Engaging Black Female Students in a Year-Long Preparatory Experience for AP CS Principles

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ABSTRACT

In 2020, over 116,000 students took the Advanced Placement Computer Science Principles (AP CSP) Exam. Although Black female students have participated in AP CSP at higher rates than for the AP CSA course, their representation is still disproportionately lower than the school population of Black females. In this Experience Report, we present the early results of an NSF-sponsored effort that provides an AP CSP preparatory experience and CS career awareness to Black female students from rural, urban, and suburban communities in the state of Alabama.

At the project's core is a peer-learning community (PLC) facilitated by Black female teachers with deep knowledge of AP CSP. An intensive summer experience prepares students for the AP CSP course through culturally-responsive, project-based learning experiences designed to connect advanced computing concepts to the students' personal lives and career aspirations. Interactions and support continue throughout the academic year to facilitate AP exam readiness. Online interactions among the PLC members serve to mitigate the barriers that young women of color typically encounter when pursuing CS education, increasing their persistence and success in CS.

We examined whether students' project participation enhances self-efficacy and perceived competency in CS, increases positive attitudes, awareness, and desire to pursue CS studies and careers, and mitigates perceived socio-cultural barriers to pursue studies and careers in CS. Our initial findings include AP CSP examination qualifying rates (87.5%) that exceed the 2019 national/statewide rates for all subgroups (including Alabama White male students), increased perceptions of Black females as belonging in CS, and gains in computing self-efficacy throughout the academic year.

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CCS CONCEPTS

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1 Introduction

Since 2017, the AP CS Principles (AP CSP) exam has set participation records and emerged as the College Board's fastest growing AP course [1]. With a focus on a broader curriculum to address diversity, equity and inclusion (DEI) goals, the number of Black and female students taking the AP CSP exam has increased by 121% and 136%, respectively, in three years [2]. We have observed similar growth of participation in our own state (Alabama). For the 2007 AP CSA exam, Alabama only had 3 female students and 3 students from underrepresented racial and ethnic groups enrolled in the course. By May 2019, Alabama's participation had surged to 778 female students for AP CSP (40% of overall exams) and 488 underrepresented students (25% of overall exams). Although 139 Black female students from Alabama completed the AP CSP exam that year (consistently within the top three states in the nation, per capita), the proportion of qualifying scores (i.e., a 3 or above) for this demographic has continued to be well below Alabama's proportion for all students, and also below the national proportion for Black female students. One may wonder why a curriculum designed with a focus on DEI has not led to more successful outcomes in this demographic. A potential answer to this question is the fact that **curriculum alone does not necessarily promote engagement**. The most exciting and diverse curriculum can be taught in a classroom where students who are underrepresented may question their own abilities (e.g., due to a lack of previous educational experiences), ultimately leading to lost opportunities for broadening interest in computing. In this Experience Report, we summarize the first-year of a project (called the LEGACY project, with photos and details at: http://legacy.ua.edu) designed to offer a deep preparatory experience for Black female students enrolled in AP CSP courses.

The primary goal of LEGACY is to determine whether participation in a peer-learning community increases Black female students' self-efficacy, attitudes, and identification with CS, which in turn should positively reflect in their AP CSP scores. The focus of the intervention was the development of a peer community of CS learners because peer relationships are known determinants of academic beliefs, self-confidence, and achievement in adolescents [3]. LEGACY focuses on Black female students due to them being the most underrepresented group in CS in Alabama and they are a demographic with unique barriers that require focused solutions. Black female students are at the intersection of two traditionally marginalized groups, but their experiences have typically been reduced to the experiences of their race or gender, which ignores the fact that race and gender are not experienced in isolation from each other [4]. Few studies have focused on how this intersection determines STEM experiences for Black women and girls (see [5] for a review), and even fewer focus on the experiences of Black women in computing [6, 7, 8, 9, 10, 11]. Black women must contend with barriers that reflect both racism and sexism, and this "double bind" problem [6, 12] must be addressed holistically, rather than assuming they are women who happen to be Black, or Blacks who happen to be women [13]. The role of Black women in computing has historically been minimized, in a way similar to their "invisibility" in social movements affecting women (e.g., the Women's Liberation Movement) or Blacks (e.g., the Black Lives Matter movement) [14]. Solomon et al. suggest that Black women in CS resort to identifying with either being female or being Black (thus negating an important part of their identity), but academic resiliency requires that they accept the fact that they are Black women and that their race and gender cannot be separated [9].

A lack of identification with CS that incorporates the intersection of race and gender can have devastating consequences for Black female students' career choices. Black female students have the same interest in CS as White female students, but are often dissuaded by an awareness of the barriers they may experience as Black women pursuing careers in STEM [15]. This awareness, compounded with the scarcity of Black women role models in CS, can lead to mismatches between Black female students' emerging professional identities and the prototypical image of a CS professional, which can reduce professional identification [16]. Because identification with a profession is fundamental to predicting who will pursue [17] and persist [18] in a technical career, we anticipate strong CS identification is essential to develop CS interest, persistence, and success in Black female students [9].

Our project departs from a deficit perspective in which Black female students' success in CS is hindered by societal and professional barriers, and instead focuses on the potential benefits of strongly identifying with being a Black female who is part of a community of emerging computer scientists. LEGACY students are provided with "preparatory privilege" [19] that includes physical resources needed for success, deep instruction in learning objectives for AP CSP, and a network of both horizontal (peer participants) and vertical (teachers) mentors who provide the social support and role modeling for student participants to "See it to be it!". The first-year participants in our project, many who are potential first-generation college students, lived on two different college campuses for 7 days over the Summer of 2019, learned about college preparation and career options, and prepared for the AP CSP course. Because all students and teachers were also Black females (three of the co-authors of this paper), this experience created a peer-learning community (PLC) aimed at reducing isolation and increasing feelings of belonging in CS. The results of our first cohort of students suggest that our project is having a positive impact in terms of increased qualifying rates, enhanced self-efficacy while enrolled in an AP CSP course at their school, and a robust identification with CS professions.

Our paper is organized as follows: in Section 2, we summarize the implementation activities of our project, from recruitment in Spring through enrollment in the AP CSP exam the following Spring. Section 3 offers an overview of our research and evaluation goals, and Section 4 presents the results of our project evaluation. We discuss our lessons learned in Section 5 and offer our concluding remarks and next steps in Section 6.

2 First-Year Project Implementation Activities

In this section, we summarize the specific implementation details of our project from our first-year experience.

2.1 Program Recruitment and Incentives

Over the past decade, Alabama has forged an enduring and productive community of practice that has prepared more than 275 AP CSP teachers. Each LEGACY recruitment cycle begins with a call for participation that is shared with these teachers to encourage Black female students formally committed to enrolling in AP CSP in the next school year to apply to our program. Approximately 40 young Black women are selected for the program annually across all areas of Alabama. Where possible, the program gives priority to selecting multiple applicants from the same school to promote peer-to-peer student classroom support during the school year. Students are recruited from rural, suburban and urban schools across the state of Alabama. We just completed our first year of implementation.

Many of the Alabama high schools offering AP CSP serve students from lower socio-economic backgrounds who typically work during summers to provide income to their families. To make up for lost income, our project provides student participants with a supportive stipend. In addition, to address the lack of preparatory privilege, loaner laptops and home broadband access are provided to student participants who express need. The project also covers the AP CSP exam fee for all participants (even those who have the ability to cover the cost, as an additional incentive to encourage their participation and preparation for the exam).

2.2 Instructional and Peer Learning Timeline

The project activities occur during an intense summer preparatory experience and academic-year events that facilitate peer camaraderie and content knowledge depth.

2.2.1. Summer Institute. Participants convene initially in June at the University of Alabama (UA), a predominantly white institution, for a 5-day immersion in hands-on CS activities in a residential Institute setting. The Institute is designed to promote a student PLC that takes a deep-dive into key concepts in the AP CSP curriculum. Instruction is provided by 3 highly experienced Black female AP CSP Teacher Leaders from Alabama high schools. The Teacher Leaders mentor students as they explore the AP CSP five Big Ideas and the core Computational Thinking Practices students are expected to develop throughout the curriculum, by engaging them in inquiry-based, collaborative, and culturally-responsive activities. The content is evenly distributed over the week to allow students to deeply reflect on their learning while being guided by the Teacher Leaders to look through the lens of their own cultural and community needs to understand the creative ways in which computing can solve problems and address these needs. The week culminates in the assignment of a mock Create Performance Task that participants work on independently in an interim period of approximately 5 weeks with support from the Teacher Leaders through virtual "office hours."

The Summer Institute ends with a reconvening in July at Tuskegee University (TU), a Historically Black institution for a 2-day residential experience during which time students present their Create projects to their peers and discuss the content and strategies they learned. The presentations and discussions surrounding the mock Create task are structured as scaffolded practice for the assignments that students will be required to complete as part of their AP CSP experience over the ensuing school year. Teacher Leaders provide final feedback to the students on their Create task and ensure that they continue to build AP CSP content knowledge.

The student PLC is strengthened during the Summer Institute through engagement in many social activities (e.g., team meals, fraternization in the dorms) and interactions with Black female role models in STEM who share their own career trajectories as a way to build CS and STEM career awareness. In the dormitories at both UA and TU, Black undergraduate female students majoring in CS serve as assistants, providing near-peer mentoring to the participating high school students.

2.2.2. Academic School Year Component. The students formally take the AP CSP course in their schools, but continue to receive support from our project. Teacher Leaders maintain a Moodle project site to support the students' PLC through frequent posts and questions about AP CSP content. The forum also serves as a "safe space" for students to ask questions about the course that are answered by their peers and mentors. GroupMe and Remind groups are also used through both the summer and academic year to maintain continuous communication among students, Teacher Leaders, and project personnel. In addition, several face-to-face Saturday study sessions are organized for the students throughout the year at different geographic regions of Alabama to provide assistance with the most recently taught topics in their AP CSP courses and allow them to practice taking AP CSP exams. Each student attends at least one Saturday session in the Fall and one in the Spring. These face-to-face sessions also allow the friendships that were initiated in the summer to serve as a source of encouragement throughout the year. The Teacher Leaders also offer four evening webinars in each of the Fall and Spring terms for students to discuss current AP CSP topics in their class and meet with their peers virtually. We also communicate with the AP CSP teachers at the school of each participant and ask them to encourage their students to take advantage of the project opportunities that are available on Saturdays and evenings.

3 Research and Evaluation Overview

Research, combined with continuous project evaluation, supports the need to determine what works, how it works, and for whom. By documenting the outcomes and impacts of this work, we seek to hone the implementation model over time.

3.1 Project Participants

Participants in this study were 38 Black female students (from over 120 applicants) intending to complete the AP CSP course in the subsequent school year, and who represent the first cohort of our project. Participants were recruited in the Spring of 2019 and were part of the study from May 2019 through May 2020.

3.2 LEGACY Research Questions

Participants' responses to surveys and open-ended questions, and AP CSP exam results, serve as evidence for research questions:

- *Q1*. To what extent does student project participation result in AP CSP exam scores that compare favorably to statewide and national groups?
- *Q2*. Do students who participate in the project gain in computational thinking self-efficacy?
- *Q3*. Does participating in a PLC of Black young women improve attitudes about the capacity of Blacks and women to succeed in CS?
- *Q4*. Does participating in a PLC increase Black female students' identification with CS professionals?

3.3 Data Collection and Instruments

Survey instruments were selected to specifically address the variables of interest (self-efficacy with computing, attitudes toward computing, and identification with CS). Data were collected at three points in time: (1) before the Summer Institute (June 2019), (2) after the Summer Institute (July 2019), and (3) at the end of the 2019-2020 academic year (May-June 2020).

- Computational thinking self-efficacy questionnaire (CTSE; adapted from [20]) to assess self-efficacy in 8 areas of computational thinking (scale: 1-5): (1) abstraction; (2) problem decomposition; (3) algorithmic thinking (including operators and expressions); (4) control flow; (5) collection, representation, and analysis of data; (6) global impact of computing; (7) incremental and iterative processes in programming; and (8) program testing and debugging.

- The Gender and Racial Attitudes Toward Computing inventory [21], which assesses the extent to which respondents' view gender and race as determinants of success in CS (scale: 1-5).
- An adaptation of the STEM Professional Identity Overlap (STEM-PIO [22]; we refer to this adaptation as CS-PIO). This one-item pictorial instrument asks students to select the degree to which their current image of themselves overlaps with the image they have of a CS professional. In its application to the more general image of a STEM professional, STEM-PIO scores are positively associated with STEM attitudes and self-efficacy, mastery goal orientation, and agentic behaviors toward professional goals (see [22] for instrument validation).
- Participants submitted AP CSP Explore and Create Performance Tasks on or before the due date of May 26, 2020. Students' AP CSP exam scores were released on July 15, 2020, at which time teachers and students reported their scores to us.
- National and statewide AP CSP data available publicly.

Survey data were analyzed using repeated-measures analyses of variance (ANOVAs) followed by post-hoc (Tukey's) analyses to assess the significance of relevant comparisons. Trends in student scores were analyzed with chi-square tests. Relationships between demographic variables and student performance were analyzed with standard Pearson's correlations. Measures were assessed for internal validity using Cronbach's alpha. Of the 38 student participants, 29 students provided data for all three assessment time points, and their data are used for all analyses in Sections 4.2-4.4.

4 Results from our First-Year Experience

Our results, across several aspects of the evaluation, suggest our approach had a positive impact on participants. In addition, the participants' qualifying rate of 87.5% is significantly higher than that of the statewide sample for 2020 (54.9%), χ^2 (1), p < .001. (Note: disaggregated results based on gender and race for 2020 were not available at the time of publication).

4.1 Student Outcomes: AP Examination

Our project participants reached high levels of assessed content knowledge and programming skills, as evidenced by their attainment of AP CSP examination scores that outperformed nearly all comparison groups.

4.1.1. Comparison with Statewide and National Samples. AP scores of student participants were compared with the AP National sample and Statewide sample for 2019. Of the 38 program participants, 32 received AP exam scores and 28 students qualified with a score of 3 or higher. This qualifying rate of 87.5% compares very favorably with disaggregated national and statewide results from 2019 (Figure 1). The participants' qualifying rate was *numerically higher than every comparison group* and significantly higher than:

- National groups: All students and all female students, χ^2 (1), p < .05; Black female and Black male students, χ^2 (1), p < .001
- Alabama groups: White male students (statewide), χ^2 (1), p < .01; all students, female students, Black female students, White female students, male students, and Black male students, χ^2 (1), p < .001.

4.1.2. Disaggregated Results by School Type and Demographics. We sought to determine predictors of higher AP CSP scores. We considered: (1) the number of PLC sessions attended during the academic year, (2) school-level percent of free and reduced-price lunch (%FRPL, as a proxy for socio-economic status), (3) school locale, and (4) number of program participant peers at each participants' school. Higher exam scores were significantly associated with attending more PLC sessions (p < .01) and *not* significantly associated with %FRPL, locale, or peers. Students who attended 4 or more PLC sessions (n = 26) had mean AP scores of 3.04, significantly greater (p < .05) than the mean of 2.08 for the 12 students who attended fewer sessions (note: students who did not take the exam were coded as score = 0). Higher locales codes (i.e., more rural) were positively associated with higher %FRPL (p < .01). Correlation matrices are presented in Figure 2.

4.2 Computational Thinking Self-Efficacy (CTSE)

Students' Computational Thinking Self-Efficacy (CTSE) increased throughout participation in the project, $F(2, 56) = 59.76$, p < .001. Post-hoc analyses revealed that total CTSE scores (based on 20 items) were higher after the Summer Institute (Post-SI) than they were prior to participation in the project (Pre-SI), p < .001, and continued to increase through the academic year (EndYear), p < .005 (Figure 3). Reliability levels (Cronbach's α) at each of the three time points (Pre-SI, Post-SI, End of Year) were good (α= .81, α=.73, α=.73, respectively). Each of the 8 subscales representing one of the areas of computational thinking were considered for analysis. However, only two subscales, Algorithmic Thinking and Control Flow, had sufficient reliability levels for meaningful analysis, ranging from α=.41 to α=.74 across the three time points. Scores for algorithmic thinking and control flow increased both through the Summer Institute (ps < .001), and the academic year (ps < .05 and .001, respectively). Overall, these results suggest that, although students were confident in their understanding of the relevance of computing and how to organize complex tasks even before participating in the project, the Summer Institute increased their computational thinking self-efficacy particularly for solving problems algorithmically and programming control flow.

4.3 Race and Gender: CS Attitudes (RGCSA)

Participants' attitudes concerning the capacity of people from all racial backgrounds and women to be capable and successful in CS increased throughout the year-long program, $F(2, 56) = 11.41$, p < .001, and the source of this effect appears to be largely due to the increases in positive attitudes during the academic year, p < .01 (Figure 3). Total score reliability levels at each of the three timepoints (Pre-SI, Post-SI, End of Year) were acceptable (α = .68, α = .69, α = .65, respectively). These gains were also evident based on the gender subscore (ps <.05, marginal reliabilities of α=.53 to α=.65). A limitation of this measure is that it does not specifically address the intersection of race and gender; however, these results suggest that students' identity as Black individuals and as young women who do CS was increasingly more positive after returning to traditional classroom instruction, even if (as Black young women) they were in the minority.

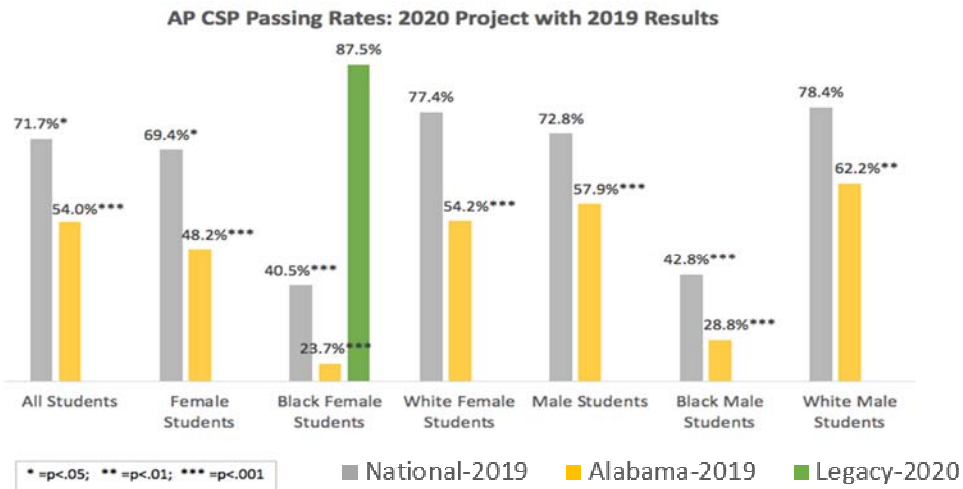

Figure 1. AP CSP Qualifying Rates for Project Participants Compared with 2019 National and Alabama Exams

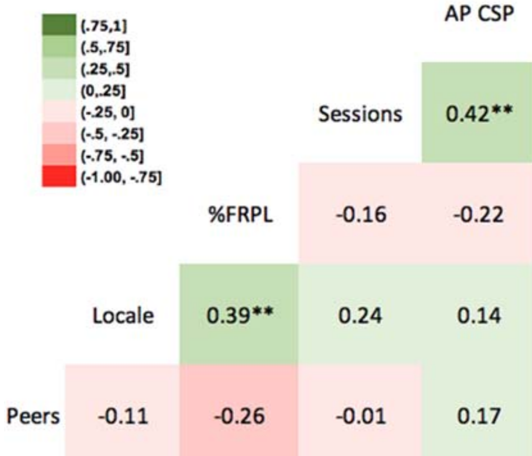

Figure 2. Individual and School-level Correlates of AP CSP Exam Scores

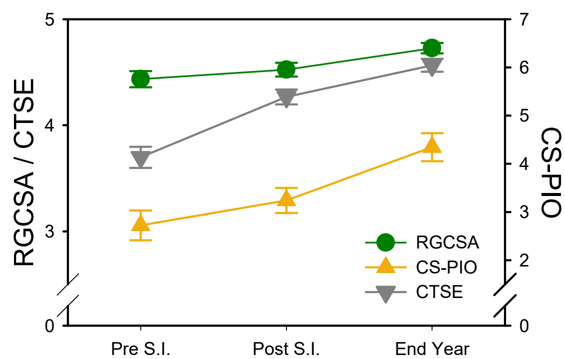

Figure 3. Computational Thinking Self-Efficacy (CTSE), Racial and Gender Attitudes toward CS (RGCSA), and CS Professional Identity Overlap (CS-PIO). Brackets represent standard error of the mean.

4.4 Identification with CS (CS-PIO)

Identification with science is known to determine selection of [16] and persistence in [17] science careers, and the same can be expected of computing careers. The instrument selected for this measure (the CS-PIO) asked participants to compare their current image of themselves with the ideal image they have of a CS professional, and determine the extent to which those images overlap. This measure has the advantage of using each individual's current identity as a basis for comparison to that individual's view of a CS professional. Students' CS-PIO scores increased through participation in the project, $F(2, 56) = 17.32$, $p < .001$ (Figure 3). The primary source of this effect was an increase in identification with CS through the academic year, $p < .001$. Note that there was a numeric increase in identification with CS during the Summer Institute, which suggests that this 7-day experience set the stage for the increased identification with CS observed during the academic year. Importantly, 59% of students stated that they intended to pursue a major or minor in CS, with 71% of those students stating that participating in the program was a determinant in this career choice. Students with higher CS-PIO scores (5 or higher) were more likely (58%) to state an intention to pursue CS as a major than students with lower CS-PIO scores (4 or lower; 39%).

4.5 Limitations and Threats to Validity

We obtained the May 2020 AP CSP scores for our participants, but we did not have the gender/race disaggregated National and Alabama scores for 2020. There is an obvious threat to validity in our analysis regarding the use of 2019 AP CSP data in comparison to our 2020 results. However, the available *aggregated* National and Alabama results for May 2020 are very similar to May 2019, such that we expect the project claims of success to remain valid. A second threat to validity is the potentially negative effect on the need for our participants to move to virtual instruction (due to COVID-19) about 2 months before the AP CSP performance tasks were due. We lost three of our participants who did not submit their performance tasks during the pandemic, and a fourth student who had a severe health challenge. A third threat to validity is the fact that, we describe here one cohort of students, and the extent to which these results are generalizable will be determined by subsequent assessment of future cohorts. Finally, our participants do not reflect a random sample, rather a select sample of students who all had an interest in exploring a CS course before entering the program. Thus, our results may be limited in scope to students who have an initial interest in CS.

5 Discussion and Lessons Learned

Establishing a PLC and providing students with the resources to prepare for the AP CSP exam had a large positive impact on their acquisition of CS concepts (as evidenced by the overall success of the cohort in the AP CSP examination), computing self-efficacy, attitudes toward CS, and identification with CS. The cohort and preparatory experience appears to have reduced potential differences in AP CSP exam achievement among students from schools in different locales (rural vs. urban) or economic strata (high or low %FRPL). Student feedback on the program was overwhelmingly positive, with many directly crediting their participation in the program for their successful completion of the AP CSP course. In the words of a student, "*I never thought I'd be able to code on my own. After LEGACY, my teacher was so impressed with the things I was able to do and the things I knew about computer science without his guidance. The sense of independence I gained from LEGACY is what I'm most proud of.*"

Although this paper reflects our experience with a single cohort, the most important lessons learned from the first year of implementation of our program is that continued support, establishment of a strong network of peers sharing a common experience, and use of the intersectional identity of Black females as a catalyst for learning, led to very positive outcomes for student interest and desire to persist in CS.

Due to the COVID-19 pandemic, the cohort of students introduced in this paper had to abruptly change from an in-person classroom modality to remote instruction. However, an impressive number of students successfully completed the course and examination requirements with scores that reflect a deep understanding of the core concepts of the AP CSP course, regardless of the school locale or %FRPL. It was also clear that participation in program activities positively correlated with student performance in the AP CSP exam (the average AP CSP exam score for students in our project who completed all requirements was 3.25, a result that was one of the more exciting aspects of our evaluation). Thus, encouraging participation and maintaining close contact with students over the summer and throughout the academic year was key to the successful outcomes observed.

At the core of the students' success with AP CSP and the majority's desire to include CS as part of future studies and careers is the PLC that they forged with support from three deeply nurturing Black CS Teacher Leaders. These teachers and the project's near peer mentors (i.e., undergraduate CS majors at UA and TU) had significant influence on the participants, showing them that they too can excel in CS. The PLC was facilitated by a Moodle course section, with communication tools such as GroupMe and Remind. The network of AP CSP teachers across our state allowed us to initiate the deep recruitment in many geographical locales. The trust and communication channels developed with the AP CSP teachers over the past decade also permitted us to integrate our project experience more into the academic year component of the program, rather than just a summer experience.

Additionally, our project is spearheaded by faculty and researchers with deep passion for broadening participation in CS who leveraged a robust in-state CS network that has been built over the last decade. This allowed the program to collaborate with teachers, advisors, inspiring CS professionals and other role models to provide a deeply enriching, fulfilling and potentially life-changing experience to the participants, many of whom come from socio-economically distressed backgrounds. With potential for replication at other sites, our project has the ability to produce a large cadre of Black female Computer Scientists in preparation for the computing workforce, thus gradually contributing to the diversification of this diversity-starved sector.

As further evidence of the success of our program, the female participants in our project have already achieved national recognition. We were happy to learn that three of the students in our project were selected as one of the 300 National Honorable Mentions in the National Center for Women in IT (NCWIT) Aspirations program. Furthermore, some of the project participants helped to lead an NCWIT AspireIT project that offered a 6-week CS experience for middle school students, allowing our participants to be a near-peer mentor to younger students in their community.

Self-reflection was built into the evaluation process. We examined what was working with each component of the project and made adjustments as needed (e.g., adding more locations across our state for the Saturday study sessions to reduce the travel time for students in rural areas).

6 Conclusion and Next Steps

Although AP CSP has greatly expanded CS awareness to many Black female students, both nationally and within our own state, we observed that Black females in Alabama were significantly underperforming in comparison to the national average exam score. In this Experience Report, we summarized our first-year effort to provide a year-long preparatory experience to Black females enrolled in an AP CSP course in Alabama. From the belief that *curriculum alone does not drive engagement and interest among those underrepresented in CS*, we mentored 38 students and provided them with summer and academic year experiences related to curating a PLC focused on raising self-efficacy, and expanding student content knowledge to enter the course with preparatory experience equal or exceeding that of their classmates (who may be majority non-Black). The first-year results suggest that our approach significantly raises self-efficacy and overall qualifying rates for Black females enrolled in AP CSP. Our next steps include adapting the program from the lessons learned and offering two more cohort experiences, while also tracking the college and career choices among past participants (e.g., three of our first-year participants are enrolled as CS majors at UA). We also are very interested in sharing our model with others who would like to prepare Black females for the AP CSP course.

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