TABLE OF CONTENTS

PROJECT DESIGN

Education Development Center (EDC), with partners at Abt Associates (Abt) and North Carolina State University (NCSU), proposes a five-year project to refine and study the impact of the *Improving Equity in AP CS Principles* program, a two-year computer science (CS) equity program centered on the implementation of the *Beauty and Joy of Computing* (BJC) curriculum. BJC is a College Board-endorsed Advanced Placement (AP) Computer Science Principles (CSP) course designed to provide students with a rigorous and engaging introduction to CS and to support the participation of students from groups underrepresented in computer science. Originally designed at the University of California Berkeley (UCB) as an introductory course for non-CS majors, BJC has been adapted by EDC and UCB for use in a full-year high school AP course. The BJC course uses the blocks-based visual programming language Snap*!* to increase accessibility and engagement for students; employs a project-centered approach, with projects in a variety of contexts (e.g., games, art/design, mathematics); supports culturally responsive instruction; and incorporates critical social implications of computing in the content of the course. (See Appendix I-A for more about BJC and its creative approach to successfully engaging diverse students in AP CS). BJC is free to schools and available online; its ongoing development and use is supported by EDC, UCB, NCSU, and the global software company SAP.

The *Improving Equity in AP CSP* program will provide participating schools with robust school and teacher supports to strengthen implementation of BJC and help ensure that high-need students have access to equitable CS instruction. We define high-need students to include girls, Black and Latinx students, and students from low-income families, each of whom are under-represented in computing. The proposed work responds to *Absolute Priorities 1 & 2* and *Competitive Preference Priority 1* to expand CS opportunities for underserved students.

PROJECT GOALS, OBJECTIVES, AND OUTCOMES. The *Improving Equity in AP CS Principles* program will build the capacity of participating high schools to support an AP CSP program centered on use of BJC and to achieve these goals: (1) increased AP CSP **enrollment** for girls, Black and Latinx students, and students from low-income families; (2) increased AP CSP **exam taking** for girls, Black and Latinx students, and students from low-income families; (3) increased AP CSP **exam passing** for girls, Black and Latinx students, and students from low-income families, as represented in our logic model on page 24. Our design builds on NSF-funded projects that have supported the development of BJC and its early implementation in New York City (NYC) in a diverse set of over 100 high schools. In this project, we propose to refine and test the program of supports that we have found critical to effective implementation, and to investigate the impact of BJC in supporting equitable access to and progression within CS as a field of study. In total, 15–20 districts, 80 schools (40 treatment schools with 80–100 teachers serving approximately 2,000 students and 40 comparison schools) will participate in the project.

The three central components of the *Improving Equity in AP CS Principles* program will be: (1) a **school CS equity program** designed to broaden participation in CS coursework through specific strategies and resources for recruiting, enrolling, and retaining high-need students; (2) a **teacher learning program** that builds capacity for equitable and rigorous CS instruction and prepares teachers to support AP CSP success; and (3) **the use of BJC** with support for fidelity to the AP CSP framework and BJC design principles.

School CS equity program. This program will support the school-level coordination needed to tackle structural and social barriers to broadening participation. Participating schools will:

- Create a **school CS equity team** to bring together the school principal, one or more guidance counselors, CS teachers, and other relevant personnel to plan and coordinate CS supports;

- Participate in **an orientation webinar** that introduces the program and shares resources on the importance of CS education for college and career readiness for high-need students;
- Conduct a **self-assessment**, using a structured tool provided by the program, to determine existing barriers to enrollment and evaluate current recruitment strategies;
- Create a **CS implementation plan** for the school that sets student recruitment targets and identifies promising strategies, builds teacher capacity and leadership, and uses data on student enrollment, exam taking and exam passing, to review progress toward AP CSP goals;
- Participate in **one on-site consultation and two online consultations per year** with project staff, to support the review of student data and the refinement of the implementation plan;
- Participate in **an AP CSP exam webinar** that reviews student registration, preparation supports, and strategies to ensure student readiness for the exam; and
- Employ strategies in the program's **Recruitment Toolkit** to support the engagement of high-need students in CS. We will partner with SAP to extend our collection of available materials to support recruitment, creating additional video resources that counter current perceptions of who participates in CS (see Appendix G for letter of support from SAP).

Teacher learning program. This comprehensive program will span two years and prepare teachers to teach AP CSP using BJC. The program will help teachers understand the goals of the course, and the requirements of the AP CSP framework and exam, and prepare them to teach the curriculum. It will incorporate professional development (PD) provided by partner NCSU that is specifically designed to support teachers with little or no CS experience. It will provide teachers with time to experience the curriculum as learners themselves, to learn critical CS content, and to investigate instructional approaches that foster student engagement and creativity, especially for

student groups under-represented in computing. Teachers will receive a total of 70 hours of support through their participation across two years, and will:

- Participate in an **orientation webinar** to introduce AP CSP, BJC, and the program.
- Attend a **one-week online summer institute,** in the first year of participation, that provides an introduction to BJC, *Snap!*, and the AP CSP framework and exam. The institute is designed to support strong implementation of the initial BJC units and offers opportunities for planning, help anticipate student challenges, and provide access to experienced BJC teachers. Sessions highlight features of BJC designed to appeal to students with no prior CS experience, and focus on instructional strategies that support engagement of all students, such as customizing programming projects to foster creativity and connect with students' interests.
- Attend five one-hour **webinars during each school year** that will provide opportunities to strengthen content knowledge and instructional practice, and to better understand the AP CSP exam. Webinars will provide just-in-time support for upcoming units and information about the AP CSP exam, and delve further into ideas introduced in the summer institute.
- Participate in **an online small learning group** that meets 6–8 times each school year to discuss successes and challenges and to share and adapt classroom resources.
- Connect in **an online teacher forum** with BJC teachers, developers, PD providers, and Snap*!* programmers across the country. Teachers share resources, receive support for challenges in teaching the programming labs, and learn from experienced BJC teachers.
- Explore the opportunity to **partner with software engineers** who volunteer in AP CSP classrooms across the country through Microsoft's *Technology Education and Literacy in Schools* (TEALS) program (see Appendix G for details on this partnership). This will be an optional component for interested teachers.

- Participate in **a seminar** after the first year of teaching BJC to reflect on students' successes and challenges in the course and identify strategies for increasing success the next year;
- For teachers using the Spanish-language version of BJC to support English Language learners, UCB will offer an optional **Spanish-language PD** and **online teacher forum**.

The teacher learning program will offer an additional leadership opportunity for experienced BJC teachers through an application process. In the summer after Year 1 of implementation, invited teacher leaders will become part of the **Leadership Academy** and trained to lead BJC PD sessions, building capacity for scaling and sustaining CS courses. This will provide an additional mechanism to increase capacity at the school, district, and regional level to strengthen implementation and sustain program improvements.

Use of BJC. Participating teachers will commit to using BJC in their AP CSP courses. Students using BJC complete five units that align to the major topics of the AP CSP curriculum, each designed to attract students to the joy of programming, the beauty of the intellectual ideas behind CS, and the societal impacts of technology. BJC is carefully sequenced to offer the appropriate levels of scaffolding and challenge as students' understanding of CS concepts and programming develop. Each unit is supported by a *Teacher Guide* with pacing suggestions, assessments, solutions, and correlations to the AP CSP standards and a curated set of teacher-created resources such as videos, lesson plans, and assessments.

BJC curriculum resources have been field-tested extensively in NYC schools and in many other classrooms across the country. Classroom testing of BJC has provided a better understanding of the challenges that teachers and students encounter and the supports that aid implementation, and BJC has been revised to incorporate lessons learned from that testing. Several targeted refinements to BJC that will enhance students' and teachers' experience of the

curriculum will be made possible in this project through our partnerships with UCB and SAP, including a Spanish translation of BJC and updates to Snap*!* that will provide additional debugging features and online pair-programming capabilities. Through our partnership with the College Board as part of the AP CSP providers community, we receive up-to-date information related to ongoing changes and resources for the AP CSP course, and data on student performance specific to BJC, which can be used to identify areas for curriculum improvement and inform updates to the BJC units. In this project, participating teachers will be supported to:

- Teach five core units of BJC, including all programming labs and discussions on the social implications of computing, which are critical to meeting the AP CSP standards;
- Use equitable instructional practices consistent with the pedagogical and content principles (e.g., learning by doing, helping students recognize and enjoy their own logic and creativity) behind the design of the curriculum (Goldenberg et al., 2020);
- Follow the BJC pacing guide, which suggests the order and timing of units to ensure that students complete critical AP CSP content and are well-prepared for the exam; and
- Use BJC resources to prepare students for the AP CSP performance task, an essential part of the exam conducted in-class, and to support student preparation and success on the multiple-choice portion of the exam (through, for example, self-checks and vocabulary review).

The details of the project design assume that by the 2021–2022 school year students will return to school full-time in person and other school activities such as school CS team meetings and PD will be conducted in person. However, if that is not the case, we are fully prepared to modify the activities to be fully remote. We already have experience offering the BJC PD in a virtual format without loss to quality and participant satisfaction, and in our work in NYC, we are adapting teacher and school supports for use in both virtual and hybrid formats.

The chart below summarizes the relationship among the project goals, objectives, and outcomes.

Table 1. Goals, objectives, and outcomes

Goal #1: Increase AP CSP enrollment for girls, low-income, Black, & Latinx students.	
Objectives	40 CS equity teams will: 1) participate in an orientation webinar and six consultations across two implementation years; 2) conduct a self-assessment; 3) create a CS implementation plan; and 4) employ strategies from the *Recruitment Toolkit* to meet enrollment targets for high-need students.
Outcomes	Greater # and % of students enrolling in AP CSP across participating schools, and for the following groups of interest: girls, low-income, Black, and Latinx students.
Goal #2: Increase AP CSP exam taking for girls, low-income, Black, & Latinx students.	
Objectives	40 CS equity teams will: 1) participate in an AP CSP exam webinar; and 2) leverage equitable strategies to register high-need students for the AP CSP exam.
Outcomes	Greater # and % of students taking the AP CSP exam across participating schools, and for the following groups of interest: girls, low-income, Black, and Latinx students.
Goal #3: Increase AP CSP exam passing for girls, low-income, Black, & Latinx students.	
Objectives	80–100 teachers at 40 high schools will: 1) attend an orientation webinar, a one-week summer institute, five school-year webinars, and a year-end seminar, 2) participate in an online small learning group and an online teacher forum, and 3) will be supported to teach an AP CSP course using the BJC curriculum with fidelity and with the BJC resources provided.
Outcomes	Greater # and % of students passing the AP CSP exam across participating schools, and for the following groups of interest: girls, low-income, Black, and Latinx students.

Recruitment. We will work with 40 high schools (10 in Cohort 1, and 30 in Cohort 2) with each school participating for two school years. We will also recruit 40 high schools to participate as comparison schools. Schools will be drawn from an estimated 15–20 districts. The choice of AP CSP curriculum is sometimes made at the district level, but it has been our experience that the choice to implement AP CSP and choice of curriculum are more often decisions left to the school level, and in many cases, to the CS teachers themselves. Our recruitment efforts will ensure commitment to participation by both schools and teachers and will secure support for their involvement in the program and sharing of student AP CSP data by the districts. We will target a diverse set of treatment districts, including districts with (1) high schools that do not already offer AP CSP or want to increase their AP CSP participation and success; (2) high schools that qualify for Title I funding, and (3) high schools with substantial populations of high-need students. Within each treatment school, we will recruit the participation of 1–3 CS teachers.

Teachers will be compensated with a stipend for their participation. We will use EDC's network of relationships with school districts and state departments of education to assist with recruitment in Year 1 to ensure the needed commitments from districts, schools and teachers (see letters of support in Appendix C for examples of demonstrated support for recruitment within states).

Formative data collection. As shown in Table 2 below, data will be collected from BJC teachers and other CS equity team members to support continuous improvement, track program implementation fidelity, and measure school and teacher mediators.

Table 2. Formative data sources

Data Sources	Participants	Content
Pre-program survey	School CS equity team members	Administrator support and engagement, CS school climate, and school capacity to recruit diverse students to CS; use of school supports and request for feedback (mid-year and end-of-year only)
Mid-year survey		
End-of-year survey		
School self-assessments		Data on schools' plans for implementation and sustainability
School CS implementation plans		
Consultation notes		
Focus groups	AP CSP teachers	Successes and challenges of the program and AP CSP course
Pre-PD survey		CS self-efficacy, CS instruction preparedness and confidence, and comfort with CS content and pedagogy; implementation of the BJC curriculum, preparedness for supporting students with the AP CSP exam, and request for feedback (mid-course and post-course only)
Post-PD surveys		
Mid-course surveys		
Post-course surveys		
Exit tickets (webinars, PD days, small group sessions)	School CS equity team members; AP CSP teachers	Program participation and effectiveness; request for feedback

NEEDS OF THE TARGET POPULATION. Attention to broadening participation in CS has grown as projections for future jobs in the CS and science, technology, engineering and mathematics (STEM) fields have rapidly increased (Bureau of Labor Statistics, 2018). In 2011, Blacks and Hispanics made up just 13% of the STEM workforce in the U.S. even though they were 26% of the workforce at large, and there were twice as many men employed in a STEM occupation as women (Landivar, 2013). While employment in computer-related occupations has grown

dramatically (338% since 1990s), women continue to be underrepresented in computer-related occupations and the share of women in computer occupations has even gone down seven percentage points in the same time period (Funk & Parker, 2018). Because STEM jobs have relatively higher earnings, the lower representation of women, Blacks, and Hispanics has significant implications on income. In addition, the increasing role of algorithms and machine learning in our society underscores the need to diversify the STEM workforce. The harmful effects of systemic bias in computer algorithms and applications have been documented in facial recognition systems, financial and healthcare systems, as well as criminal justice and policing (Angwin et al., 2016; Benjamin, 2019; Buolamwini 2016: O'Neill, 2016).

Structural and social barriers to access and success in CS learning. The higher level of educational attainment required for STEM positions is a barrier to entry for women, Blacks, and Hispanics. Of CS degrees awarded in 2016, 76% were to White or Asian students, and 79% were to male students (Data USA, n.d.). Rigorous high school CS courses would allow students to explore interests in CS and build needed skills for success in later college coursework. Past research has also shown that taking and passing an AP exam can improve college outcomes (Mattern, Shaw, & Xiong, 2009). However, opportunities for students to learn CS in high school are limited for girls, Black and Latinx students, and students from low-income families. Fewer girls and underrepresented minority students participate in CS classes, and students from low-income families are less likely to attend schools with access to CS classes (Code.org Advocacy Coalition, et al., 2019). Google & Gallup (2016) found that Black students are less likely than White students to have classes dedicated to CS at the school they attend (47% vs. 58%, respectively). The lack of exposure and access to CS creates disparities in students' opportunities to learn, and persistent social barriers foster narrow views of who does CS and can dampen

interest and advancement (Google & Gallup, 2016). In a survey of over 1600 students in grades 7–12, Wang and Moghadam (2017) found that students from lower-income families, Black, Hispanic, and female students reported less access to CS learning at school. They also found that structural barriers in access and exposure to CS were prevalent for Black and Hispanic students, while social barriers such as lower awareness of CS opportunities outside of classes, less encouragement from teachers and parents, and less exposure to role models in the media seemed stronger for girls. High school teachers identified students' perceptions of who does CS and feelings of not belonging when in CS classes as barriers to diversity in relation to gender, minority students, and socioeconomic status in CS classrooms (Gretter et al., 2019).

KNOWLEDGE FROM RESEARCH AND EFFECTIVE PRACTICE. The project design builds on research about effective approaches that broaden participation in CS learning, support teacher learning, and provide school-level support for CS success; and builds on implementation work in NYC.

AP CSP broadens CS participation in high school. The College Board, with the NSF, introduced the AP CSP course and exam specifically to broaden participation in CS by making the field more attractive to women and racial and ethnic minorities. AP CSP offers a "multidisciplinary approach to teaching the underlying principles of computation," introducing "the creative aspects of programming, abstractions, algorithms, large data sets, the Internet, cybersecurity concerns, and computing impacts" (College Board, 2018b) to interest a more diverse population of students. The approach has been successful. With the launch of AP CSP in 2017—the biggest launch of a new AP course in College Board history—there was a 79% jump in participation in AP CS, with over 100,000 students taking either the pre-existing AP CS A or the new AP CSP exam. Moreover, in just the first year of AP CSP, the number of girls who took an AP CS course more than doubled, as did the numbers of Latinx/Hispanic and Black/African

American students. Access to and participation in AP CSP is a critical lever for diversifying CS enrollment in high school, and for increasing students' likelihood of considering CS-related opportunities in colleges and careers (College Board, 2018a, 2018c).

CS teacher professional development. Prepared and knowledgeable CS teachers are essential to realizing the goals of broader access and participation in CS. However, Gordon and Heck (2019) found that a majority of CS classes in schools with the most students eligible for FRPL are taught by teachers with little to no experience teaching the subject. To address the lack of qualified K–12 CS teaching candidates, teacher education and supports need to be improved, including offering more engaging and rigorous courses and developing CS teaching certifications (NCWIT, 2020), CS teaching incentives (Barr & Stephenson, 2011), and improvements in teacher PD and preservice teacher preparation (Barr & Stephenson, 2011; NCWIT, 2020). 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 (K–12 Computer Science Framework Steering Committee, 2016; Century et al., 2013; Price, et al., 2016).

Systemic school support for CS education. While much attention has focused on building teacher capacity and the design of teacher learning experiences, less attention has been paid to the larger school and district context for CS education. Many administrators believe that there is a lack of demand for CS, but one survey found the opposite, that over 90% of parents and students reported high interest in learning CS (Wang et al., 2016). In one study, competing priorities in high schools was identified as a challenge to CS implementation, an issue that requires the involvement of principals and the broader school community (Villavicencio et al.,

2018). In addition, principals and superintendents reported barriers that include the need to dedicate time to other courses, testing requirements, and the lack of qualified teachers (Wang et al., 2016). A 2017 Education Trust report suggests that to foster success in AP, school leaders need to eliminate barriers and create supports that will help students succeed. These supports include optimizing the master schedule, preparing students early, setting a clear expectation that all students are suited for AP, and providing access to support systems and tutorials increase students' chances of success.

Additional recommendations from research for building diversity in CS learning access include changing perceptions about who participates in CS; administrators becoming more supportive of CS through more flexible curriculum, class schedules, standardized testing, and graduation requirements; and promoting a variety of CS education pathways (Wang et al., 2016). Other ideas include removing prerequisites for CS entry level courses, ensuring that administrators and counselors are well versed in CS course offerings and promote them to students, displaying student CS work in various venues, describing CS courses in inclusive ways, and using community partnerships to make connections to the workplace from CS visible (Hug, Guenther, & Wenk, 2013). Gretter et al. (2019) suggest that combating stereotypes about who is successful in CS, making CS learning and diversity a school-wide priority, increasing administrators' and counselors' understanding of CS career paths and the need to promote them with diverse students, and making connections for students between CS classes and industry.

Results from prior BJC implementation in NYC. The design of the *Improving Equity in AP CSP* project builds on this research and our own work in NYC implementing BJC with over 150 teachers and more than 5,000 students. Preliminary 2016–17 findings from a BJC field-test indicate that teachers using the curriculum and participating in summer PD made statistically

significant pre/post gains in content knowledge, self-efficacy, self-rated preparation/ effectiveness, self-rated programming ability and knowledge/fluency. Students in the BJC course in 2016–17 (n=311) showed significant pre/post gains on a content assessment, with small to medium effect sizes. Findings for student engagement and attitudes included significant gains for confidence and identity sub-scales, but no significant gains for interest and belongingness. Girls and Black and Latinx students achieved similar gains on the content assessment and on engagement and attitude measures as male and non-Black and Latinx students. Student enrollment data in NYC indicate gains in the percentages of female, Black, and Hispanic students participating in BJC classes, and taking and passing the AP CSP exam. On the 2017 AP CSP exam, 2,854 NYC students took the exam, and 2,076 passed—a 73% pass rate compared with 74% nationwide with higher percentages of female, Black, and Hispanic students in NYC taking the AP CSP exam than nationwide (Mark & Klein, 2019). The proposed work builds on our existing experiences with BJC and provides an opportunity to refine the teacher learning and school support components into a comprehensive program, implement and test it in diverse school sites, and generate evidence of its impact in a rigorous evaluation.

PROJECT CONTRIBUTION. The results of this work will advance knowledge in the field about supports needed for successful implementation of rigorous CS curricula and instruction in high-need schools and contribute to the understanding of how AP CSP supports can be designed to support greater participation from girls, Black and Latinx students, and students from low-income families. Our findings will document the impact of BJC on students' AP CSP enrollment, exam taking, and exam passing, contributing to the research base on the curriculum, PD, teaching practices, and schools supports that promote equity and success for all students. The impact of the proposed work extends beyond the participating high schools to other high-need

schools that offer AP CSP. The findings can inform developers of AP CSP curricula, the College Board AP CSP development committee, and policymakers as well. Administrators, teachers, and policymakers can use these findings to promote implementation of teacher PD and instructional materials that show promise for improving outcomes for students underrepresented in CS.

Management Plan

Roles of key personnel and partners. EDC has assembled a leadership team that offers directly relevant experience in K–12 CS research, intervention fidelity, and site recruitment with a successful track record of leading large, complex projects focused on CS education, teacher professional learning, curriculum implementation, and the study of school- and district-level supports. The project will be led by PI/PD **June Mark** who will ensure that project goals are met, monitoring activities and timelines as detailed in Table 3 (see p. 16). Ms. Mark will manage EDC staff, project partners, budgets, reports, and dissemination, and oversee the refinement of BJC materials and teacher and school supports. She will be the primary point of contact with the EIR program, and serve as liaison to the EIR evaluation technical assistance provider. Ms. Mark has over 30 years of experience leading federally funded grants in CS and mathematics education and is currently PI for EDC's research-practitioner partnership with NYC schools to implement BJC. **Deborah Spencer** will lead efforts to recruit schools and refine the school CS equity program, and will monitor and ensure implementation of all support components in treatment schools. Both Ms. Mark and Ms. Spencer are experienced in managing large-scale research on curriculum implementation and impact, and have successfully recruited and retained robust samples for similar studies. **Linda Caswell** will lead the evaluation team at Abt; she has over 15 years of experience designing, managing and providing technical assistance on evaluations of K–12 interventions and curricula, including studies focused on STEM and computer science. She

currently serves as the lead evaluator for two EIR grants and since 2010, has provided evaluation technical assistance to grantees of various federal programs. Dr. Caswell is WWC-certified and conducts systematic evidence reviews for several federal agencies. **Mary Fries** was a developer of the BJC curriculum at EDC and has substantial experience working with BJC teachers; she will lead the refinement of BJC and the teacher learning program. **Tiffany Barnes**, professor of CS, will lead a team at NCSU that will provide summer institutes for participating schools in 2021, 2022, and 2023, school-year webinars and small group learning opportunities. Barnes has, through prior NSF funding, developed both in-person and online teacher institutes for over 600 BJC teachers throughout the U.S. **Kelsey Klein** will serve as liaison to the evaluation team at Abt and lead the formative data collection and analysis team. **Julie Zeringue** will collaborate closely with Ms. Spencer on recruitment and support formative data collection and analysis. **Dan Garcia**, professor of CS and co-developer of BJC, will coordinate the contributions of UCB, which will provide support for the teacher learning program; support improvements to Snap*!* informed by the research; and support for the Spanish-language teacher PD and online forum. **Bernat Romagosa** and other staff at SAP will support improvements to the Snap*!* interface, organize online collaborations for BJC teachers around the world, and share videos of SAP ambassadors talking about their careers. **Microsoft TEALS Managers** will provide support and training for volunteer software engineers in BJC classrooms. **Monica Roman** at the College Board will facilitate resource sharing with the AP CSP team and support dissemination efforts (see Appendix B for CVs and Appendix G for partner commitments).

RESPONSIBILITIES, TIMELINE, AND MILESTONES. To ensure clarity of roles and to achieve the objectives of the proposed project on time and within budget, project stakeholders have agreed to the following assignment of responsibilities, aligned to project tasks, timeline, and milestones.

Table 3. Project activities and milestones

Initial project planning and development (Year 1)
• Confirm personnel, meet with evaluator by February 2021 [EDC, Abt] • Establish communication mechanisms among partners by February 2021 [EDC, Abt, NCSU] • Develop intervention development plan by February 2021 [EDC] • Develop study design plan, submit to DOE by April 2021 [Abt]
Refinement of *Improving Equity in AP CSP* program (Year 1)
• Refine CS Equity component by April 2021 [EDC] • Refine teacher learning component by June 2021 [EDC, NCSU]
Recruitment of 40 treatment schools and 40 comparison schools (Years 1–2)
• Refine recruitment strategy by March 2021 [EDC] • Recruit 80 treatment & comparison schools by May 2021 (C1) and by May 2022 (C2) [EDC]
Research agreements established with districts (Years 1–2)
• Identify district research requirements by March 2021 (C1) or 2022 (C2) [Abt] • Confirm agreements with districts by June 2021 (C1) or 2022 (C2) [Abt]
Program implementation in treatment schools (Years 1–4)
• Project team members collaborate to refine program components (weekly) [EDC, NCSU, UCB, SAP] • Maintain regular communication with 15–20 districts (monthly) [EDC] • Develop CS equity team in 40 schools by May 2021 (C1) or 2022 (C2) [EDC] • Provide team, teacher orientation webinars by June 2021 (C1) or 2022 (C2) [EDC] • Schools conduct self-assessment by June 2021 (C1) or 2022 (C2) [EDC] • Schools recruit high-need students by July 2021 (C1), July 2022 (C1, C2), and July 2023 (C2) [EDC] • Teachers attend one-week summer institute and (optional) Spanish-language PD in August 2021 (C1) or 2022 (C2) [NCSU, UCB] • Teachers use BJC curriculum in 2021–2022 (C1), 2022–2023 (C1, C2), and 2023–2024 (C2) [EDC] • Teachers participate in webinars, small learning group sessions, and the online teacher forums in 2021–2022 (C1), 2022–2023 (C1, C2), and 2023–2024 (C2) [EDC, NCSU, UCB] • Teachers explore TEALS and SAP opportunities in 2021–2022 (C1), 2022–2023 (C1, C2), and 2023–2024 (C2) [EDC, Microsoft, SAP] • Schools create CS implementation plans by November 2021 (C1) or 2022 (C2) [EDC] • Schools attend AP CSP exam webinar in December 2021 (C1) or 2022 (C2) [EDC] • Provide consultations in 2021–2022 (C1), 2022–2023 (C1, C2), and 2023–2024 (C2) [EDC] • Teachers attend year-end seminar in June 2022 (C1) or 2023 (C2) [EDC] • New teachers attend one-week summer institute in August 2022 (C1) or 2023 (C2) [NCSU] • Teachers (subset) attend Leadership Academy in summer 2022 (C1) or 2023 (C2) [CSU] • Schools refine CS implementation plan in 2022–2023 (C1) or 2023–2024 (C2) [EDC]
Continuous improvement of *Improving Equity in AP CSP* program (Years 1–4)
• Collect formative data and use fidelity data to inform improvements each year [EDC, Abt] • Implement refinements to program each year [EDC, NCSU, UCB, SAP]
Collect student data and fidelity data (Years 1–5)
• Agree on school, teacher, and student participation and performance goals each year [EDC, Abt] • Collect program fidelity data, determine program fidelity each year [EDC, Abt] • Collect student enrollment, AP exam data as available in 2022, 2023, and 2024 [Abt]
Data analysis and dissemination of findings (Years 4–5)
• Conduct and finalize data analyses by July 2025 [Abt] • Disseminate learnings to amplify impact by December 2025 [EDC, Abt, CSforAll, College Board]
Ongoing oversight of grant (Years 1–5)
• Monitor tasks, timeline, and deliverables (bi-weekly) [EDC] • Oversee grant and review for compliance (monthly, annually, and as needed) [EDC] • Establish subcontracts and complete annual reporting by December each year [EDC]

COSTS IN RELATION TO OBJECTIVES, DESIGN, AND SIGNIFICANCE OF THE PROJECT. The staff, partners and advisors on this project are appropriately budgeted and well-positioned for success in implementing what promises to be a high profile and impactful study. Participating institutions are well-resourced and have demonstrated high levels of commitment to this work. Costs are allocated in line with similar research studies of the same scope and complexity. Project activities and outcomes will be significantly enhanced by longstanding supporters and partners such as the College Board, UCB, SAP, and Microsoft, all of whom are eager to support, widely disseminate, and scale the results of the project (as detailed in letters of support in Appendix G and in the budget narrative). The proposed investment in BJC will make a major contribution in documenting the impact of this rigorous, highly acclaimed and unique course that stresses a joyful and creative approach to CS, designed to attract and engage girls, low-income, Black, and Latinx students and make progress in advancing equitable access to and progression within CS.

FEEDBACK AND CONTINUOUS IMPROVEMENT PROCEDURES. EDC management systems and procedures are designed to align project goals with performance measures; ensure high-quality standards for activities and deliverables are met; utilize data-driven continuous improvement methods for ongoing refinement; and anticipate risks and potential remediation strategies. Our continuous improvement approach to performance management stresses ongoing internal data collection (formative data, adherence to activity and deliverable timelines, budget and staff allocations) to support team reflection and inform ongoing dialogue with stakeholders about potential refinements. To support organization-wide use of these data-driven practices, EDC offers comprehensive project management training led by external experts which confers certification recognized by the Project Management Institute (PMI); Ms. Mark and Ms. Spencer both have this certification. Below we outline specific ways we will operationalize this approach.

Table 4. Plan to ensure feedback and continuous improvement

1. In the planning phase (January 2021–June 2021), project staff and partners will review project goals, methods, staffing, roles and responsibilities to ensure clarity and coordination.
2. Bi-weekly meetings of project staff will ensure careful monitoring of tasks, timelines, and deliverables; ensure coordination among project staff; and surface areas where additional attention or a shift in strategy are needed. Teams leading specific strands of the work (e.g., recruitment, teacher PD) will meet weekly. All project partners will meet monthly to ensure coordination.
3. In years 1–4, the project will collect formative data on the implementation of support components in each participating site, tracking participation and ensuring ongoing communication with teachers and school teams to ensure robust engagement.
4. Draft versions of project products, including the school CS equity team self-assessment and the *Recruitment Toolkit,* will be reviewed by teachers and administrators at non-participating schools that are already implementing BJC, to ensure usability from a practitioner perspective.
5. Regular check-ins with participating districts, schools, and teachers will ensure open and ongoing communication between the project and implementation sites.
6. Participants will be solicited for feedback on all provided project support—including, for example, PD events, consultations with school teams on implementation—to ensure continuous improvement.
7. Evaluation activities begin early and will provide ongoing feedback to the leadership team. Abt will provide regular input through monthly meetings, supplemented with as-needed communication.

It is also important to note that refinements arising from this project related to the BJC curriculum, teacher supports, and school implementation will be shared with the national community of BJC teachers and schools—extending the impact of our continuous improvement approach in this study beyond the project.

DISSEMINATION. EDC is well-positioned to widely promote project findings to support scaling the use of the BJC curriculum (freely available online), and the teacher and school-level supports refined and tested by this project. EDC will promote review of findings within the national STEM community through our leadership of two NSF technical assistance centers—the Community for Advancing Discovery Research in Education (CADRE) and the STEM Learning and Research Center (STELAR)—each of which support dissemination of innovative approaches among STEM education researchers across the country. We will also work with collaborators at the College Board and CSforAll to share information about the project and the impact of BJC on students' enrollment and performance within the AP CSP community.

Dissemination of our research results will accelerate adoption of BJC by districts nationally by demonstrating its efficacy in multiple districts, each offering varying institutional supports and track records recruiting and supporting high-need students in AP CSP. Our findings will provide a deeper understanding of the CS teacher and school supports that promote success for these students. Staff and project partners will share implementation progress and findings through conference papers and presentations that reach high school CS educators and developers, education policymakers, CS education advocates in the public and private sectors, and the college and careers-focused CS education and STEM research community (e.g., *American Educational Research Association*, *CSforAll Summit*, ACM *Special Interest Group for CS Education*, *RESPECT (Research in Equity and Sustained Participation in Engineering, Computing, and Technology),* and *Computer Science Teachers Association*). We will submit findings to publications that reach CS education audiences and beyond (e.g., *Educational Leadership*, *ACM Inroads)*; in year 5, a research article presenting evaluation findings will be submitted to a peer-reviewed journal such as *Computer Science Education, Journal of Research on Technology in Education,* or *Computers & Education*. To extend our reach, we will leverage EDC's ongoing outreach to PreK–16 education practitioners, policymakers, and researchers through its website, visited by a quarter of a million visitors each year, and social media accounts on LinkedIn, Twitter and Facebook. EDC Communications will support the project in sharing findings via social media, briefs, infographics, reports, podcasts, articles, videos, and blogs.

PROJECT EVALUATION

Abt Associates, a nationally recognized research organization with extensive experience conducting field tests of educational interventions, will conduct a comprehensive independent evaluation of the *Improving Equity in AP CSP* program that includes (1) an outcome evaluation

of changes in treatment schools during implementation, (2) an impact study using a quasi-experimental design (QED) that estimates the effectiveness of the program at increasing the likelihood of students in AP CSP taking and passing the AP CSP test, and (3) an implementation evaluation that assesses the fidelity of implementation of the program in each implementation year and looks at the relationship of implementation to outcomes. The QED for the impact study will be designed and conducted to generate evidence aligned with the WWC rating of Meets Standards with reservations. It will focus on outcomes for students who are traditionally underrepresented in AP CSP, including girls, Black and Latinx students, and low-income students. Below we present the components, design, and analysis (Table 5) followed by the research questions for the outcomes, impact, and implementation evaluations (Table 6).

Table 5. Evaluation components, design, and analysis

Component	Design	Analysis
Outcomes evaluation	Pre-post comparison of school and student outcomes in sample of BJC treatment schools	Outcomes for each BJC school at the end of 1 and 2 years of implementation
Impact evaluation	QED comparing outcomes for matched students and schools in BJC treatment schools and non-BJC comparison schools	Impacts of BJC AP CSP curriculum versus non-BJC curriculum at the end of 1 and 2 years of implementation
Implementation evaluation	Descriptive study of fidelity of implementation in BJC treatment schools	Fidelity of each key component of BJC for treatment schools at the end of 1 and 2 years of implementation

Table 6. Research questions and data sources

Research Question	Data Source(s)
Outcomes Evaluation	
1. Does participation in AP CSP increase in BJC schools overall and specifically for girls, Black, Latinx, and low-income students?	School-level AP CSP course enrollment data; school enrollment and demographic data
1a. How are changes in AP CSP participation related to school characteristics and school outcomes?	
Impact Evaluation	
2. What is the impact of BJC on the likelihood that all students (a) *take the AP CSP exam* and (b) *pass the AP CSP exam* one and two years after implementation?	School-level AP CSP course enrollment data; individual-level AP CSP exam data; individual and school demographic data
2a. What is the impact specifically for girls, Black, Latinx, and low-income students?	
3. Are the impacts of BJC moderated by student, teacher, and school characteristics?	School-level AP CSP course enrollment data; individual-level AP CSP exam data; individual, teacher, and school demographic data; teacher and school survey data
4. Are the impacts of BJC mediated by teacher and school factors?	
Implementation Evaluation	
5. To what extent are the key components of BJC intervention model implemented with fidelity each year?	Teacher surveys, PD attendance records, program documents
6. How does implementation fidelity vary across schools, districts, and key components of the program?	Teacher surveys, PD attendance records, program documents
7. What is the relationship between fidelity of implementation and effectiveness at the school level?	Implementation fidelity scores in each of 2 years, school-level course enrollment data, individual-level AP CSP exam data

OUTCOMES AND IMPACT EVALUATION. To answer research question 1, Abt will conduct descriptive pre-post analyses using outcomes measured at baseline and at the end of each implementation year to examine changes in the direction and magnitude of outcomes. To answer research questions 2–4, which are impact questions, Abt will use a matched QED design with a total of 80 schools, half using BJC and half using a non-BJC AP CSP curriculum. One cohort of 20 schools (10 treatment, 10 comparison) will be recruited to participate for the 2021–22 and 2022–23 school years. A second cohort of 60 schools (30 BJC, 30 non-BJC) will be recruited to

participate for the 2022–23 and 2023–24 school years. We will collect Year 1 and Year 2 pre- and post-test data for each cohort; data will be aggregated across cohorts for analysis.

To be eligible for the study, treatment schools can be of two types: 1) schools preparing to implement AP CSP for the first time that agree to use BJC; or 2) schools currently using non-BJC curricula who agree to instead use BJC for two years. Within each block, treatment and comparison schools will be matched on key baseline characteristics (test scores, demographic composition, and percentage receiving Free or Reduced Price Lunch [FRPL]). Students will be matched within schools using baseline achievement and demographic characteristics. We assume half the schools will have one section of AP CSP with an average of 20 students; half the schools will have more than one section, with an average of 40 students. Year 1 post-test impact data will be collected in spring 2022 for the first cohort and spring 2023 for the second; year 2 post-test impact data will be collected in spring 2023 for the first cohort and spring 2024 for the second.

The analysis model will nest students within schools. Student-level outcomes will be a function of pre-test data and student-level covariates; school-level variables will include a treatment indicator, school-level covariates, and an indicator for matching blocks, where within blocks, schools are matched on cohort as well as baseline measures of achievement, demographics, FRPL, and participation in AP CSP. Preliminary statistical power calculations indicate that a sample of 40 treatment schools and 40 comparison schools results in:

- MDEs of 9.8 and 9.2 percentage points for the entire sample of enrolled students for taking and passing the test, respectively (in a class of 20 students these MDEs correspond to increases of 2 students taking the test and 1.8 students passing the test); and
- MDEs of 11.1 and 10.4 percentage points within a 50 percent subgroup of enrolled students (e.g., females, minorities) for taking and passing the test, respectively. In a class of 20

students with 10 female students these correspond to increases of 1.1 female students taking the test and 1.0 female students passing the test (see Appendix I-B for additional details).

All proposed outcomes for the impact evaluation will meet WWC outcomes standards for reliability, validity and consistency of data collection procedures across conditions. Administered by the College Board each spring, AP exams are well-established exams used for college credit or placement. The outcome measures are individual-level indicators for taking and passing the AP CSP test among enrolled students. The AP test has demonstrated reliability across a wide variety of subjects (Bridgeman, Morgan, & Wang, 1996). Research has also shown that taking and passing an AP exam can improve college outcomes (Dougherty, Mellor, & Jian, 2006; Mattern, Marini, & Shaw, 2013; Mattern, Shaw, & Xiong, 2009; Morgan & Klaric, 2007; Murphy & Dodd, 2009). In addition, to further ensure valid and reliable data on relevant outcomes, we will use appropriate and rigorous methods to answer impact research questions, establish baseline equivalence in the analytic samples as required by WWC standards, and use analytic samples large enough to detect a moderate program effect size on student outcomes.

IMPLEMENTATION EVALUATION. The implementation study is based on the program logic model (see Table 7 on page 24), which articulates the program's key components, mediators, and outcomes. We assume that if the key components—BJC curriculum use, teacher learning program, and school CS equity program—are implemented with fidelity, teachers' practice will improve and schools' ability to recruit, engage and support student to participate in AP CSP will increase, both of which will lead to increases in the number and types of students enrolling in AP CSP and taking and passing the AP CSP exam. The long-term impact will be greater participation of female, Black and Latinx, and low-income students in CS during high school through a combination of improved implementation and increased sustainability of AP CSP

programs in high-need high schools, with EDC incorporating findings across districts to improve program supports. Abt will work closely with EDC to revise the logic model's components, mediators, or outcomes if needed, and to develop appropriate and systematic measures of fidelity of implementation for each of the key components of the program logic model.

Table 7. Improving Equity in AP CSP logic model

Inputs	Key Components	Mediators	Outcomes
Knowledge gained supporting BJC implementation in NYC schools, focused on girls, Black, & Latinx students Design expertise for BJC PD & workshop models, including online versions Expertise with large-scale studies focused on high-need students	**BJC curriculum use** **Teacher Learning Program** • Orientation webinar • Summer institute • School-year webinars • Online small learning group • Online teacher forum • Year-end seminar • Leadership Academy **School CS Equity Program** • School CS equity team • Orientation webinar • Self-assessment • Implementation plan • Consultations • AP CSP exam webinar • Recruitment Toolkit	**Teacher Mediators** • Fidelity to BJC • Increased comfort with CS content & pedagogy • Increased self-efficacy • Increased preparedness for & confidence with CS instruction **School Mediators** • Increased capacity to recruit diverse students • Improved CS planning & sustainability strategy • Increased administrator support & engagement • Enhanced school climate	**Student Outcomes** • Increased AP CSP enrollment • Increased likelihood of taking the AP CSP exam • Increased likelihood of passing the AP CSP exam • Overall and for girls, Black, Latinx, & low-income students

Abt and EDC will also establish thresholds for what constitutes adequate fidelity at the program level for each key component. Table 8 (on page 25) shows each of BJC's key components, examples of the types of indicators to be measured to assess fidelity of those components, the data sources that can be used for measurement, and the acceptable thresholds for fidelity of implementation. Abt will conduct analyses for each year of program implementation (Years 2–4), using data from, for example, teacher surveys, PD attendance records, and program documents. We will combine the indicators for each component, compare the scores to the pre-determined threshold to determine the level of implementation fidelity for each school and for all schools combined, and report results to EDC at the end of each year to provide feedback on

implementation progress and to identify program strengths and weaknesses. Abt will also conduct exploratory analyses to examine the relationship between the implementation fidelity measures and student outcomes. Although these last analyses are not causal, they will provide important information to help explain variation in outcomes across schools in the program.

Table 8. Logic model components and measurement of fidelity

Key Component	Indicators	Data Source	Threshold for fidelity
BJC curriculum use	• Grantee provides curriculum and additional resources	• Teacher survey (materials received)	• 100% of teachers report receiving all relevant resources
Teacher Learning Program	• Grantee holds orientation webinar • Grantee holds one-week summer institute • Grantee holds trainings during year (webinars, small learning groups) • Grantee provides online teacher forum • Grantee holds year-end seminar • Grantee holds Leadership Academy	• Teacher attendance records for orientation webinar • Teacher attendance records for summer institute • Teacher attendance records for school-year trainings • Teacher survey (frequency of use of online platform) • Teacher attendance records for year-end seminar • Teacher attendance records for Leadership Academy	• 100% of teachers attend orientation webinar • 85% of teachers attend all 5 days of summer institute • 80% of teachers attend at least half of trainings • 80% of teachers report accessing online platform at least twice a month • 90% of teachers attend year-end seminar • 85% of invited teachers attend Leadership Acad.
School CS Equity Program	• Grantee supports school CS equity team • Grantee holds orientation webinar • Grantee creates school self-assessment • Grantee supports schools in developing implementation plans • Grantee holds school consultations • Grantee holds AP CSP exam webinar • Grantee creates Recruitment Toolkit	• Review of school CS team composition & registration • Attendance records for orientation webinar • Review of draft and final school self-assessment • Review of school CS implementation plans • Consultation meeting agendas for each school • Attendance records for AP CSP exam webinar • Review of draft and final Recruitment Toolkit	• 100% of schools develop CS equity team • 100% of schools attend the orientation webinar • 85% of schools complete self-assessment • 85% of schools develop CS implementation plan • 85% of schools have consultation meetings with grantee both years • 100% of schools attend AP CSP exam webinar • 100% of schools receive Recruitment Toolkit

REFERENCES

Angwin, J., Larson, J., Mattu, S., & Kirchner, L. (2016, May 23). *Machine bias.* ProPublica. https://www.propublica.org/article/machine-bias-risk-assessments-in-criminal-sentencing

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K–12: What is involved and what is the role of the computer science education community? *ACM Inroads, 2*(1), 48–54.

Benjamin, R. (2019). *Race after technology: Abolitionist tools for the new Jim Code*. Polity Press.

Bridgeman, B., Morgan, R., & Wang, M. M. (1996). *Reliability of advanced placement examinations*. Educational Testing Service. https://www.ets.org/Media/Research/pdf/RR-96-03.pdf

Buolamwini, J. (2016, November). *How I'm fighting bias in algorithms* [Video]. TED Conferences. https://www.ted.com/talks/joy_buolamwini_how_i_m_fighting_bias_in_algorithms?language=en

Bureau of Labor Statistics. (2018). *Occupational outlook handbook: Computer and information technology occupations*. U.S. Department of Labor. Retrieved April 18, 2018, from https://www.bls.gov/ooh/computer-andinformation-technology/home.htm

Century, J., Lach, M., King, H., Rand, S., Heppner, C., Franke, B., & Westrick, J. (2013). *Building an operating system for computer science*. http://outlier.uchicago.edu/computerscience/OS4CS/

Code.org Advocacy Coalition, Computer Science Teachers Association, & Expanding Computing Education Pathways Alliance. (2019). *2019 State of computer science education report: Equity and diversity*. https://advocacy.code.org/2019_state_of_cs.pdf

College Board. (2018a). *AP computer science expansion*. Retrieved August 30, 2018, from https://reports.collegeboard.org/ap-program-results/ap-computer-science-expansion

College Board. (2018b). *Computer science principles: Course details*. Retrieved August 30, 2018, from https://advancesinap.collegeboard.org/stem/computer-science-principles/course-details

College Board. (2018c, February 21). *More students than ever are participating and succeeding in Advanced Placement*. Retrieved August 30, 2018, from https://www.collegeboard.org/releases/2018/more-studentsthan-ever-are-participating-and-succeeding-in-advanced-placement

Data USA. (n.d.). *Computer science: Diversity*. Retrieved August 30, 2018, from https://datausa.io/profile/cip/computer-science-6#demographics

Dougherty, C., Mellor, L., & Jian, S. (2006). *The relationship between Advanced Placement and college graduation.* National Center for Educational Accountability. https://files.eric.ed.gov/fulltext/ED519365.pdf

Education Development Center (EDC) & University of California Berkeley (UCB). (2020). *The Beauty and Joy of Computing: An AP CS Principles course.* https://bjc.edc.org.

Funk, C. & Parker, K. (2018). *1. Diversity in the STEM workforce varies widely across jobs*. Pew Research Center. https://www.pewsocialtrends.org/2018/01/09/diversity-in-the-stem-workforce-varies-widely-across-jobs/

Goldenberg, E. P., Mark, J., Harvey, B., Cuoco, A., & Fries, M. (2020). Design principles behind Beauty and Joy of Computing. In *Proceedings of the 51th ACM Technical Symposium on Computer Science Education: SIGCSE '20*. 7 pages. DOI: 10.1145/3328778.3366794

Google Inc. & Gallup Inc. (2016). *Trends in the state of computer science in U.S. K–12 schools*. http://goo.gl/j291E0

Gordon, E. M. & Heck, D. J. (2019). *2018 NSSME+: Status of high school computer science*. Horizon Research, Inc. http://www.horizon-research.com/horizonresearchwp/wp-content/uploads/2020/02/2018-NSSME-Status-of-High-School-Computer-Science.pdf

Gretter, S., Yadav, A., Sands, P., & Hambrusch, S. (2019). Equitable learning environments in K-12 computing: Teachers' views on barriers to diversity. *ACM Transactions on Computing Education, 19*(3), Article 24 (January 2019), 16 pages. https://doi.org/10.1145/3282939

Hug, S., Guenther, R., & Wenk, M. (2013). Cultivating a K12 computer science community: A case study. In *Proceeding of the 44th ACM technical symposium on Computer science education: SIGCSE '13*. 275–280. https://dl.acm.org/doi/pdf/10.1145/2445196.2445278

K–12 Computer Science Framework Steering Committee. (2016). *K–12 computer science framework*. http://www.k12cs.org/

Landivar, L. C. (2013). Disparities in STEM employment by sex, race, and Hispanic origin. *American Community Survey Reports*, ACS-24, U.S. Census Bureau. https://www.census.gov/library/publications/2013/acs/acs-24.html

Mark, J. & Klein, K. (2019). Beauty and Joy of Computing: 2016–17 Findings from an AP CS Principles course. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, Minneapolis, Minnesota USA, February-March 2019 (SIGCSE'19), 7

Improving Equity in AP Computer Science Principles: Scaling Beauty and Joy of Computing pages. DOI: 10.1145/3287324.3287375

Mattern, K. D., Marini, J. P., & Shaw, E. J. (2013). *Are AP students more likely to graduate from college on time?* The College Board. https://files.eric.ed.gov/fulltext/ED556464.pdf

Mattern, K. D., Shaw, E. J., & Xiong, X. (2009). *The relationship between AP exam performance and college outcomes.* The College Board. https://files.eric.ed.gov/fulltext/ED561021.pdf

Morgan, R., & Klaric, J. (2007). *AP students in college: An analysis of five-year academic careers.* The College Board. https://files.eric.ed.gov/fulltext/ED561034.pdf

Murphy, D., & Dodd, B. (2009). A *comparison of college performance of matched AP and non-AP student groups*. The College Board. https://files.eric.ed.gov/fulltext/ED561022.pdf

National Center for Women & Information Technology (NCWIT). (2020) *Moving beyond computer literacy: Why schools should teach computer science.* www.ncwit.org/schools

O'Neill, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy.* Crown Random House.

Price, T. W., Cateté, V., Albert, J., Barnes, T., & Garcia, D. D. (2016, March). Lessons learned from "BJC" CS Principles professional development. In *Proceedings of the 47th ACM Technical Symposium on Computer Science Education: SIGCSE '16*. 467–472. https://doi.org/10.1145/2839509.2844625

Villavicencio, A., Fancsali, C., Martin, W., Mark, J., & Cole, R. (2018). *Computer science in New York City: An early look at teacher training opportunities and the landscape of CS implementation in schools*. The Research Alliance for New York City Schools. https://research.steinhardt.nyu.edu/research_alliance/publications/cs4all_nyc

Wang, J., Hong, H., Ravitz, J., & Moghadam, S. H. (2016). Landscape of K-12 computer science education in the U.S.: Perceptions, access, and barriers. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education: SIGCSE '16*. 645–650. https://doi.org/10.1145/2839509.2844628

Wang, J. & Moghadam, S. H. (2017). Diversity barriers in K–12 computer science education: Structural and social. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education: SIGCSE '17.* 615–620. https://dl.acm.org/doi/pdf/10.1145/3017680.3017734