Beauty and Joy of Computing:

2016–17 Findings from an AP CS Principles course

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ABSTRACT

In 2016–17, the College Board launched the Advanced Placement (AP) Computer Science Principles (CSP) course and exam. The AP CSP course was designed with the goal of broadening participation in computer science, and aims to introduce students to the creative aspects of computing by engaging students in developing computational artifacts related to their interests. The big ideas of the course include programming, abstraction, algorithms, data and information, the Internet, and also the global and societal impacts of computing.

With support from the National Science Foundation (NSF), the Beauty and Joy of Computing in New York City partnership created the Beauty and Joy of Computing (BJC) course that is aligned to the AP CSP framework and endorsed by the College Board. The partnership recruited over 100 NYC teachers to implement the course, provided professional development (PD) and implementation support, and conducted research on the course implementation and the effects on teachers and students.

This paper reports on findings from the implementation of BJC as an AP CSP course in NYC from the 2016–17 school year. It addresses student performance on a content knowledge assessment, a survey of students' attitudes toward computer science, and the 2017 AP CSP exam. Given the intentional design of the BJC course and AP CSP framework to address diversity and equity, student outcomes are also disaggregated by gender and race/ethnicity.

KEYWORDS

computer science education, K-12 curriculum, Computer Science Principles

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1 Introduction

The National Science Foundation (NSF) and the College Board developed the Advanced Placement (AP) Computer Science Principles (CSP) course and framework to broaden participation in computer science (CS), especially among females and students from racial and ethnic groups historically underrepresented in CS, and to provide an engaging and lively introduction to CS for high school students [1, 2, 3, 4]. The course was part of an NSF-led initiative (CS10K) to train 10,000 high school teachers to teach CS [5, 6]. Following pilots at the college and high school levels, CSP became an official AP course during the 2016–17 school year with the first administration of the CSP exam taking place in May 2017.

To support adoption of AP CSP, the NSF and other organizations funded a number of projects to develop curriculum materials aligned to the AP CSP framework and to provide professional development (PD) for high school teachers to become aware of curricular options, learn about pedagogical practices that support equitable CS instruction, and to plan for implementation and use in their own schools and classrooms [3, 7]. The Beauty and Joy of Computing (BJC) curriculum, described here, grows out of one of those curriculum development and implementation efforts.

2 About BJC and the BJC4NYC partnership

BJC was initially developed at the University of California, Berkeley (UCB) as a course for non-CS majors using the Snap! visual programming language [8]. In 2014, with support from the NSF, UCB partnered with Education Development Center (EDC) to create, test, and refine BJC, a yearlong high school AP CSP course adapted from the college-level course of the same name. In the BJC for NYC (BJC4NYC) partnership, the NYC Department of Education (NYCDOE) and the Foundation for Computer Science in NYC (CSNYC) partnered with EDC and UCB to recruit and train over 100 BJC teachers from a demographically representative set of NYC high schools. North Carolina State University (NCSU) joined the partnership to support BJC PD beyond NYC, and to

develop online resources for teacher PD. The BJC4NYC partnership goals were to attract more female, black, and Latinx students in NYC to the joy of programming, the beauty of the intellectual ideas behind CS, and the social impacts of technology. The results of the partnership include the creation of the BJC curriculum for high school use, alignment to the AP CSP framework and endorsement of the course by the College Board, recruitment of more than 100 NYC teachers to implement the course, and the provision of more than six weeks of PD and ongoing implementation support for three cohorts of NYC teachers. The PD and supports were designed to increase teachers' CS content knowledge and prepare them to teach BJC. Beyond NYC, NCSU has led PD for hundreds of BJC teachers across the country [9, 10].

BJC was designed to be a version of AP CSP that would deepen students' understanding by placing more emphasis on programming than the framework requires. This choice came from the authors' desire to provide students with engaging computer science experiences that are fun, and that help students feel competent and confident that they can "do" computer science. BJC is designed so that students can see the power of their own logic and the beauty and elegance of the code they create to express their creativity, especially on projects that are personally relevant and interesting. A key goal of the course is that students experience programming itself as something they enjoy and know they can do.

Moreover, programming is central to developing important ideas and ways of thinking (e.g., abstraction and algorithmic thinking) that are characteristic of computer science. The programming content features recursion and higher-order functions because of the powerful and beautiful way that they exemplify abstraction, one of the core ideas in computer science and the AP CSP framework. Traditionally, higher-order functions have been considered too difficult for high school students. The authors hypothesized that the explicit visual representations that the blocks-based programming language Snap! provides will make higher-order functions accessible to a diverse population of high school students. The non-programming parts of the course focus on the social implications of computing, and give students opportunities to analyze computing innovations balancing optimism about the affordances of computer technologies with a critical stance toward specific uses.

3 Related Research

Attention to broadening participation in CS has grown as projections for future jobs in the computer science and science, technology, engineering and mathematics (STEM) fields have rapidly increased [11], along with the recognition that there is a need to diversify the STEM workforce. In 2011, blacks and Hispanics made up just 13% of the STEM workforce even though they were 26% of the workforce at large, and there were twice as many men employed in a STEM occupation as women [12]. Of CS degrees awarded in 2016, 76% were to white or Asian students, and 79% were to male students [13]. This has led to the recognition that access to computer science is an equity issue, and there is a

need for more opportunities for students to engage with computer science ideas and practices in K–12 education, and greater encouragement to pursue computer science in college and careers.

The need for more opportunities for students to learn CS in high school is particularly pronounced for female students and students from racial and ethnic groups historically underrepresented in computing and technology (URG). Buzzetto-More and colleagues found that inadequate programming skills from coursework prior to college is a barrier to minorities participating in computing disciplines in college [14]. The College Board has reported that students who take AP computer science are eight times more likely to major in CS [15]. Chute found that lack of exposure to STEM was a contributing factor to low rates in minority and female participation [16]. Research points to the need for contextualizing the study of CS in order to engage these students. The National Center for Women & Information Technology (NCWIT) encourages schools to make CS curricula relevant to students, to recruit female and URG students, and to use inclusive pedagogies [17]. Estrada et al. point to the importance of personal relevance and beneficial uses of technology, which they argue may be more important in attracting URG students [18]. One target of state- and district-level CS4All initiatives has been to broaden students' participation in CS courses, especially among female and URG students, and especially in high school courses such as AP CSP.

Given that the AP CSP course and exam are so new, there is little research data or findings on the effects of the AP CSP course and associated curriculum programs to date. The extant literature focuses on describing the goals and ideas behind the CS Principles framework and course including course goals, big ideas, and computational thinking practices [3, 4, 19, 20]; and describes curriculum and PD efforts aimed at preparing teachers to teach AP CSP courses and introducing teachers to equitable pedagogies for teaching CS [9, 21, 22, 23, 24]. Many CS education initiatives have focused heavily on teacher PD as essential to realizing the goals of broader access and participation in CS. Findings about what contributes to effective PD for teaching AP CSP is now emerging from these teacher PD efforts. Guidance on teacher PD in CS includes recommendations to customize PD to support teachers with varied CS backgrounds, attend to novice teachers' content knowledge, contextualize PD experiences in classroom curricula and pedagogy, focus on increasing access and equity, and encourage collaboration and community among teachers [9, 22, 25, 26]. Support and funding for PD opportunities in CS by the NSF, Infosys, and other funders has catalyzed the spread of CS courses and instruction in K–12 schools [27]. Some research details teachers' experiences teaching AP CSP, along with discussion of the challenges encountered teaching CSP [28, 29]. In terms of outcomes, Hamlen and colleagues reported on teacher and student effects resulting from an AP CSP PD project [30]. There is a need for more literature examining the effects of AP CSP programs on teacher and student outcomes, including CS participation, CS knowledge, and attitudes toward CS.

4 Broadening CS Participation in High School

The introduction of the AP CSP course and exam sought to broaden participation in CS by making the field more attractive to women and black, Hispanic, and Native American students, groups historically underrepresented in CS. The goals included increasing the proportion of female and URG students enrolling in AP computer science courses and passing the AP CS exams. Participation in AP CS A (a Java-based programming course), the only AP computer science course being offered prior to the introduction of AP CSP, is dominated by white and Asian males. The early College Board data on the impact of the CSP course on student participation are encouraging. With the launch of AP CSP in 2016–17—the biggest launch of a new AP course in College Board history—there was a 79% jump in participation, with over 100,000 students taking an AP CS exam, either AP CS A or AP CSP. Moreover, in the first year of AP CSP, the number of girls who took an AP CS course more than doubled, as did the numbers of Hispanic/Latinx and black/African American students. In 2018, there was a 50% rise in the number of students taking the AP CSP exam, from 50,000 students in 2017 to 76,000 students in 2018. From 2017 to 2018, there were also substantive gains in the number of black, Hispanic/Latinx, and female students taking and passing the AP CSP exam. Access to and participation in AP CSP is a critical lever for diversifying CS enrollment in high school, and for increasing students' opportunities to consider CS-related opportunities in colleges and careers [31, 32, 33]. As a result of AP CSP, participation in CS is growing, and the greatest gains in participation are among females, black, and Hispanic/Latinx students. The studies reported here focus on the outcomes related to the implementation of one specific curriculum, Beauty and Joy of Computing, designed to be aligned to the AP CSP framework.

5 Research Goals and Context

In addition to developing the high school version of the BJC curriculum and providing PD for teachers in NYC who use BJC, our NSF-funded project conducted a set of research and evaluation activities, partnering with Haynie Research and Evaluation. The goals of the data collection and analyses were three-fold:

- 1) to inform design as well as revisions to curriculum materials,
- 2) to report on project quality and effectiveness, and
- 3) to report research-based knowledge to the CS education field.

To this end, the partnership supported implementation and collected teacher and student data for three years looking at teacher outcomes, and student gains in content knowledge and attitudes toward computer science prior to and after taking a BJC AP CSP course. The data presented here, from two sub-studies, largely addresses student outcomes, and is from school year 2016–17, the second year of project data collection and the first year the AP CSP exam was offered. Sub-study 1 was specifically interested in a subset of the BJC research study results on the student survey and content assessment. Supplementing other BJC student data collection in NYC, the first year of AP CSP administration allowed

us to see how BJC students fared on the AP CSP exam compared to students who were taught AP CSP content not using BJC. Sub-study 2 aimed to analyze the results of all students in NYC who took the AP CSP exam in 2017, specifically comparing BJC and non-BJC students.

6 Research Questions

The research questions reported here in this paper include:

1. Has participation in BJC AP CSP broadened student participation in CS?
2. Do students enrolled in a BJC AP CSP course gain in content knowledge from the beginning to end of the year? Are student gains similar when disaggregated by gender and URG status?
3. Do students enrolled in a BJC AP CSP course gain in interest, confidence, belongingness, and identification with computing? Are student gains similar when disaggregated by gender and URG status?
4. How do summative AP test scores of BJC students in NYC compare to other students in NYC not taught with the BJC curriculum?

7 Methodology

Below we describe our research samples, data collection procedures, instrumentation, and data analysis methods for BJC4NYC student participation data and both sub-studies.

7.1 Data Collection Procedures

Student participation in BJC data collection procedures. NYCDOE tracked student enrollment in BJC courses in NYC. Information on student enrollment overall and by subgroups of interest (e.g., gender and race) was collected, summarized, and provided by NYCDOE.

Sub-study 1 participants and data collection procedures. All students enrolled in a BJC AP CSP course in NYC were asked to complete a content assessment and an attitude survey at the beginning (October–December 2016) and end (May–June 2017) of the 2016–17 school year. Students were included as BJC research participants if they completed all four data collection instruments: the pre- and post-course content assessments and the pre- and post-course surveys. In 2016–17, the sample included 311 students across 24 NYC high schools. A majority of the sample was female (54%), non-URG (63%), and juniors in high school (57%); just 10% of students had taken a CS course previously. Student content assessments and attitude surveys were administered online via SurveyMonkey using links provided to them by their teacher.

Sub-study 2 participants and data collection procedures. In May 2017, 2,854 students took the 2017 AP CSP exam in NYC. Demographically, students were 57% male, 43% female; 13% black, 20% Hispanic with 33% of students from underrepresented racial and ethnic groups and 65% were designated as in poverty based on eligibility for free or reduced price lunch or identification by the NYCDOE Human Resources Administration as receiving certain types of public assistance. Thirty percent of students who

took the 2017 AP CSP exam in NYC were taught using the BJC curriculum. NYCDOE's Research and Policy Support Group (RPSG) provided the 2017 AP CSP exam scores for NYC students through a data request.

Note that the sub-study 1 and sub-study 2 samples overlap but neither is completely inclusive of the other. Specifically, some of the AP CSP exam takers in NYC participated in the BJC research study (sample 1), and not all BJC research study participants took the AP CSP exam (sample 2).

7.2 Instrumentation

The measures used in this study include:

Student Enrollment Memorandum. NYCDOE wrote a memorandum summarizing student enrollment in BJC courses across NYC. Summary information was included overall and by student demographics.

Content Assessment. The pre- and post-course student content assessment was developed by using released AP CSP items, UCB BJC assessments, and parallel items developed by BJC curriculum developers, AP CSP curriculum developers and CS content knowledge experts. The assessment is made up of 30 items intended to measure AP CSP Big Ideas 2–7 (Abstraction, Data and Information, Algorithms, Programming, The Internet, and Global Impact) as well as the BJC-specific topics of recursion and higher order functions. Big Idea 1 (Creativity) is not covered on the assessment as it is an overarching concept that is not explicitly assessed on the AP CSP Exam [1]. Two items were removed prior to analysis because of mistakes in the item wording or in the response options. The assessment provides two overall sum-scores: one for the AP CSP Big Ideas (21 items, Cronbach's $\alpha = 0.80$) and one for the BJC-specific topics (7 items, Cronbach's $\alpha = 0.53$). Given Cronbach's α for the BJC-specific topics sub-score does not meet the standard of 0.70, only students' Big Ideas sub-score was analyzed.

Attitude Survey. The pre- and post-course student attitude surveys were adapted from [34, 35, 36] and included scales to measure CS-related confidence (Cronbach's $\alpha = 0.79$), interest (Cronbach's $\alpha = 0.91$), belongingness (Cronbach's $\alpha = 0.77$), and identity (Cronbach's $\alpha = 0.84$). Belongingness refers to the feeling that you fit in and there are others like you in CS, while identity refers to whether or not you and others you know view yourself as a CS person. Confidence, interest, and belongingness were rated on a 4-point Likert scale from strongly disagree to strongly agree; identity was rated on a 3-point scale (1=No, not at all; 2=Maybe, at least a little; 3=Yes, very much).

2017 AP CSP Exam. The 2017 AP CSP exam was administered on Friday, May 5, 2017 to students across the United States. Scores range from 1 to 5; a score of 3 or above is a passing score.

7.3 Data Analysis

To answer the first research question, student enrollment information was captured from NYCDOE's memorandum on BJC enrollment in NYC. To answer the second and third research

questions, pre-course and post-course student content assessment and attitude survey data collected from BJC research participants in NYC high schools were analyzed using the following analytic procedures. Scale scores were calculated for content knowledge (AP CSP Big Ideas) by summing the corresponding items and for attitudes toward CS (interest, confidence, belongingness, and identity) by averaging the corresponding items. The mean of each scale was calculated for pre- and post-course data. Then, dependent samples t-tests were run to determine if the mean values changed significantly from pre- to post-course. In addition, gain scores were calculated from pre- to post-course by subtracting pre-course scores from post-course scores, and regression analyses were run on the gain scores by gender and URG status to determine if students underrepresented in CS make similar gains as those not underrepresented. Results are also presented for the regression analyses with a school sample size variable, or the number of research participants in the school, included as a covariate to take into account the variation in the number of students from each school in the sample, which ranged from 1 to 74 students. To answer the fourth research question, frequency distributions and passing rates were calculated for the overall NYC sample; for the sample after taking into account large, demographically unique schools; and broken out by curriculum (taught AP CSP with the BJC curriculum versus not with the BJC curriculum). The chi-square test of association was used to determine if there were significant differences in AP CSP exam scores by curriculum. IBM's SPSS Statistics version 24 was used to analyze all research study data.

8 Findings

Given the broadening participation goals of BJC and the AP CSP course, we first report BJC student participation findings, followed by the student outcome findings for our two sub-studies.

8.1 Student participation

Student enrollment for BJC classes in NYC during 2016–17 was 1,383 students. Of those students, 43% were female, and 57% were male. Reported race/ethnicity showed black 27%, Hispanic 28%, Asian 23%, white 19%, multi-racial 1%, and Native American 1%. Students were mostly juniors (33%) and seniors (44%); 18% were ninth and tenth graders. Sixty percent of BJC4NYC students received free or reduced price lunch, 2% were ELs, and 7% were students with disabilities. Students were enrolled in schools that covered all five boroughs of NYC. Many of the participating schools did not previously have CS programs or the ability to offer them until this opportunity. Student data for 2017–18 are still being collected; however, the preliminary student enrollment for BJC classes in NYC is 2,383 students, showing gains in percentages of female (49%), black (33%), and Hispanic (29%) students.

8.2 Sub-study 1

Students showed significant pre- to post-course gains in AP CSP Big Ideas content knowledge; specifically, average scores increased from 9.09 pre-course to 10.75 post-course for a significant gain of 1.66 ($p < 0.001$, Cohen's $d = 0.43$). URG status

and gender are significant factors for content knowledge; non-URG and male students performed significantly better on the content assessment than URG and female students, respectively, both at pre-course and at post-course ($p < 0.05$ for all, Cohen's d ranged from 0.30 to 0.63). See figure 1, below, for pre- and post-course means overall and by subgroup. But for gains, there was no gender difference on the content assessment with male scores increasing from pre- to post-course by an average of 2.00 and female scores increasing by an average of 1.52 ($p = 0.299$). By contrast, non-URG students both started and ended the course with higher scores and showed significantly greater gains on the content assessment than URG students (gains of 2.10 and 0.92, respectively, $p = 0.011$, $d = 0.31$). School sample size was also included in a set of regression analyses as a covariate. After taking into account school sample size, gender remained insignificant; however, URG status changed from significant to insignificant ($p = 0.698$). Thus, after taking into account the number of research participants in each school, non-URG and URG students had similar gains on the content assessment pre- to post-course. In short, female and URG students achieved similar gains on the content assessment as male and non-URG students, respectively, taking into account school sample size.

Figure 1: Pre- and post-course content assessment scores

Figure 2 below contains student pre- and post-course means for variables measuring student attitudes toward CS. Significant, positive differences were found from pre- to post-course for confidence ($p = 0.015$, $d = 0.14$) and identity ($p = 0.001$, $d = 0.20$); no significant gains were found for interest or belongingness. Overall, male students and non-URG students reported more positive attitudes toward CS than females and URG students. However, females and URG students showed similar gains in confidence, interest, belongingness, and identity from pre- to post-course as males and non-URG students, respectively. As with the content assessment results, school sample size was then included in the model. After taking into account school sample size, gender and URG status still were not significant predictors of the CS attitude gain scores.

	Pre-Course	Post-Course
Attitude Scale	Mean (SD)	Mean (SD)
Confidence	2.80 (0.55)	2.87 (0.55)
Interest	2.91 (0.64)	2.93 (0.70)
Belongingness	3.02 (0.49)	3.07 (0.50)
Identity	2.01 (0.53)	2.10 (0.52)

Figure 2: Average scores (and standard deviations) for the four student pre- and post-course attitudes toward CS scales

8.3 Sub-study 2

The overall passing rate for the 2017 AP CSP exam in NYC was 72.7%. Of the 30% of students who took the 2017 AP CSP exam in NYC and were taught with the BJC curriculum, 67.2% passed the 2017 AP CSP exam. However, the student demographics of those two groups differed. Because over 50% of NYC students who took the AP CSP exam were from two high-performing high schools that had student demographics that differed from the norms for the city's schools overall, additional analyses were conducted without those two schools.

Two participating high schools—we call them North and South—had significantly different demographics from other NYC schools, and one of the schools was a selective high school requiring an entrance exam in NYC. They had 1,519 and 135 students take the 2017 AP CSP Exam, respectively. Together, students from these two schools made up 58% of NYC students who took the 2017 AP CSP exam. Demographically, these schools have significantly fewer URG students, students with individualized education plans (IEP), and students designated as in poverty. Both schools were also significantly more likely to have sophomores and significantly less likely to have seniors sitting for the exam. Because of the size and demographic make-up of the schools, these two schools were removed prior to additional analysis. Both schools had a pass rate over 90% on the 2017 AP CSP exam. At North HS, 131 of 1519 students were taught using BJC; their pass rate was 100% compared to 91.6% for students not taught with BJC. At South HS, all 135 students were taught using BJC, and their pass rate was 91.8%.

Excluding these two schools, 1,192 students (42% of NYC AP CSP exam takers) from 75 schools took the exam in NYC. The remaining students, demographically, were mostly juniors and seniors; 54% male; 61% URG; and 77.5% designated as in poverty. Of these students, only 45.9% passed the 2017 AP CSP Exam, with 19% receiving a score of 1 and 35.2% receiving a score of 2. Excluding North and South High Schools, almost half of students who took the 2017 AP CSP Exam in NYC were taught using BJC, and students taught with the BJC curriculum passed at a significantly higher rate (54.2%) than students not taught with BJC (37.7%).

9 Limitations

The results reported here are limited in several ways. For sub-study 1, the biggest limitation is teacher and student response rates. Over half of teachers trained to teach BJC in 2015–16 or 2016–17 did not collect student data in 2016–17. Of the teachers

who did collect student data, classroom response rates varied considerably from 25% to 100%. Data collection may have been limited because research incentives are not permitted for teachers in NYC. For sub-study 2, the biggest limitation was that classification of BJC curriculum use to either users or non-users was based on our knowledge of curriculum use gathered from College Board data, teacher surveys, and NYCDOE records. However, this data is incomplete, and our records about use of the BJC curriculum could not be verified for some teachers. In addition, it is possible that there are teachers who used BJC but did not indicate use to the College Board, or did not attend the NYCDOE-sponsored PD, and therefore, we were unaware of their use.

Furthermore, there are limitations that span the entire study. First, due to small sample sizes for most schools, our analyses could not take into account the nesting of students within schools, teachers, and classrooms. In the final year of project data collection, we hope to have a large enough sample to conduct analyses that do take this nesting into account. Relatedly, we do not take into account teacher or school-level factors that likely impact students' scores on the attitude survey, content assessment, and 2017 AP CSP exam, nor do we take into account student factors beyond gender and URG status. Finally, there is limited research on the validity of the measures used, including for the 2017 AP CSP exam. While all scales and assessments were developed thoughtfully and then tested, little exists in the field of computer science by which to validate them. In addition, it is important to note that these results are preliminary, and further analysis of the 2016–2017 results are underway. Also underway is analysis of subsequent administrations of the attitude survey, content assessment, and AP CSP exam accounting for these limitations.

10 Discussion and Implications

A number of state- and district-wide efforts are currently aimed at broadening participation in computer science in K–12 schools across the U.S. Particular attention at the high school level has been focused on the introduction and implementation of a new AP course, CSP, designed both to attract a broader audience of students to computer science and to engage them in the important content ideas and characteristic ways of thinking employed in the field of computer science. In the last decade, a number of curriculum programs have emerged to support schools in offering the AP CSP course. The College Board provides teachers and schools with links to a set of curriculum programs that have been reviewed and endorsed for the AP CSP course [7].

In the results reported here, we are encouraged about the gains in participation in CS in NYC, particularly among female, black, and Hispanic students. To continue to attract greater numbers of these students, active recruitment is needed, and there is still much to do to ensure that these students have multiple experiences that continue to spark their CS interests, and encourage them to pursue CS and CS-related courses and careers. It is also essential to dig deeper into the results to examine whether the demographics of the BJC AP CSP classrooms in NYC schools mirror the overall demographics of their school populations, and

that gains in access and achievement are similar across different student groups. As for achievement gains, while we saw similar gains on the content assessment for females and males, as well as for URG and non-URG students when taking into account the variation in school research sample size, males and non-URG students started out scoring higher on the content assessment at pre-test. What earlier CS experiences need to be provided to close these starting achievement gaps?

In addition, implementation efforts found that there were substantive differences in the school contexts where the BJC AP CSP course was introduced. For some schools, the BJC course was the very first AP course offered at the school, and many students in these schools often did not see themselves as ready to take an AP course or exam, and some students were not accustomed to the level of demand expected in the course. We feel that it is critical to better understand the broader contexts of the schools where AP CSP is being implemented, and to develop and test the needed supports so that rigorous CS courses can be implemented and sustained in diverse school settings.

Since these implementation efforts are all relatively new, there is great interest in understanding the successes and challenges of introducing CS through the AP CSP course. There is also a demand for evidence that demonstrates the AP CSP course and the curriculum programs developed to support teaching and learning CSP are increasing participation as desired, and also showing desirable outcomes for teacher and student learning. Moreover, it is critical to examine student outcomes particularly for students from groups historically underrepresented in computing, including female students, black, and Hispanic/Latinx students. The results of this work can advance knowledge in the field about promising strategies to broaden participation in CS and about supports for successful implementation of rigorous CS curricula and instruction.

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