA: Learning Policy Institute.

Carver-Thomas D and Darling-Hammond L (2017) *Addressing California's Growing Teacher Shortage: 2017 Update*. Palo Alto, CA: Learning Policy Institute. Available at: https://learningpolicyinstitute.org/product/addressing-californias-growing-teacher-shortage-2017-update-report.

Century J, Lach M, King H, et al. (2013) *Building an Operating System for Computer Science*. Chicago, IL: CEMSE, University of Chicago with UEI. Available at: http://outlier.uchicago.edu/computerscience/OS4CS/# (accessed 25 November 2020).

Cheryan S, Plaut VC, Handron C, et al. (2013) The Stereotypical Computer Scientist: Gendered Media Representations as a Barrier to Inclusion for Women. *Sex Roles* 69(1): 58–71. DOI: 10.1007/s11199-013-0296-x.

Code.org Advocacy Coalition (2019) *2019 State of Computer Science Education: Equity and Diversity*.

Computer Science Teachers Association (2013) *Bugs in the System: Computer Science Teacher Certification in the U.S.* 978-1-4503-2310–9. New York, NY: Association for Computing Machinery, Inc.

Darling-Hammond L, Sutcher L and Carver-Thomas D (2018) *Teacher Shortages in California: Status, Sources, and Potential Solutions*. Getting Down to Facts II, Technical Report. Palo Alto, CA: Policy Analysis for California Education.

Egalite AJ and Kisida B (2018) The Effects of Teacher Match on Students' Academic Perceptions and Attitudes. *Educational Evaluation and Policy Analysis* 40(1): 59–81. DOI: 10.3102/0162373717714056.

Egalite AJ, Kisida B and Winters MA (2015) Representation in the classroom: The effect of own-race teachers on student achievement. *Economics of Education Review* 45: 44–52. DOI: 10.1016/j.econedurev.2015.01.007.

Gershenson S, Hart CMD, Hyman J, et al. (2018) *The Long-Run Impacts of Same-Race Teachers*. w25254, Working Paper, 12 November. National Bureau of Economic

Research. DOI: 10.3386/w25254.

Goldhaber D, Quince V and Theobald R (2018) Has It Always Been This Way? Tracing the Evolution of Teacher Quality Gaps in U.S. Public Schools. *American Educational Research Journal* 55(1): 171–201. DOI: 10.3102/0002831217733445.

Goldhaber D, Strunk KO, Brown N, et al. (2018) *Teacher Staffing Challenges in California: Exploring the Factors That Influence Teacher Staffing and Distribution*. Getting Down to Facts II, Technical Report. Policy Analysis for California Education. Available at: https://eric.ed.gov/?id=ED594738 (accessed 28 May 2019).

Holt SB and Gershenson S (2019) The Impact of Demographic Representation on Absences and Suspensions. *Policy Studies Journal* 47(4): 1069–1099. DOI: 10.1111/psj.12229.

Howard K and Havard D (2019) Advanced Placement (AP) Computer Science Principles: Searching for Equity in a Two-Tiered Solution to Underrepresentation. *Journal of Computer Science Integration* 2(1): 1–15. DOI: 10.26716/jcsi.2019.02.1.1.

Jacob BA and Guardiola J (2020) *Career and Technical Education in Michigan: Access and Participation*. Policy Brief, January. Ann Arbor, MI: University of Michigan Youth Policy Lab.

Lambert D (2018) California adopts first computer science standards for K-12 students. Available at: https://edsource.org/2018/californias-first-computer-science-standards-set-for-approval/601985 (accessed 25 November 2020).

Lambert D (2019) California moves to get more K-12 students into computer science classes. Available at: https://edsource.org/2019/california-moves-to-get-more-k-12-students-into-computer-science-classes/612158 (accessed 25 November 2020).

Landa J (2020) *Repairing the Teacher Pipeline for People of Color: Three Essays on Minority Teacher Scholarships*. Doctoral Dissertation. University of Connecticut.

Lewis C, Bruno P, Raygoza J, et al. (2019) Alignment of Goals and Perceptions of Computing Predicts Students' Sense of Belonging in Computing. In: *Proceedings of the 2019 ACM Conference on International Computing Education Research (ICER '19)*, Toronto ON, Canada, 2019, pp. 11–19. ACM Press. DOI: 10.1145/3291279.3339426.

Lim J and Meer J (2020) Persistent Effects of Teacher-Student Gender Matches. *Journal of Human Resources* 55(3). University of Wisconsin Press: 809–835. DOI: 10.3368/jhr.55.3.0218-9314R4.

Lindsay CA and Hart CMD (2017) Exposure to Same-Race Teachers and Student Disciplinary Outcomes for Black Students in North Carolina. *Educational Evaluation and Policy Analysis* 39(3). American Educational Research Association: 485–510. DOI: 10.3102/0162373717693109.

Margolis J, Estrella R, Goode J, et al. (2008) *Stuck in the Shallow End: Education, Race, and Computing*. Cambridge, MA: MIT Press.

Nguyen TD and Redding C (2018) Changes in the Demographics, Qualifications, and Turnover of American STEM Teachers, 1988–2012. *AERA Open* 4(3): 2332858418802790. DOI: 10.1177/2332858418802790.

Parker MC and Guzdial M (2019) A Statewide Quantitative Analysis of Computer Science; What Predicts CS in Georgia Public High School? In: *Proceedings of the 2019 ACM Conference on International Computing Education Research*, New York, NY, USA, 30 July 2019, p. 317. ICER '19. Association for Computing Machinery. DOI: 10.1145/3291279.3341212.

Roser M and Ortiz-Ospina E (2017) Global rise of education. *Our World in Data*.

UNESCO (2015) *A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia*. Paris: United National Educational, Scientific and Cultural Organization.

UNESCO (2017) *Cracking the Code Girls' and Women's Education in Science, Technology, Engineering and Mathematics (STEM)*. Paris: United National Educational, Scientific and Cultural Organization.

United Nations (2017) *Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development : resolution / adopted by the General Assembly. A/RES/71/313*. 10 July. UN,. Available at: https://digitallibrary.un.org/record/1291226 (accessed 2 May 2021).

Wang J, Hong H, Ravitz J, et al. (2016) Landscape of K-12 Computer Science Education in the U.S.: Perceptions, Access, and Barriers. In: *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, New York, NY, USA, 17 February 2016, pp. 645–650. SIGCSE '16. Association for Computing Machinery. DOI: 10.1145/2839509.2844628.

Figures
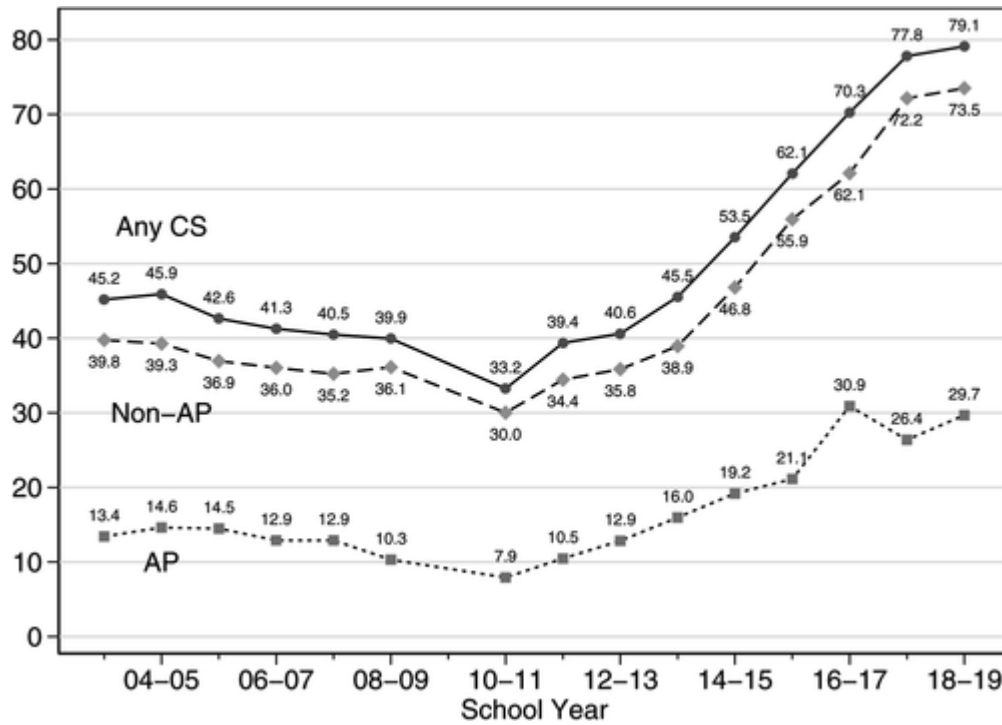
Figure 1. Percentage of California high school students enrolled in schools offering at least one

computer science course. Data are not available for the 2009–2010 school year. AP: Advanced
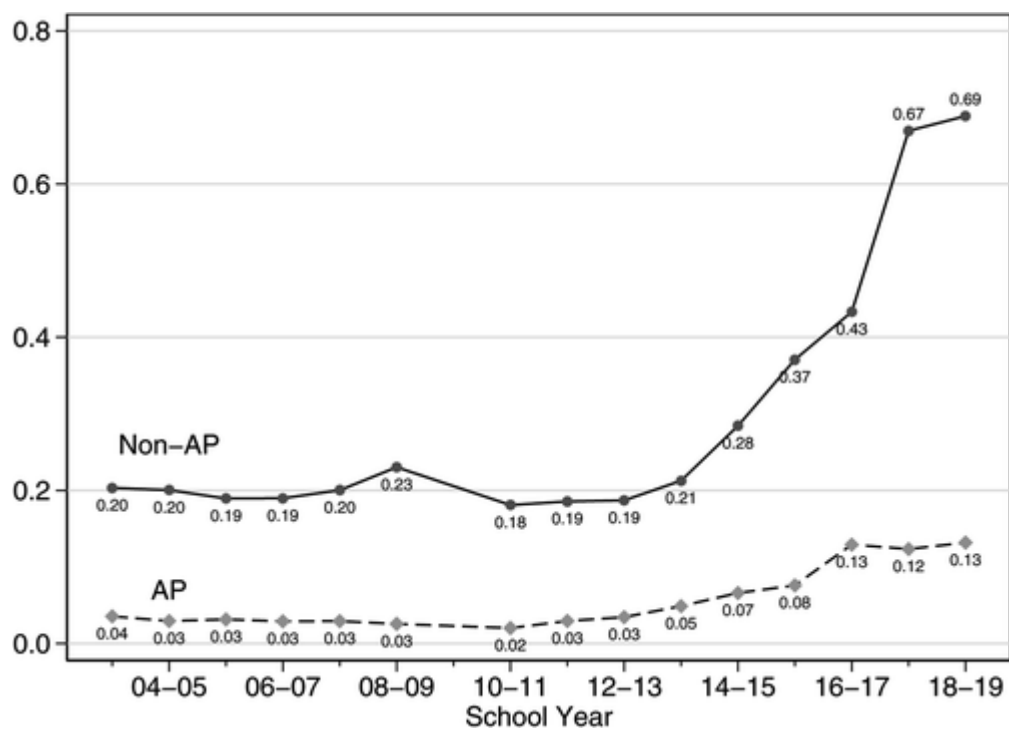
Placement.

Figure 2. Percentage of high school course enrollments that are in computer science. Data are not

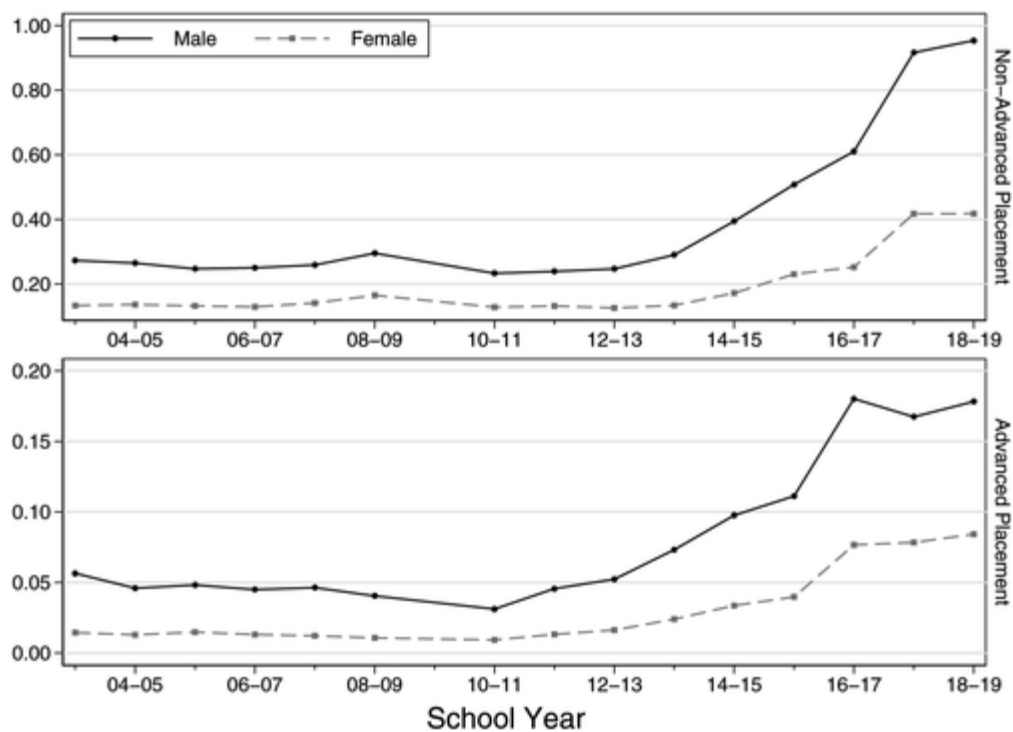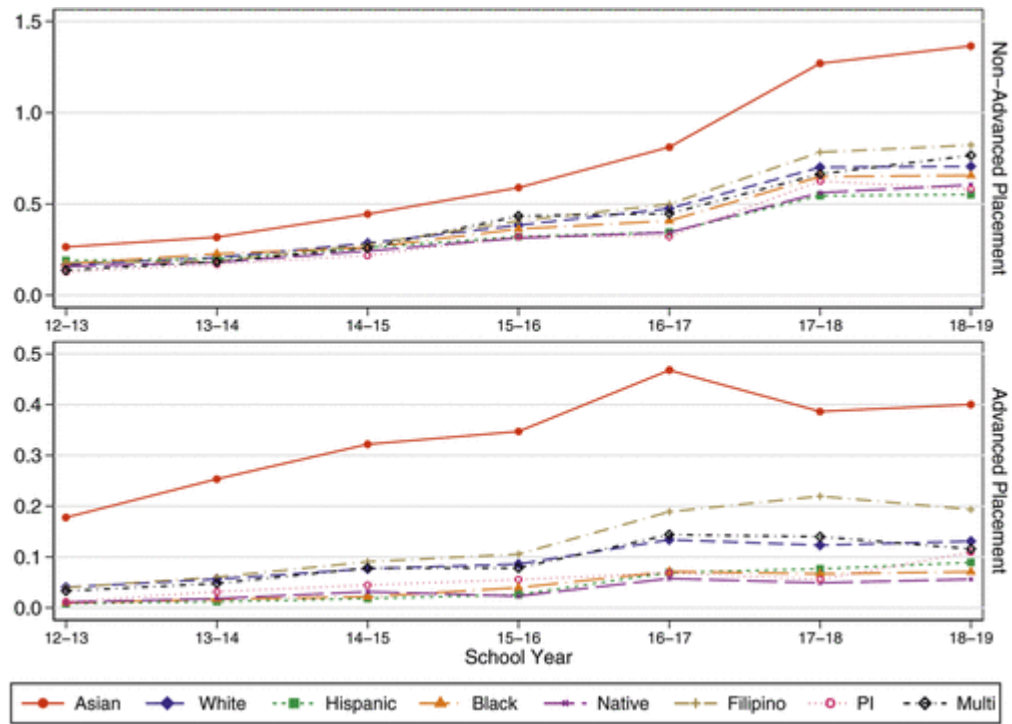available for the 2009–2010 school year. AP: Advanced Placement.

Figure 3. Percentage of high school course enrollments that are in computer science by gender.

Data are not available for the 2009–2010 school year.

Figure 4. Percentage of high school course enrollments that are in computer science by race. PI:

Pacific Islander.
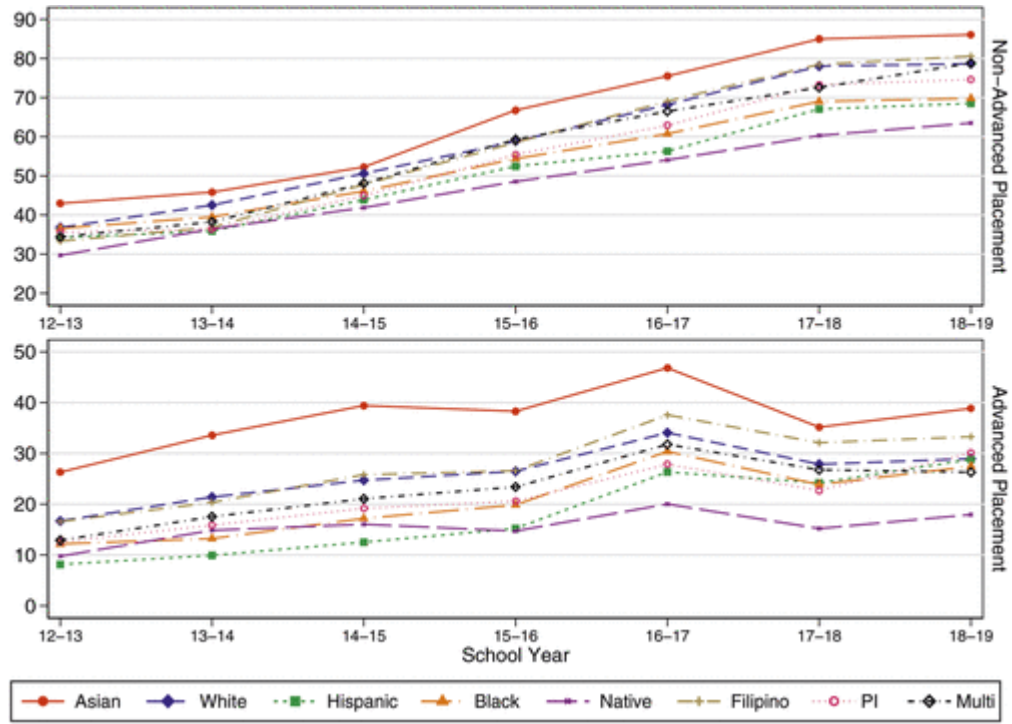
Figure 5. Percentage of California high school students enrolled in schools offering computer science courses, by race. PI: Pacific Islander.
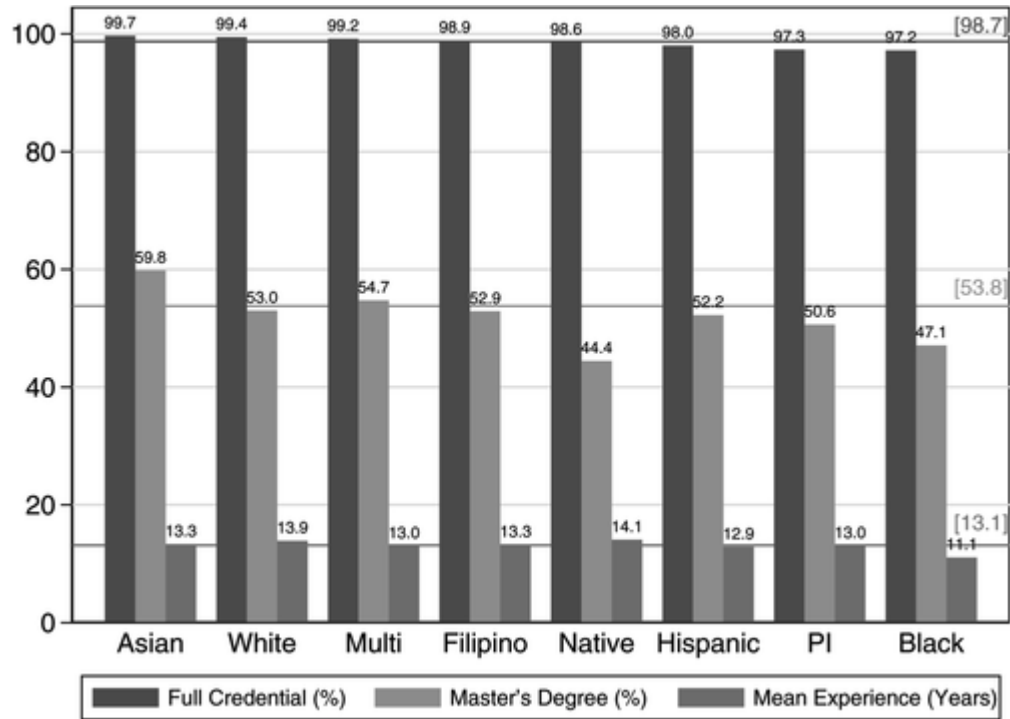
Figure 6. Average computer science teacher qualifications by student race (enrollment-weighted)

in 2018–2019. Horizontal lines and numbers in brackets indicate statewide means. PI: Pacific

Islander.
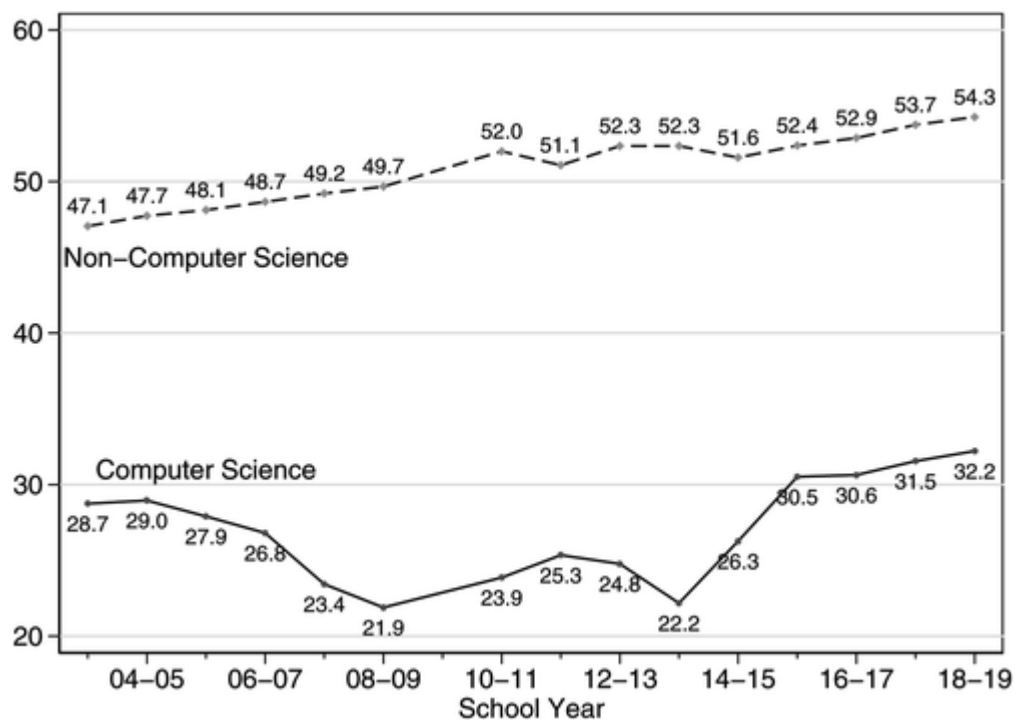
Figure 7. Percentage of course enrollments taught by female teachers. Data are not available for
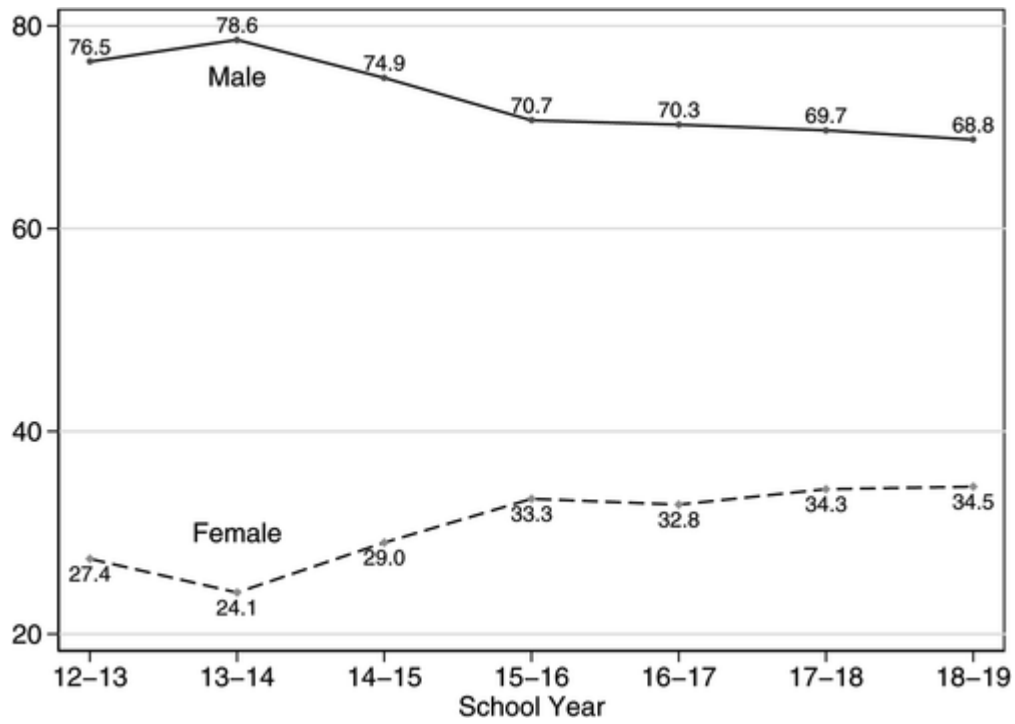
the 2009–2010 school year.

Figure 8. Percentage of computer science enrollments taught by same-gender teachers.
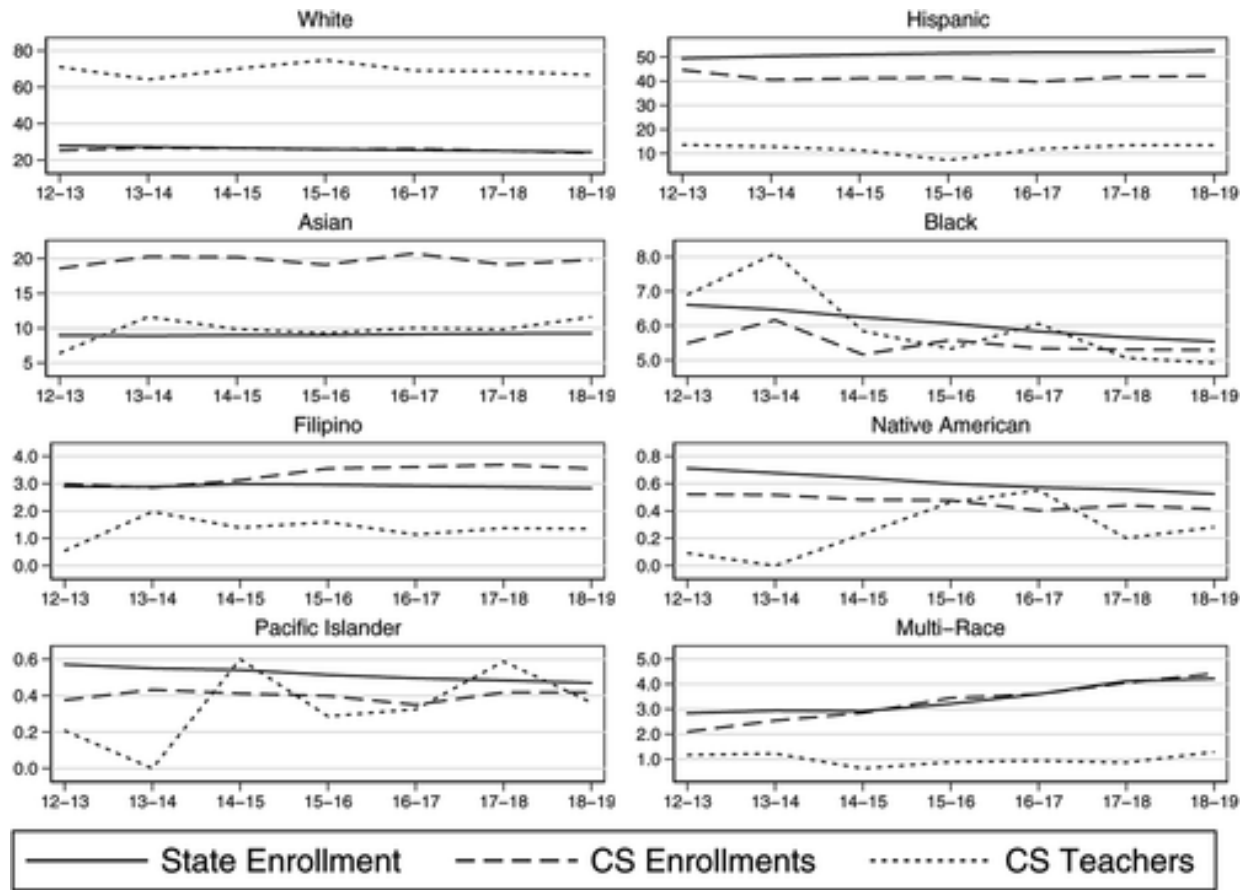
Figure 9. Percentage of statewide enrollment, computer science (CS) enrollments, and CS teachers from different racial groups. CS teachers are weighted based on the enrollments in their courses.
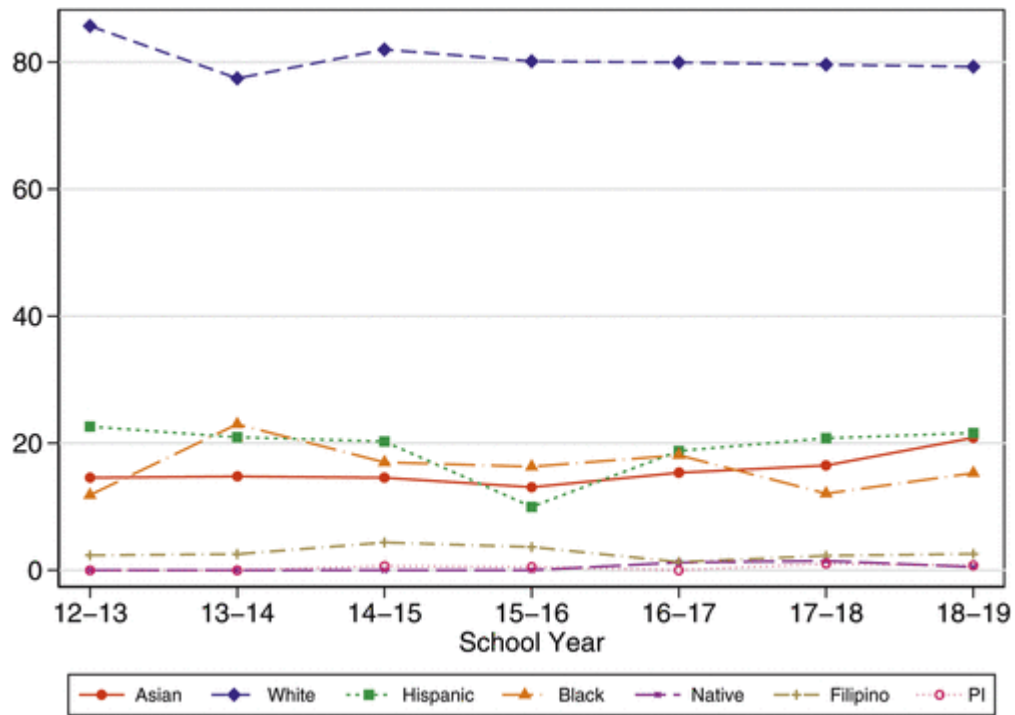
Figure 10. Percentage of computer science enrollments taught by same-race teachers. PI =

Pacific Islander.