Seeking Equitable Computer Science Education in Massachusetts: How Well Are We Doing?

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Overview

Since the mid-2000s, Massachusetts has endeavored to increase access to computer science (CS) education for all of the state's K–12 public school students. During this period, those driving Massachusetts's efforts to develop a coherent and systemic approach to CS education have recognized the critical importance of grounding their work in a commitment to equity. As CS is arguably poised to join reading, writing, and arithmetic as the "4th 'R,'"[1] access to at least foundational CS knowledge and skill becomes necessary for full participation as an informed and effective citizen.

Many have also made the argument that a serious commitment to equitable CS education is important for individual economic advancement, particularly advancement of those students who are historically underrepresented in well-paying jobs, as well as for the nation's ability to innovate and compete on a global stage.

> *For a sector that has an enormous impact on the way we all live our lives in the 21st century economy, there is a startling lack of diversity in the field of computer science. In 2014, a large group of technology companies released the diversity statistics of their employee base . . . revealing women and people of color to be vastly underrepresented.*
>
> *. . . One foundational part of the solution [to the lack of diversity] is to address the inequity in access to computer science education, which begins at the P–12 years for many students of color and others from historically underserved communities. . . . Nationwide, black students make up just 2 percent of all AP computer science test-takers, and the single largest black-white scoring gap among all AP exams is in computer science.*[2]

Over the past 10 years, we have seen a substantial national effort to raise public visibility regarding equity in K–12 CS education. Within Massachusetts, this work has largely focused on increasing the availability of CS courses in high schools across the state and, simultaneously, on developing a cadre of CS teachers to offer these courses. Thus, it seems a good time to assess the state's early-stage progress toward achieving its goals with respect to equity. To this end, we report on statistics comparing 2006 and 2016 outcomes for Massachusetts students on the Educational Testing Service's AP Computer Science A exam (AP CS A), which assesses computing skills in the context of Java programming.

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[1]Cutts, Q., Esper, S., & Simon, B. (2011). Computing as the 4th "R": A general education approach to computing education. *ICER '11: Proceedings of the seventh international workshop on Computing Education Research* (pp. 133–138). Association of Computing Machinery.

[2]Kopp, W. (2014). Equal access to computer science education is critical for a diverse technology sector. In B. Ganapathy, C. Olson, E. Fraser, & T. Wells (Eds.), *Creating digital fluency, state by state, city by city: Computer science education in the U.S.* (p. 7). TATA Consultancy Services. https://www.stemconnector.com/wp-content/uploads/2017/03/STEM_White_Paper_DigitalFluency.pdf

We have chosen to use AP CS A-taking as the measure of progress toward equity for three reasons: (1) Demographic data going back more than a decade are available, (2) this exam is a nationally recognized assessment of CS knowledge and skill, and (3) the performance of Massachusetts students can be tracked over time; AP exam scores are equated across years such that a given score (for example, a 3) indicates the same level of achievement in 2006 as it does in 2016, making comparisons of outcomes across time relatively straightforward and free of the need to contextualize results.

The good news and the not-so-good news for Massachusetts

Nationally, the AP CS A exam is attracting a larger proportion of AP test-takers. Between 2006 and 2016, the increase in the number of high school students taking the AP CS A exam increased faster than the rate of AP test-taking overall: The total number of AP tests taken has doubled, while the number of AP CS A exams taken has tripled. Nonetheless, the AP CS A exam comprises a relatively small percentage of all AP exams administered nationwide: less than 1% (0.8%) and 1.2% of all AP exams administered in 2006 and 2016, respectively.

- **Some good news:** In the past decade, Massachusetts has seen an increase in the rate of high school students' AP CS A exam-taking that is twice that of the nation as a whole. While only 376 Massachusetts students took the exam in 2006, 2,279 took it in 2016—more than a seven-fold increase, as opposed to the national tripling of AP CS A test-takers.

- **Some not-so-good news:** There has been mixed progress in terms of changing the gender or racial composition of the Massachusetts students who take the AP CS A exam.

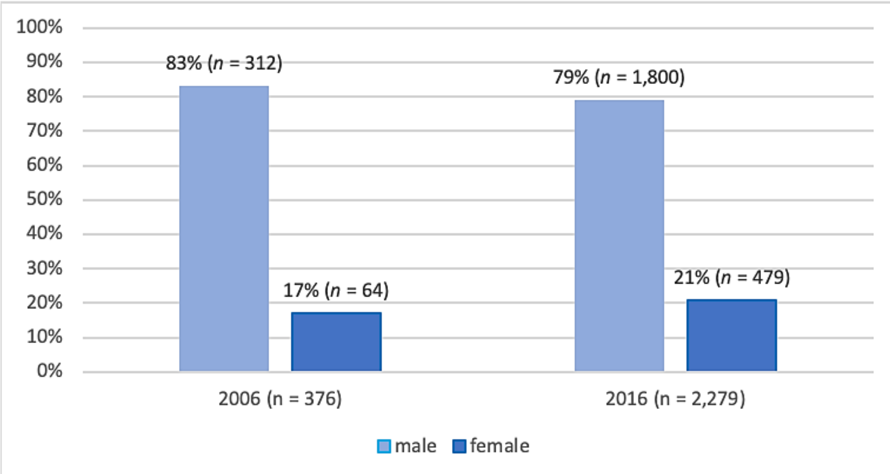
Gender differences[3]

Although the state's student population is essentially evenly split by gender (51% male and 49% female), the students taking the AP CS A test are predominately male, despite the overall increases in the number of students of both genders who take the exam, and a modest (4%) increase in the percentage of female test-takers (see Figure 1).[4]

[3]Gender is increasingly being recognized as a social construction that involves more subtlety and fluidity than the historical articulation of a female-or-male binary. The data available from the College Board for the time frame covered in this report, however, is binary in categorizing students as either male or female.

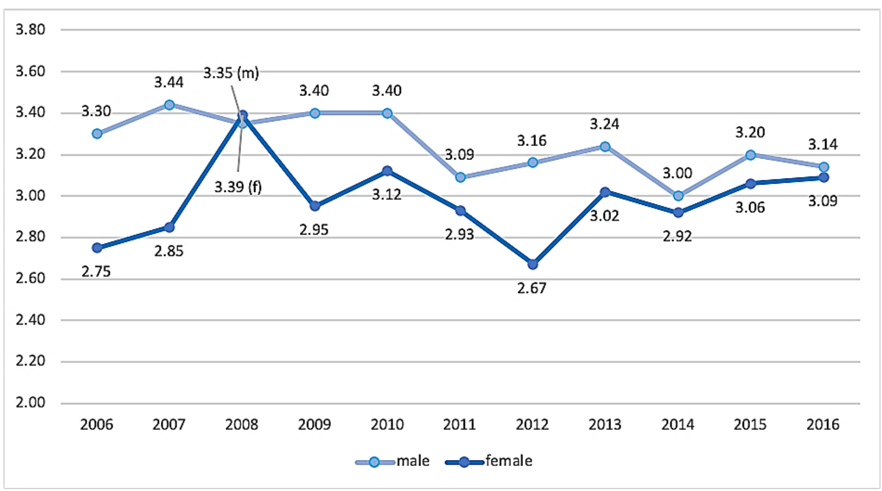
[4]Perhaps a more accurate comparison would be the percentage of students, by gender, taking the AP CS A exam as a function of the overall percentage of *high school students* in the state. At the time of writing, we did not have access to gender demographics for high school students only.

Figure 1: Gender composition of Massachusetts AP CS A test-takers in 2006 and 2016



- **Some not-so-good news:** On average, male students outperform their female counterparts on the exam (see Figure 2).
- **Some good news:** This gap may be closing. Between 2006 and 2016, the average scores of female AP CS A test-takers have generally increased, particularly over the past three or four years. While there was some volatility between 2006 and 2013, the variability observed in females' scores during this time is likely related to the small numbers of females taking the exam. After 2013, females began to steadily close the gap and by 2016 were nearing parity.

Figure 2: Average AP CS A scores by gender in Massachusetts from 2006 to 2016[5]

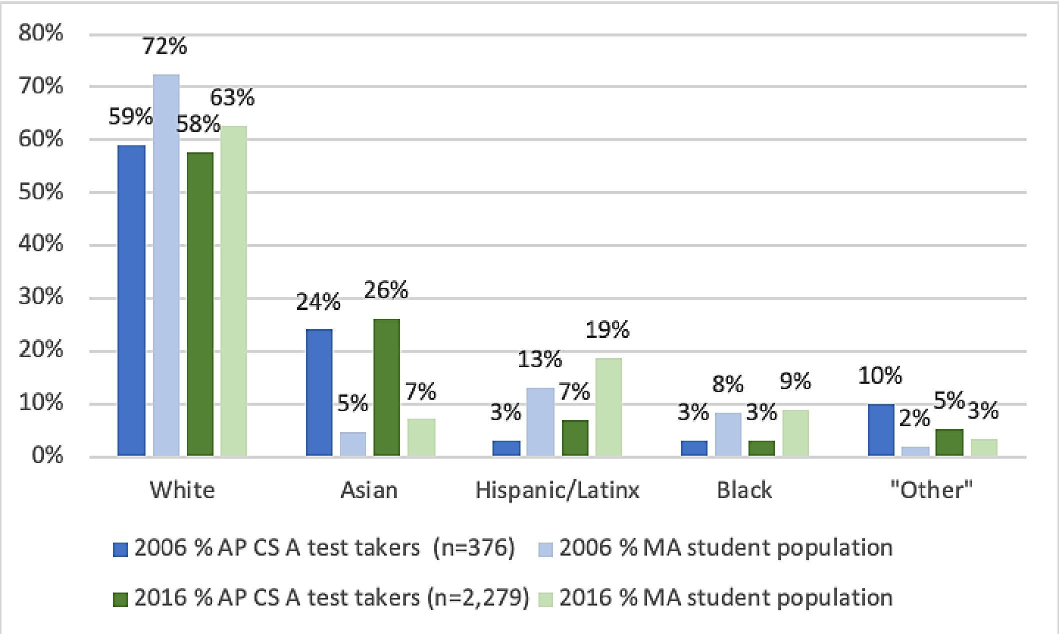


[5]AP scores of 3 and above are considered to reflect students who are capable of successfully doing work in an introductory-level college course.

Racial differences

Overall, Massachusetts has been, and remains, a state with a predominately white student population. Given that white students currently comprise two-thirds of the K–12 population, it is not surprising that the majority of students taking the AP CS A exam are also white. The proportion of white students taking the exam has remained unchanged in the past decade, even as the overall percentage of white students enrolled in Massachusetts has decreased by nearly 10% (see Figure 3).

Figure 3: Racial composition of AP CS A test-takers as a function of overall Massachusetts student demographics



*"Other" category includes students identified as multi-race, non-Hispanic; Native American; or Native Hawaiian, Pacific Islander.

The result of this changing state demographic is that the percentage of white AP CS A exam-takers is now a reasonably accurate reflection of the overall proportion of white students enrolled in public and charter schools in the state.[6] In contrast, in both 2006 and 2016, Asian students have been overrepresented among AP CS A test-takers; although they make up less than 10% of Massachusetts students, Asian students comprise one-quarter of the exam-takers.[7] Conversely, in both 2006 and 2016, the percentages of students taking the AP CS A

[6]Again, a more accurate comparison might be the percentage of students, by race, taking the AP CS A exam as a function of the overall percentage of *high school students* in the state. At the time of writing, we did not have access to racial demographics for high school students only.

[7]Our colleague Joe Wong recently observed that the category of "Asian" students comprises students from a variety of ethnic backgrounds, not all of whom are equally represented among AP CS A test-takers. This

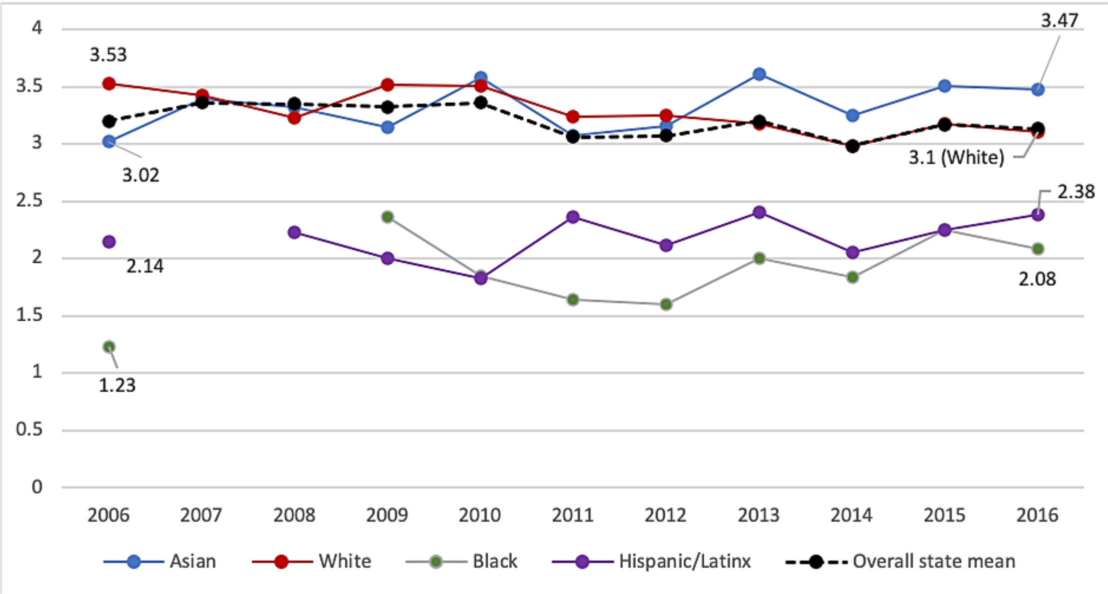
exam who were Hispanic/Latinx or Black were substantially under-representative of the statewide student demographics for these two racial groups.

- **Some good news:** The percentage of Hispanic/Latinx students taking the AP CS A exam has outpaced the overall growth of the population of Hispanic/Latinx students attending school over the past 10 years, more than doubling from a very modest 3% of AP CS A test-takers to 7%.

- **Some not-so good news:** The extremely low percentage of Black students taking the AP CS A exam has remained relatively constant, a fact that those who are striving for equity in CS outcomes find deeply troubling.

Figure 4 presents the mean AP CS A scores over the past 10 years in Massachusetts, disaggregated by race.

Figure 4: Average AP CS A Scores by race in Massachusetts from 2006 to 2016



Again, the results are mixed.[8]

- **Some good news:** As more Black and Hispanic/Latinx students have taken the exam over the past decade (and, presumably, as the quality of classroom instruction and test preparation have improved), scores for these two subgroups have trended upward.

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observation requires a more nuanced and in-depth look at the outcomes of students within this category than we can undertake with the current data set.

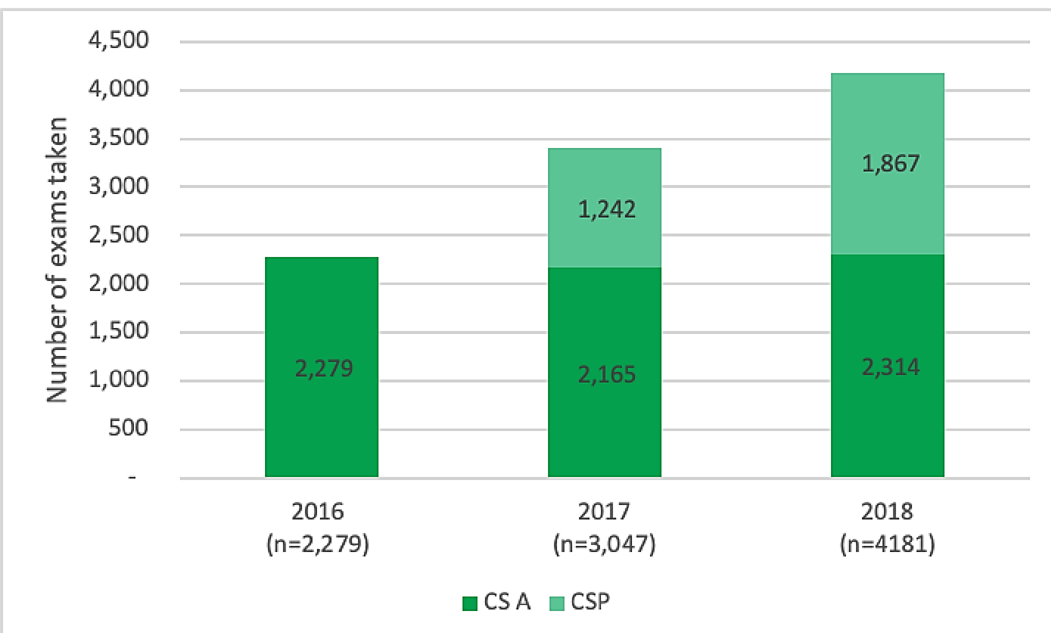
[8]Discontinuities in Figure 4 for Black students (a gap in the data for 2007 and 2008) and Hispanic/Latinx students (2007) are due to the small number of students taking the exam during those years, leading to an inability to calculate a meaningful average score.

- **Some not-so good news:** As a group, Black and Hispanic/Latinx students have consistently performed more poorly on this exam than their white and Asian peers. While the mean AP CS A score for all Massachusetts test-takers has consistently been at 3 or above (the dashed line in Figure 4), it is clearly the performance of the white and Asian students that are pulling up the average scores. Nearly 69% of the white and Asian students receive a score of 3 or more on the test—indicating adequate preparation for collegiate-level CS work—while only 49% of the Black and Hispanic/Latinx students do.

A second AP exam is increasing student participation

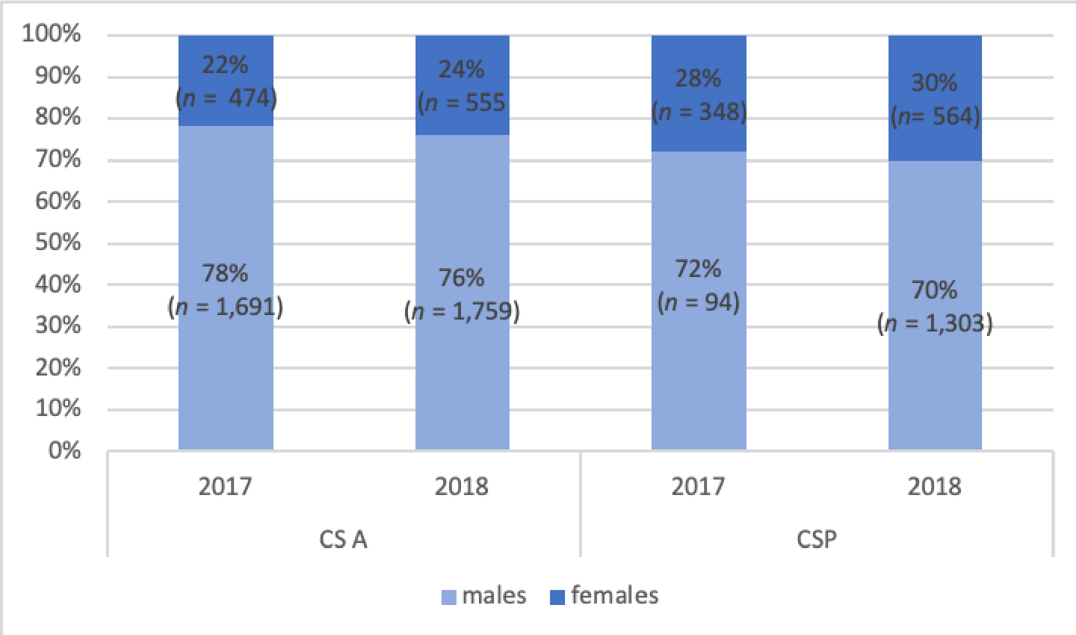
In 2017, the College Board added a second AP exam for CS, Computer Science Principles (CSP). While the AP CS A exam focuses entirely on programming (and only in a single language, Java), the AP CSP exam is broader in scope and targets seven "big ideas" in computing: creativity, abstraction, data and information, algorithms, programming, the Internet, and the global impact of computing. The introduction of the AP CSP option has increased the number of students taking AP CS exams in Massachusetts (Figure 5). While the number of AP CS A exams taken has remained fairly steady, the total number of AP CS exams taken in the state has nearly doubled in the two years for which we currently have data. AP CSP exams constituted slightly more than one-third of all AP CS exams taken in 2017 and nearly half the exams taken in 2018.

Figure 5: AP CS Exams taken in Massachusetts, before and after introduction of AP CSP



As Figure 6 indicates, a slightly higher percentage of AP CSP test-takers are female (6%); however, even as the overall number of students taking AP CS exams increased with the introduction of AP CSP, the majority of exam-takers continue to be male.

Figure 6: Gender composition of Massachusetts AP CS A and AP CSP test-takers in 2017 and 2018



The introduction of the AP CSP test has also resulted in an increase in the numbers of Black and Hispanic/Latinx students taking AP CS examinations, essentially tripling the number of Black students and doubling the number of Hispanic/Latinx students taking an AP exam for CS in 2017 and 2018 (Figures 7a and 7b).

Figure 7a: Number of Massachusetts students taking AP CS-A and AP CSP in 2017, by race

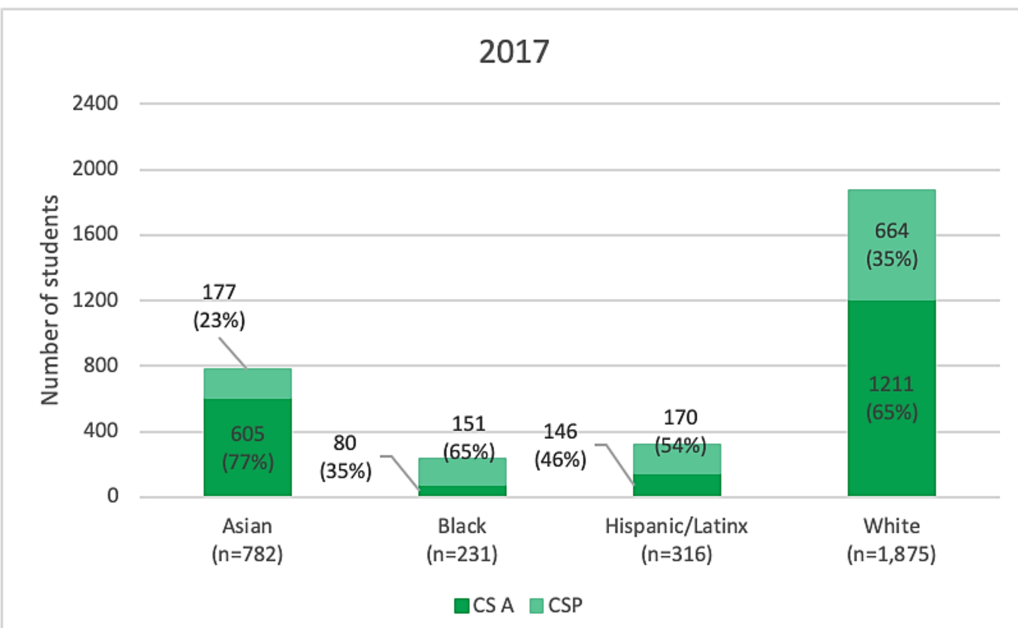
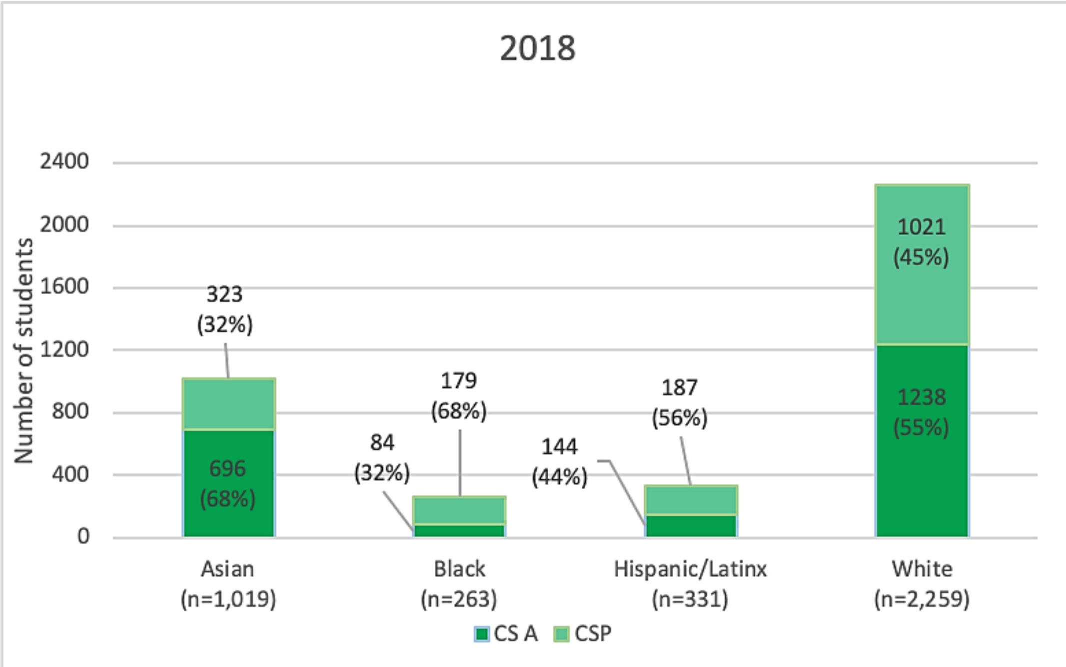
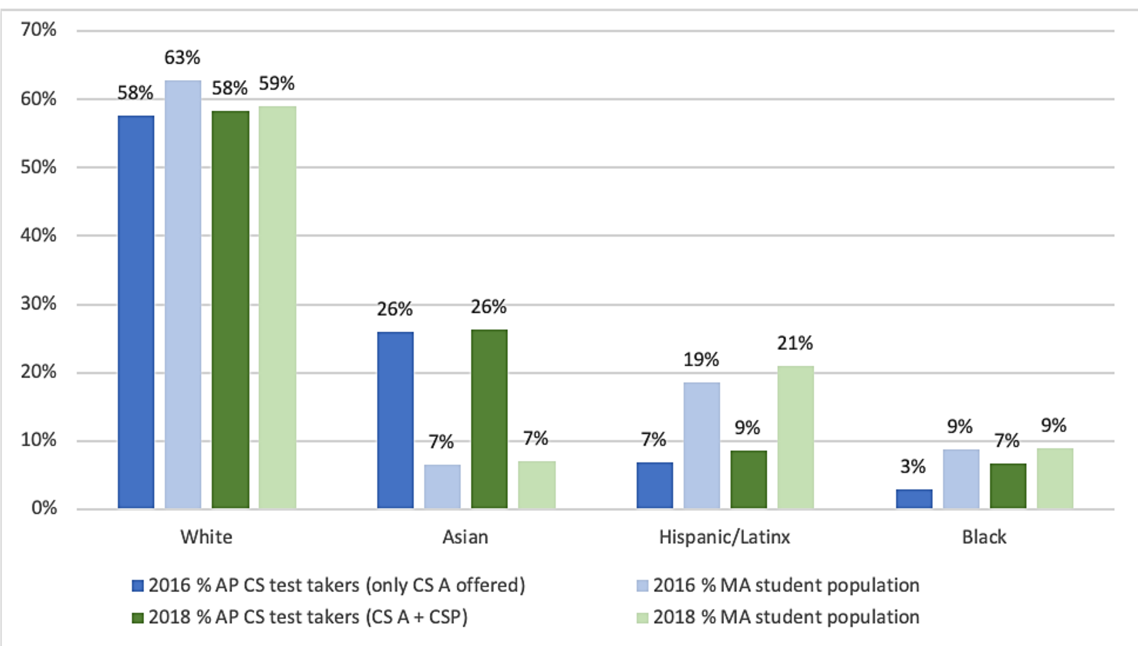


Figure 7b: Number of Massachusetts students taking AP CS-A and AP CSP in 2018, by race



For Black students, these increases have led to nearly proportional representation among AP CS test-takers: In 2018, Black students represented 9% of the student population in Massachusetts and 7% of students taking AP CS exams. However, this is not the case for Hispanic/Latinx students, who are still underrepresented among AP CS test-takers (Figure 8).

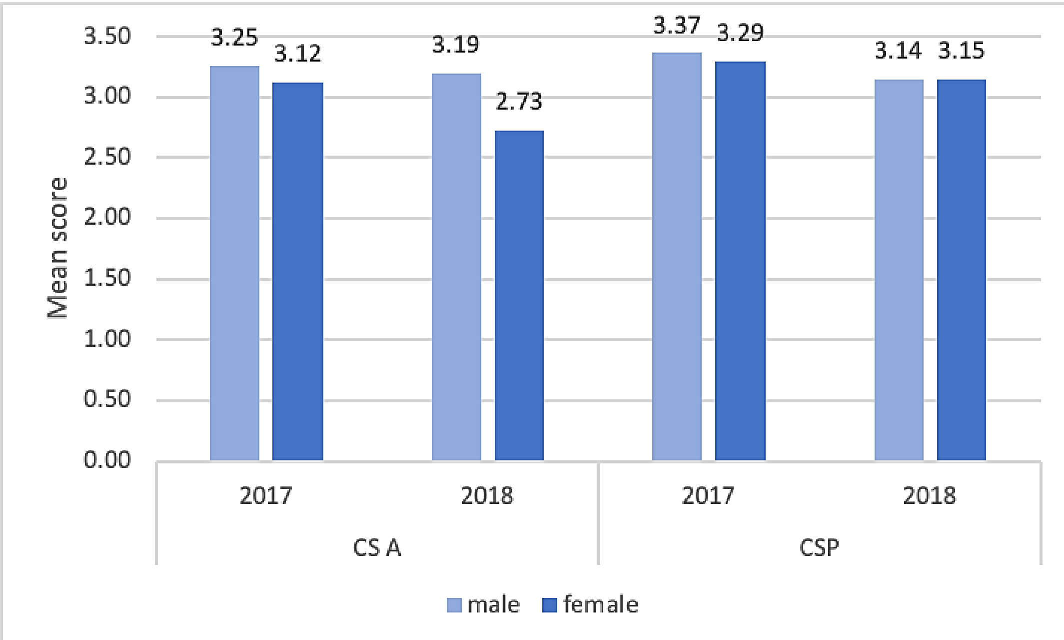
Figure 8: Racial composition of all AP computer science test-takers as a function of overall Massachusetts student demographics



With only two years of achievement data for AP CS exams, the effect of adding the AP CSP option on student performance by gender or by race is still unclear.

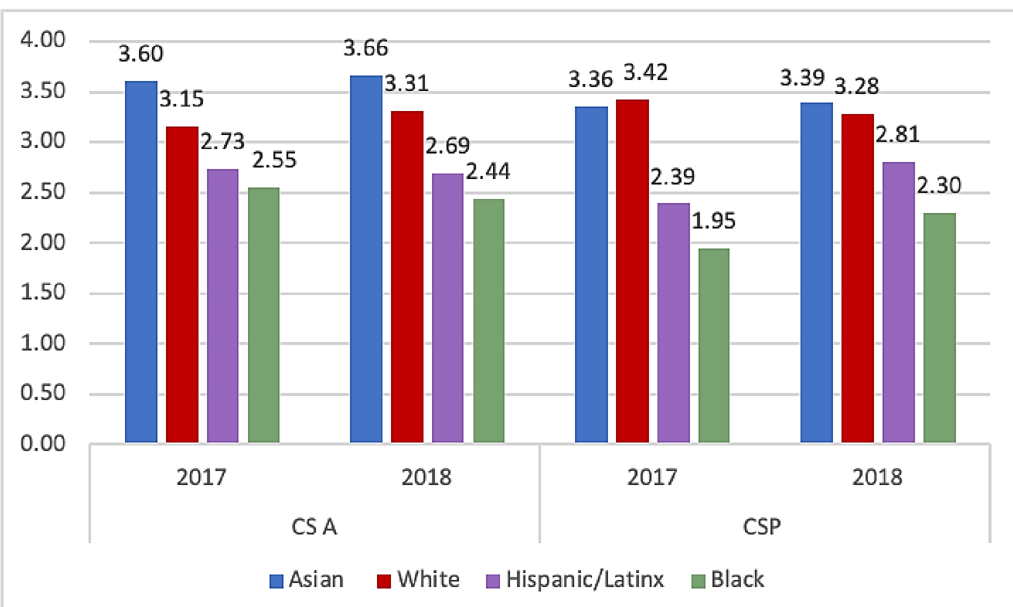
Mean scores for both males and females were somewhat lower in 2018 than 2017, but overall it appears that females are continuing to close the gender gap (Figure 9).

Figure 9: Mean scores on AP CS A and AP CSP, by gender, of Massachusetts students



There do not appear to be clear patterns of performance by racial group for the two years for which we currently have both AP CS A and AP CSP data (Figure 10).

Figure 10: Mean scores on AP CS A and AP CSP, by race, of Massachusetts students



Because the AP CSP is relatively new, many schools are still in the process of identifying curriculum materials that will address the topics addressed in that exam, as well as qualified teachers to offer these courses to students. We are hopeful that the availability of this broader-purpose exam will continue to increase student participation in CS courses, particularly among groups of students who have thus far been underrepresented in high school AP CS courses.

Other equity considerations

The AP CS data indicate that Massachusetts still has a lot more work to do to ensure that all of its high school students have access to and experience success in CS courses. We can turn to recent nationwide studies to identify some of the likely challenges to reaching the state's goal of CS for all. Google and Gallup recently collaborated on several reports examining factors that affect the participation of females and students of color in CS, concluding that both structural and social barriers impede participation,[9] including barriers related to access to high-quality instruction—or even the opportunity to simply access CS courses. Issues of access are magnified at the elementary and middle school grades, where students often, crucially, begin to develop lifelong affinities for particular subject areas and/or career possibilities.

While addressing these inequities is no simple task, there are some potential solution pathways on which Massachusetts can embark. Structural barriers, for example, may be addressed by CS leaders continuing to marshal resources to increase the number of qualified CS teachers (both those currently practicing and those who will enter teacher preparation programs), by offering CS courses in every public school in the state, and by promoting the inclusion of rigorous CS courses as part of the state's recommended MassCore program for high school graduation.

Social barriers may be somewhat more challenging and may require more concerted and creative efforts on the part of Massachusetts CS leaders and state educators. For example, students who fail to see "people like me" represented in CS-related work or activities may not develop an interest in CS or a sense of self-efficacy as CS learners. So too, students who receive messages (both subtle and not so subtle) from peers and adults in their lives that communicate low expectations and perhaps even active discouragement of CS-related career aspirations have a steep uphill climb to persist in seeking opportunities and in securing support for academic success.

[9] Google, Inc., & Gallup, Inc. (2016). *Diversity Gaps in Computer Science: Exploring the Underrepresentation of Girls, Blacks, and Hispanics.* http://services.google.com/fh/files/misc/diversity-gaps-in-computer-science-report.pdf; Google, Inc. (2014). *Women who choose computer science—What really matters.* https://docs.google.com/file/d/0B-E2rcvhnlQ_a1Q4VUxWQ2dtTHM/edit; Google, Inc., & Gallup, Inc. (2015). *Searching for computer science: Access and barriers in U.S. K–12 education.* https://services.google.com/fh/files/misc/searching-for-computer-science_report.pdf

If the state is to succeed in promoting equitable access to high-quality CS education, there must be systemic efforts to engage adults who work directly with students to take responsibility for examining their biases, both explicit and implicit, and to develop skills and strategies for supporting all students' access to high-quality CS learning opportunities.[10]

And while this discussion has centered on race and gender as markers for assessing the equity of CS education, the focus on these two areas that need improvement may mask other forms of disadvantage or underrepresentation that also bear consideration by state CS leaders, for example:

- **Economic status:** Students' economic status may impact both their access to rigorous and ongoing CS education and the opportunity to defray the costs associated with taking AP tests. In 2016, just over 27% of students enrolled in Massachusetts public schools were considered *economically disadvantaged*,[11] but only 12% of AP test-takers, overall, fall into this category; of those students taking the AP CS A exam, only 11% were identified as *economically disadvantaged* (197 of 1,815 AP CS A test-takers). Attending to economic status will also help to paint a more nuanced picture of the racial/ethnic data, since student achievement is affected by complex interactions among a number of variables, which include economic status and race.[12]

- **Other subgroups for whom we need good data:** We encourage the Massachusetts Department of Elementary and Secondary Education (DESE) to gather data on access to CS course-taking and AP CS A exam-taking for additional subgroups, including English learners, students with physical disabilities, and students with cognitive or social-emotional disabilities.

[10]See, for example, Cohen, G. L., Garcia, J., Purdie-Vaughns, V., Apfel, N., & Brzustoski, P. (2009). Recursive processes in self-affirmation: Intervening to close the minority achievement gap. *Science*, *324*, 400–403; Good, C., Aronson, J., & Inzlicht, M. (2003). Adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Applied Developmental Psychology*, *24*, 645–662; and Johns, M., Schmader, T., & Martens, A. (2005). Knowing is half the battle: Teaching stereotype threat as a means of improving women's math performance. *Psychological Science*, *16*(3), 175–179.

[11]The Mass. Department of Education defines a student as *economically disadvantaged* if the student participates in one or more of the following: the Supplemental Nutrition Assistance Program, the Transitional Assistance for Families with Dependent Children, the Department of Children and Families' foster care program, and/or MassHealth (Medicaid). While this metric does not entirely align with the U.S. Census Bureau's definition of *poverty*, no comparable metric is available.

[12]American Psychological Association. (n.d.). *Ethnic and racial minorities and socioeconomic status.* https://www.apa.org/pi/ses/resources/publications/minorities; Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*(3), 417–453.

Questions to consider in moving forward

As the state moves forward with its ambitious goal of providing equitable, high-quality CS education across the K–12 spectrum, we believe that consideration of the following questions will support informed decision-making. We imagine that many other states are likewise struggling with efforts to achieve equity, and our hope is that these questions might also contribute to a broader national dialogue.

Question 1: What, specifically, are our goals for K–12 CS education?

- Our best chance of reaching all students is during the elementary school years, where we have an opportunity to lay a foundation for equitable standards-based CS learning that will drive demand and encourage participation in CS in future school years. How do schools and districts select appropriate curricula and prepare teachers, on a systemwide basis, to effectively integrate the curricula into their daily practice?
- Which CS concepts, skills, and practices are of central importance? What is the baseline for all students to be "CS literate"?
- How much CS coursework do we expect every middle and high school student to complete? What additional courses need to be offered to support students who seek CS-related college majors and careers?

Question 2: What is the most viable scaling model going forward?

- The initial-stage strategy for scaling CS has depended heavily on third parties (e.g., NSF, Code.org, Infosys Foundation) to provide funding for the large majority of K–12 CS high school teacher professional development (PD). Much of this training began with substantial funding subsidies and teacher stipends, but recently the subsidies and stipends are declining, with only a small fraction of middle and high school teachers being trained. If we are to succeed in developing a K–12 CS teaching force at scale, we need a second-stage strategy to build on the initial-stage strategy. For example, going forward, might states take primary responsibility for financially partnering with districts to implement district-based systemic models with medium-term (five- to six-year) timelines for including all students in all grades in a state's standards-based sequence of CS learning?
- What type and amount of state funding is needed to support districts in scaling CS education?
- How can states and CS advocates in the business and education communities collaborate to support districts in providing all students with this essential 21st century skill? How can state superintendent associations play a leadership role in the effort to make CS education for all both a priority and a reality?

Question 3: What are our comprehensive PD needs?

From our discussions with Massachusetts CS teachers and CS PD providers, we have learned that many CS teacher PD programs are breaking new ground by explicitly framing equity as central to the philosophy of inclusion in the rollout of new CS courses at the middle and high school levels. This suggests several questions regarding the role of teachers in addressing inequities, and how best to prepare them to do so:

- What kinds of additional PD can help teachers understand and redress current social and cultural inequities surrounding student participation in CS learning in order to provide high-quality CS instruction for all? Should we consider developing courses, to count toward licensure, that focus on understanding the factors that contribute to inequitable educational opportunities and that offer strategies to address inequities? Might such PD also serve to inform preservice course requirements in preparation for licensure?

- By asking CS PD participants to learn new subject-matter content and often new pedagogies, are we unfairly placing too much of the responsibility for achieving equitable participation and outcomes solely on them?

- The observation that "disparities within the educational system are the product of institutional structures and cultures that both disenfranchise certain groups of students and depress quality overall"[13] suggest that teachers can't address inequities alone. How can states and districts explicitly co-lead the CS equity agenda?

- What kinds of additional PD will give teachers and district leaders a deeper and richer "toolbox" for promoting CS equity?

Question 4: What does CS education look like in elementary school?

There are multiple ways to include CS skills and knowledge in the elementary school curricula that, with modest PD, are relatively simple and straightforward. Questions to consider:

- What might CS equity look like if we began implementing standards-based CS curricula in elementary school?

- Should districts and teachers together choose the CS curricula that best fits their K–5 standards? Should districts then encourage teachers to supplement the curricula with other CS-rich experiences (e.g., robotics, programming, computational thinking), as they feel comfortable?

[13]Smith, M., & O'Day, J. A. (2016, February). Chapter 9: Quality and Equality in American Education: Systemic Problems, Systemic Solutions. In I. Kirsch & H. Braun (Eds.), *The Dynamics of Opportunity in America: Evidence and Perspectives* (pp. 297–358). Educational Testing Service, p. 297.

- What is the best and most efficient strategy for providing ongoing support to elementary school teachers as they experiment with implementing CS over the first few years?

Question 5: How can we increase participation among Black and Hispanic/Latino middle and high school students in CS education, and what strategies might foster improvement in their performance?

The relatively low participation of Black and Hispanic/Latinx students in CS courses suggests that we are not providing these students, in particular, with adequate opportunities and supports for CS learning in middle and high school. Which of the following questions might we need to address, singly or in combination, to achieve greater participation in CS by these underrepresented groups?

- Many CS PD programs already incorporate equity awareness and equity recruiting strategies, but might we need broader and deeper equity training at both the district and teacher levels to achieve more satisfactory results?

- Might this broader and deeper equity training be a key step in conducting more credible outreach to parents and community-based organizations? Might it better enable teachers and district staff to engage parents' help in sustaining student participation? Might it help them engage community-based organizations in providing role models to inspire and motivate students?

- How do we address the social barriers identified earlier in this paper that may limit Black and Hispanic/Latinx students' access to CS education?

- How do we increase the number and range of CS courses taught by qualified teachers in schools that serve large numbers of Hispanic/Latinx students?

- How do we increase the number of teachers of color who are qualified to teach CS, thus providing evidence for students of color that CS is truly for all?

- What kinds of opportunities for learning CS outside of formal CS coursework (e.g., cybersecurity, robotics, artmaking with technology) might intrigue and engage students enough to encourage them to take a CS course?

- Should we strongly encourage students with little or no previous CS background to take a preparation course, such as Exploring Computer Science or Computer Science Discoveries, prior to taking AP CS courses?

- What additional supports and resources could schools provide, either during or before or after the regular school day, to support students' learning?

Question 6: What is needed in regard to districts and the larger community?

- What kinds of additional supports are needed in order to address social and structural barriers at the system level? For example, what supports do district administrators and guidance counselors need in order to address inequities related to CS learning and career awareness in their daily interactions with students?

- How do we more effectively bring parents, and community-based organizations on board, particularly parents of students in populations that are currently underrepresented in CS fields?

- How can we engage local businesses and industries and higher education in a robust data-based partnership that increases awareness of and preparation for careers in the broad array of CS-related fields?

A note on using CS education data to inform future work

A number of informative data sources regarding CS education are available in Massachusetts. For this report, we relied on annual AP CS data found in the College Board's Reports by State for Massachusetts.[14] This will continue to be a key data source for Massachusetts CS education advocates, as it provides both participation and performance data for AP CS A; as of 2017, it also includes AP CSP data.

Additionally, in June 2018, DESE issued a report titled *Access to PK–12 Computer Science Courses in Massachusetts 2016–2017*,[15] the department's first effort at capturing a wide range of demographic data related to the 392,353 Massachusetts students enrolled in 99 CS-related courses during the 2106–2117 school year.

As other states launch or continue their own efforts to systematically gather and disseminate data on their K–12 CS education programs, we should see more robust discussions about outcomes and additional steps needed to better address equity in CS education. Sharing data among all 50 states will significantly advance our goal of establishing a CS equity agenda on a national level.

It is important to remember that equity and inclusion are not limited to gender and race. Information about access to CS course-taking and AP CS A and CSP exam-taking should be gathered for other subgroups as well, including English learners, students with physical disabilities, students with cognitive or social-emotional disabilities, and low-income students.

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[14]College Board. (n.d.). *AP Data—Archived Data 2016.* https://research.collegeboard.org/programs/ap/data/archived/ap-2016

[15]Massachusetts Department of Elementary and Secondary Education. (2018). *Access to PK–12 Computer Science Courses in Massachusetts 2016–2017.* http://www.doe.mass.edu/bese/docs/fy2018/2018-06/item5.html

In closing

The AP CS A data from the past decade suggest mixed answers to the question of "How well are we doing?" in terms of both achievement and participation. Mean test scores for females appear to be catching up with those of their male counterparts. Mean scores for Black and Hispanic/Latinx students also seem to be trending upward; however, they are still substantially lower than the mean scores for their white and Asian counterparts. Overall, the state has seen increases in the *number* of students taking AP CS A exams over the past decade, yet the *percentages* of young women and of students of color have not changed as much as one would hope.

With the introduction of AP CSP in 2017, there have been substantial increases in the number of Black and Hispanic/Latinx students who have taken AP CS exams, and some increase in the number of young women who have taken AP CS exams. Nonetheless, despite these increases, the students taking AP CS exams remain predominantly male and predominantly white or Asian. While there is much more work to be done to make sure that Massachusetts can put its commitment to equity in CS education into practice, we are heartened by the progress we have observed and the cultivation of champions for the cause among educational, political, industry, and community sectors. We trust that the data presented here will inform future planning and decision-making at the state and district levels.

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