Preparing Marginalized Students for Learning Computer Science: A Case Study of Teaching Computational Thinking to Underrepresented Middle School Youth

Roslyn Arlin Mickelson [1,3]

Mohsen Dorodchi [2]

Ian Mikkelsen[3]

Sandra Wiktor [2]

Bojan Cukic [2]

Caitlin Petro[2]

Zelaya Al-Ayeisha [2]

Shakayla Alston [2]

Anthony Teddy [2]

Myat Win [2]

Barry Sherman [4]

Jeffrey Cook [4]

[1] Department of Sociology, UNC Charlotte, Direct all correspondence to rmicklsn@charlotte.edu .
This research is supported by a grant from the National Science Foundation (# 1742461).
[2] Department of Computer Science, UNC Charlotte

[3] Public Policy Program, UNC Charlotte

[4] Wilson STEM Academy, Charlotte-Mecklenburg Schools

Word Count: 8500

Abstract

This case study describes a university-middle school partnership aimed at preparing underserved youth for success in computer science (CS) and inspiring them to attend college. The objectives of the partnership were a) to inspire youth from demographic groups underrepresented to believe they could study technology, b) to prepare them for success in technology through teaching them computational thinking skills, and c) to them to attend college and major in CS. For three years, the partnership's workshops, taught by computer science undergraduates who shared a racial/ethnic, social class, or gender identity with their pupils, taught computational thinking skills to 65 middle school pupils who were low-income minoritized adolescents. The variety of data that were used to assess the outcomes of the workshops included post-workshop student responses to surveys developed by the middle school educators, observations by the researchers, interviews with the undergraduate tutors and with middle school CS teachers, and reflective essays written after each workshop by the undergraduate tutors. Analyses of data strongly suggest that for most middle school participants, the workshops were successful. Workshops appear to undercut gender and race stereotypes of who belongs in CS, taught middle school pupils computational thinking skills, and inspired the participants to go to college and study technology. In the absence of pre-tests of students' prior levels of preparation and inspiration, findings only suggest the intervention offers a strategy to both increase interests in and preparation for pursing CS among underserved youth, and in doing so, may broaden the demographics of those participating in technology.

Declarations

Ethics This study received approval from the Institutional Review Board (IRB) of the University of North Carolina at Charlotte. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed Consent to Participate Informed consent was obtained from all adult participants in this study and written informed consent was obtained from the parents of middle school student participants.

External Funding This research was supported by an award to Mohsen Dorodchi, Roslyn Arlin Mickelson, and Bojan Cukic by the National Science Foundation (# 174246).

Contributions of Authors Mickelson, Dorodchi, Cukic, Sherman, and Cook conceptualized the University/Middle School Partnership that is the focus of this study; Mickelson and Dorodchi designed the study. Formal analysis and investigation were conducted by Mickelson, Dorodchi, Mikkelsen, and Wiktor. The original draft of the manuscript was written by Mickelson, Dorodchi, Mikkelsen, and Wiktor. Reviewing and editing were conducted by Cukic, Petro, Al-Ayeisha, Alston, Teddy, Win, Sherman, and Cook.

Preparing Underserved Students for Learning Computer Science: A Model for Teaching Computational Thinking to Underrepresented Middle School Youth

Many college students have neither the interest in nor the academic preparation for pursuing the study of science, technology, engineering, and mathematics (STEM). This is especially true for computer science (Code.org, 2021). Consequently, the U.S. likely faces a mismatch between its projected technology labor force needs and the majors of future college graduates (Justice et al., 2022; U.S. Bureau of Labor Statistics, 2023). A further complication of this mismatch is that the majority of U.S. students who study technology are males from middle-class White or Asian Rim ethnic (Fry et al., 2021). Lower-income youth from all race/ethnic backgrounds, females, and students from Black, Latinx, some Asian American Pacific Islander (AAPI), and Native American ethnic groups are underrepresented in computer science (CS) relative to their proportion in the overall U.S. population (U.S. Census Bureau, 2018). This disproportionality leaves large segments of the U.S. population outside the professional computing community. Addressing the second issue could help alleviate the first problem by bringing currently marginalized segments of the population into technology fields.

This article presents a descriptive case study of a three-year middle school intervention designed to improve the likelihood that more low-income, female, and racial/ethnic minoritized middle school youth will be inspired and prepared to study technology in high school enroute to pursuing technology majors in college. It describes the development, implementation, and outcomes of a partnership between the University of North Carolina at Charlotte (UNC Charlotte) and Wilson STEM Academy, a public middle school serving the underrepresented populations previously described (Mickelson, 2015).

The partnership provided supplemental workshops to selected Wilson students enrolled in middle school CS courses three or four times a semester for three years, with a hiatus during the spring 2020 semester due to the Covid-19 pandemic. The workshops featured programming, coding, games, and instruction in computational thinking skills in order to supplement and reinforce the existing middle school CS curricula. Workshops were fine-tuned every year to fit the middle school participants' changing skill levels as they progressed from 6^{th} to 8^{th} grade. The tutors were undergraduate CS majors who also served as content developers and mentors. The gender and race/ethnic diversity among the tutors reflected the middle schoolers' own demographics, thereby offering a counterpoint to negative stereotypes that suggest females and certain people of color do not belong in the field (Mickelson, Mikkelsen, Dorodchi, Cukic, et al., 2024).

Middle School Inspiration and Preparation for Technology

Numerous studies indicate that the middle school years are a developmentally appropriate time to provide inspiration and begin academic preparation for success in high school STEM (Archer, et al., 2010; Settle et al., 2012). Adolescents begin to form interests in occupations they might pursue during these years (DeJarnette, 2012; Hammack et al., 2015; Morgan et al., 2013; Rogers & Creed, 2011). If they are insufficiently inspired, are exposed to negative stereotypes, or are unsuccessful in obtaining the academic foundations for STEM during middle school, they are unlikely to envision themselves in a STEM career. Without these foundational experiences, students are less likely to pursue high school math and science courses necessary for entering college prepared for STEM in general and CS in particular.

As middle school students begin to form career identities and think about their futures, they can be inspired by role models at home, popular culture, their communities, by teachers, and counselors. Secondary school personnel can be key sources of CS career information, especially for students who do not have access to this information from home (Deslonde, 2017). However, not all counselors and teachers in U.S. secondary school are well-informed about CS and therefore are unable to guide students to explore technology careers (Engberg & Wolniak, 2013; McKillip et al., 2012; Woods & Domina, 2014).

Secondary students who receive information about CS may have unrealistic or limited knowledge about career paths. When compounded by negative stereotypes of who does or does not belong in CS, students from underrepresented gender and race/ethnic groups can face a toxic brew of misinformation. This is also true for youth from lower income families (Hanson, 2008).

Computational Thinking

The supplemental workshops focused on teaching computational thinking (CT) skills through instruction in programming, coding, and gaming. Preparation for the field of computer science requires exposure to CT. Computational thinking is a problem-solving skill set inspired by fundamental computing science principles presented by several dimensions. It was first introduced by Wing (2006) as a series of thought process that apply fundamental concepts and theories of computer science to problem solving, system design, and the understanding of human behavior. CT teaches learners to reformulate complex problems and efficiently solve them using techniques including abstraction, recursion, and heuristic reasoning (Voskoglou & Buckley, 2012). Advocates of teaching computational thinking argue it can provide learners with a skill set for quotidian challenges as well as academic assignments (Csizmadia et al., 2015; Wing, 2006).

Since its introduction, computational thinking has since been redefined as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (Wing, 2011), Although there is no consensus as to the definitive elements of CT, several proposals include:

i) a seven-dimensional framework (computation, communication, coordination, recollection, automation, evaluation, and design) (Settle & Perkovic, 2010);
ii) a six-dimensional framework: problem formulation (abstraction, logical thinking, algorithm application, analysis and implementation of solutions, problem generalization, and migration) (CSTA & ISTE, 2011);
iii) a five-dimensional framework for CT (algorithmic thinking, decomposition, generalization thinking, abstract thinking, and assessment skills) (Csizmadia, 2015); and
iv) a refined six-dimensional framework including creativity, algorithmic thinking, critical thinking, problem solving, collaborative thinking, and communication skills) (Csizmadia, 2015).

This descriptive case study explains the aims and history of the Partnership; connects its components to the larger literature about technology education for middle schoolers, and describes the development and implementation of the model for teaching computational thinking skills to underrepresented students. Following presentation of guiding research questions, a description of the Partnership's intervention, the article identifies the research design, methods, and findings. It concludes with considerations of the findings as a potential model for augmenting the formal teaching of computational thinking skills in middle school classrooms for youth historically marginalized from the computer science field by their socioeconomic status, gender, and racial/ethnic background.

Research Questions

This case study describes the implementation of the Partnership's intervention designed to inspire, mentor, and augment the academic preparation of underrepresented adolescents enrolled in a middle school's CS courses. Based on the Partnership's aims and the prior literature, the authors sought to answer the following questions:

1. Do the Partnership's workshops inspire Wilson pupils to learn computer science?

2. Do the Partnership's workshops inspire participants to attend college and pursue computer science majors?

3. Does the gender and race/ethnic diversity of University tutors affect participants' understandings of who can become a computer scientist?

4. Do workshops augment participants' computational thinking skills?

Contours of the Problem

The problematic that motivates this study has several interrelated parts. The first is that too few US students graduating from high school are inspired to pursue CS in post-secondary venues and those who are motivated too often are ill-prepared. The poor preparation includes weak computational thinking skills. The second part follows from the first: there is a dearth of CS college graduates available for careers in technology. Labor force projections suggest a gap between demand for CS graduates and people available (U.S. Bureau of Labor Statistics, 2023). Contributing to the shortfall of college graduates with technology degrees is the relative absence of women and certain demographic groups. Nationally, females, low-income students, and youth from underserved ethnic minority groups enroll as college CS majors at rates relatively lower than their share of the undergraduate population. The lost talent from the students who are not CS majors has implications for society and the futures of these individuals, given the relative prestige and potential for high compensation in technology-based occupations.

As of 2019, national data indicate that 19% of US undergraduates pursuing a degree in computer science or a related major are women, 23 % are Asian, 5% are African-Americans, and 11% are Latinx. Whites constitute 45% and multiracial and international youth comprise the remainder of the undergraduate CS student population (Zweben & Bizot, 2022). Recent enrollment and graduation data for various computing degrees indicate gender and race/ethnic disparities persist in the state (anonymized) in which this study took place as well. In this regard, the state is not different from most other states in the U.S.

Patterns of underrepresentation become apparent when we compare overall 18-25 year-old population demographics in North Carolina, the state in which UNC Charlotte is located, with overall major choices of CS (University of North Carolina System, 2028; U.S. Census Bureau, 2018). The race/ethnicity diversity gaps are more striking in computer science enrollments than in other majors. Asians with Indian or Pacific Rim origins, who comprise 2.3% of the state's population, are overrepresented in CS (16.4%), while Native Hawaiian and Pacific Islanders are underrepresented (0.2%). Participation by Whites is higher at the University (58.1%) than other racial/ethnic groups but, overall, Whites do not enroll in CS at rates proportional to their share of the University's enrollment or their share of the state's college-going age cohort. Blacks' underrepresentation (12.5%) is greater relative to their proportion of the state's population (20.0%). Native Americans' participation (0.3%) is smaller than their share of 1.2% of the state's college-age students, but their participation in technology is slightly better (0.4%). Relative to the state's college-age population (8.1%), Latinx are slightly overrepresented at the University (10.2%), but slightly underrepresented in technology (7.4%). The gender diversity gaps are starker than those associated with race/ethnicity. Fifty percent of the state's college-aged population is female, almost 47 % of undergraduates enrolled in the University's campus are women. Yet, only 16.6% of the University's CS majors are women.

The UNCC/Wilson Partnership

In 2018, UNC Charlotte's College of Computing and Informatics (CCI) issued a White Paper that recommended greater collaboration between CCI and the larger community (College of

Computing an Informatics, 2018). CCI and the Charlotte-Mecklenburg Schools' (CMS) Wilson STEM Academy Middle School began to plan a Partnership later that year. The Partnership implemented supplemental CS workshops in fall 2019 for 6th grade students, with plans for this cohort to continue through their graduation from Wilson upon completion of 8th grade. Workshops were developed and delivered by University CS undergraduates, all of whom scholarship recipients as part of a service learning course originally linked to a scholarship program that itself was aimed at increasing the success of CS freshmen from underrepresented backgrounds (Mickelson, Mikkelsen, Dorodchi, Cukic, & Horn, 2022). The 16 scholarship recipients (henceforth, the Scholars) served as instructors and mentors to Wilson's students. They offered hands-on activities in a series of supplemental instruction materials in a range of technology skills; led field trips to UNC Charlotte's campus; and served as gender and race/ethnic role models that challenged societal stereotypes of who can become computer scientists. The workshops augmented Wilson's formal classes in CS. The undergraduate tutors/mentors, many of whom came from one or more underrepresented demographic groups, exposed the Wilson students to academic and social experiences that research suggests are necessary, albeit insufficient, for sparking interest in and preparation for STEM fields more generally and technology, in particular.

Designing the Partnership's Intervention

The Partnership's academic goals were increasing middle school students' access and exposure to CS, improving their academic skills in science and mathematics, and increasing participants' interest in post-secondary education in technology. The Partnership also aimed at several sociocultural goals: undermining negative stereotypes about who belongs in technology, enhancing youth's sense of belonging in CS, and stimulating their nascent science identity and confidence as CS learners. These elements have been previously identified as critical to student engagement and academic success in all STEM disciplines (Rainey et al., 2019). Prior research also demonstrates that stimulating interest in technology among underserved populations is more effective if done early in students' academic trajectories (Cheryan et al., 2015; Vincent-Ruiz & Schunn, 2018).

The Partnership's design team consisted of Wilson's Principal, the Coordinator of Social and Emotional Learning, and several University's faculty in computer science and sociology. The team designed the intervention as a supplement to the formal *Computer Science Discovery* curriculum taught in Wilson's CS courses (North Carolina Department of Public Instruction, 2022). The workshops launched during fall of the 2019-2020 school year with about 25 Wilson 6th graders who had been nominated by their CS teachers.

Wilson is an ideal site for this collaboration. Aside from the STEM theme of the magnet school. Roughly 96% of pupils who attend the school are racialized minorities and 98% of students are low-income as measured by their eligibility for free or reduced-price lunches and breakfasts (Charlotte-Mecklenburg Schools, 2015; Chetty, et al., 2019). In 2022, about 90% of its 490 students attended Wilson because they live in its assignment zone while only 10% enrolled via the school's magnet program. Less than 20% of Wilson students scored as proficient or above on their end-of-year standardized tests in reading and mathematics. Nonetheless, Wilson was one of only a handful of CMS schools that made substantial improvement in the 2021-2022 academic year following the pandemic closing of schools and switch to virtual classes during the previous academic year (Cook, personal communication, 2022).

Implementation of the Partnership Workshops

The first two workshops took place on the University's campus in late 2019, before the pandemic reached the peak of its spread. Scholars met Wilson's school bus upon its arrival on UNC Charlotte campus and guided the Wilson students and their accompanying faculty as they walked past the campus dorms to the Student Union, where the visitors ate lunch at all-you-can-eat-style buffet as guests of the College's Dean, who joined the group for lunch. After lunch, the Wilson students toured the campus and then convened in a classroom where they coded and played games led by the Scholars. Scholars circulated amongst the 6th graders and provided one-on-one tutoring. Immediately after the first workshop concluded, school's staff administered confidential open-ended assessments of students' experiences. The middle school youth were prompted to describe their reactions to their experiences, if and how the workshop influenced their future career and educational goals, sense of belonging in CS, and self-concepts as a science learner. All assessments were identifiable only by the CMS student ID number to ensure respondents' confidentiality.

The Partnership's Pandemic Pause and Reboot After the first two workshops, the Partnership cancelled the remaining ones planned for the 2020 spring semester because the Covid-19 pandemic schools forced both schools to suspended face-to-face learning. The Partnership's second year restarted in fall 2020 with workshops on Zoom. Thirteen new 6th graders joined the continuing workshop participants, now 7th graders. Several challenges complicated the rebooting of the workshops. These challenges were emblematic of the challenges the pandemic presented educators across the US. Internet connectivity was a problem for some University students who lived in rural communities. Although all middle school students had been provided with a laptop by the school system, a number of students came from families without internet service. Some Wilson students with home internet service could not participate because they did not have the adult assistance they required to log into the system from home.

In the Partnership's third year (fall 2021 through spring 2022), workshops resumed on Zoom. A new cohort of 6th graders was added to the continuing 7th and 8th graders. As the pandemic waned in early spring 2022, the Partnership's activities soon switched to a hybrid format, both Zoom and an in-person component. Workshops were led in-person by several undergraduate tutors who came to Wilson's campus. In-person tutors presented the material didactically, and Zoom tutors worked one-on-one with learners in Zoom breakout rooms.

Overcoming Technical and Instructional Challenges Typical middle school instructional challenges complicated the rebooted Zoom workshops in fall 2020. Many middle schoolers regularly forgot their logon credentials for their laptops. Starting delays ceased when Wilson faculty ensured all their pupils were logged on before the workshop sessions. The absence of a relationship between where Wilson students sat in the classroom and their "Zoom breakout room" assignment led to chaotic noise levels. Undergraduate tutors used their own CT skills to resolved the problem: Wilson students sat only with their breakout room peers during Zoom sessions so that their Zoom tutor could communicate without the chaotic noise linked to random seating. In June 2022, the first cohort of 8th grade Partnership veterans graduated from middle school.

Teaching Computational Thinking

The undergraduate Scholars collaboratively developed the supplemental curricula under the guidance of their University academic advisor and in consultation with Wilson's two CS teachers. Workshop activities involved concepts and techniques inherent in programming languages. These activities reinforced students' developing computational thinking skills by using block-programming with Scratch (https://scratch.mit.edu/about). Scratch is a block-based, syntax-free, visual coding language with a development environment that facilitates computational thinking to create games and animations among other creative projects. Scratch can be used to introduce the basics of coding in an intuitive environment (Meerbaum-Salant et al., 2013).

Starting with the fall 2021 workshops, Wilson students were divided into beginner and advanced groups depending upon whether they had previous exposures to the block-programming taught in past workshops. One group of undergraduate tutors taught Scratch to new 6th grade learners. The other group taught Python to more experienced 7th and 8th grade middle school students. Python (https://www.python.org/about) is a powerful text-based programming language. Python's learning curve in traditional text-based integrated development environment (IDE)'s offers a greater challenge to new learners compared to the Scratch's block-based one. For this reason, the undergraduate tutors, under supervision and direction of computer science faculty, transitioned the course content and activities from block-based to traditional text-based Python using the EduBlocks (https://www.edublocks.org) environment (2021). Both Scratch and EduBlocks environments are excellent starting points for young students to become involved with learning computational thinking because neither environment requires users to focus on syntax.

Workshops lasted for approximately 45 minutes, during which the Scholars led Wilson students through a combination of a very short didactic lecture and/or videos that presented the new materials and explained the hands-on activities for the session. The lessons explored main coding constructs such as conditional, iteration, and function call statements in addition to foundational computing concepts like input/output, assignments, operators/expressions, and built-in functions. The workshop's curriculum was developed based on computational thinking models developed for high school students, but adapted the CT pillars of decomposition, pattern recognition, abstraction, algorithms, and scaffolding for middle school pupils.

Most of the efforts to fine tune the difficulty level of the activities was based on the multidimensional scaffolding model developed by one of the authors (Dorodchi et al, 2020). The multidimensional scaffolding methodology proposes to sequence activities based on: (1) chunking by difficulty, (2) chunking by time, (3) chunking by focus, and (4) chunking by collaboration. This approach focuses on refining instructor-to-student mediums through diversifying activities, balancing the challenge levels, including pre-class and post-class assignments, and chunking instruction time.

Supplementing the Formal Curriculum's Lessons in Computational Thinking

The Python and Scratch lesson plans were designed to reinforce or, for new students, to introduce computational thinking concepts (Brennan & Resnick 2012; Grover & Pea, 2013; Grover, Pea, & Cooper, 2015). In particular, problem-solving techniques inherent in computational thinking were taught by asking middle schoolers to consider the context of a problem and how to solve it step-by-step utilizing programming constructs in a given development environment. An independent coding environment in Python lessons was used to show how text-based languages actually work. Students learned about the functionality and limitations of the tool and were encouraged to solve problems within such constraints. Doing so enabled them to analyze the given problem for each activity and take advantage of the available constructs and built-in functions to solve the problem step-by-step, following and learning the facets of computational thinking. For example, to solve a problem in computing and determine the difficulty of the tasks ahead, Wing (2006) explains that one must consider the machine which executes the solution because solving a computing problem requires understanding the machine's "instruction set, resource constraints, and its operating environment." Computing devices are limited by their programmed functionality, which forces computer scientists to adopt a computational style of thinking (Wing, 2006).

Computational thinking involves supporting and marrying engineering and mathematical thinking, using arithmetic operators, and solving mathematical problems (Wing 2006). As embodied in Figures 1 to 4 (below), the Scratch activities also covered the concepts of arithmetic and relational operators, loops, and conditionals. The following section illustrates the elements of computational thinking taught in the first Scratch lesson. It began by reviewing the definition of computational thinking and then enumerating several characteristics of the construct. Using components of a pizza, the slide explained algorithms, problem decomposition, abstraction, and pattern recognition, all elements of computational thinking. Figure 1 exhibits the slide shown to students during the lesson.

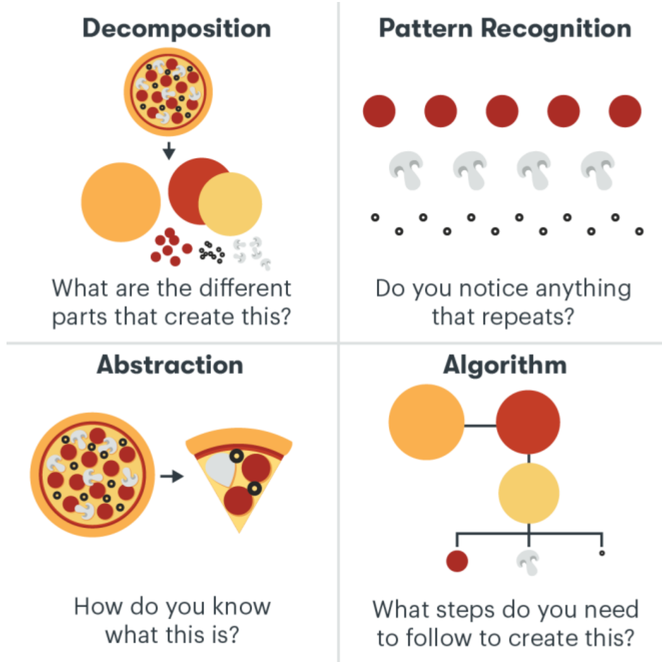

Figure 1   Elements of Computational Thinking from Partnership Workshop, Spring 2022.

The workshop required students to complete several scaffolded activities that encouraged them to apply the principles of computational thinking. Many of the class activities depicted in these slides were taken from the Scratch official website (https://scratch.mit.edu/projects/). For example, the first activity from the Scratch curriculum asked students to finish a game by implementing the missing functionalities, as illustrated in Figure 2. While students had not been introduced to formal coding syntax at this point in the curriculum, they could modify the game from its graphical interface by intuitively analyzing the environment and the range of actions permitted, allowing them to develop familiarity with this thinking strategy.

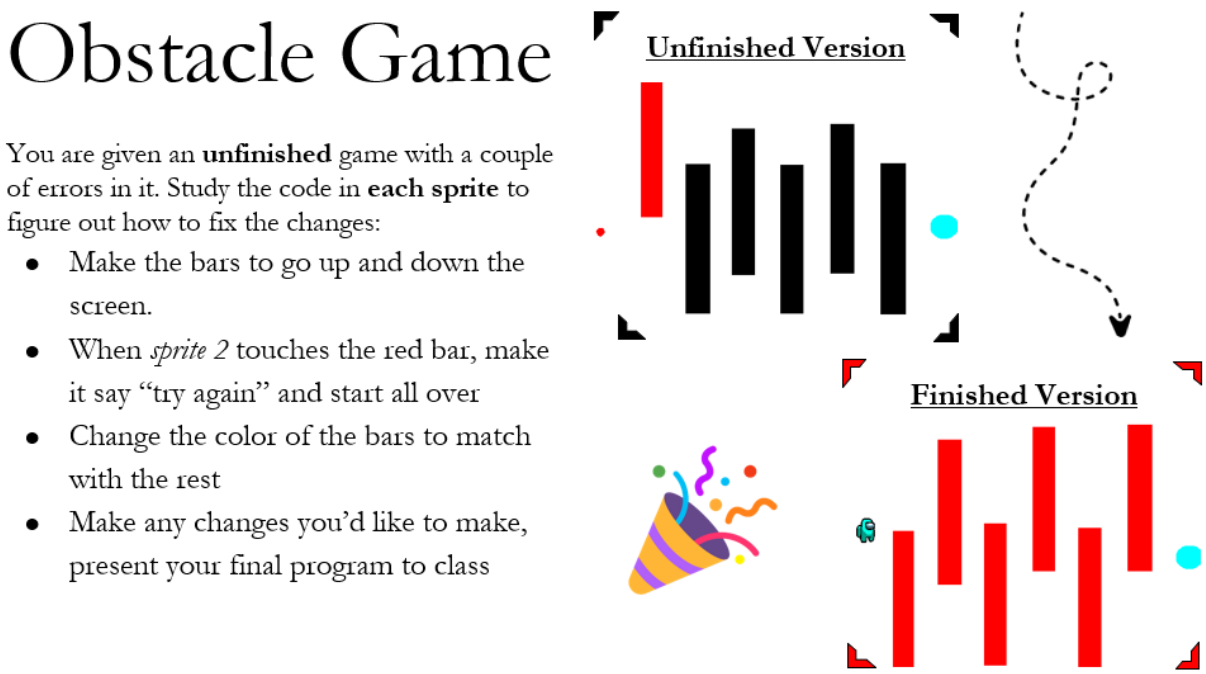

Figure 2 Introduction of the Concept of Abstraction from Partnership Workshop, Spring 2022.

The lesson in Figure 2 displays an effort to introduce abstraction by asking students to finish creating a game. To complete this activity, students did not need to understand the full functionality of the code. They only needed to analyze and implement the features that they were asked to change and learn how to ignore that which was irrelevant to the task. Wing (2006) defines this element of computation thinking as developing "the confidence [that] we can safely use, modify, and influence a large complex system without understanding its every detail."

The activity in Figure 3, only one example of many such activities, demonstrated the concept of computational thinking in a contained, gamified way appropriate for the middle school age group.

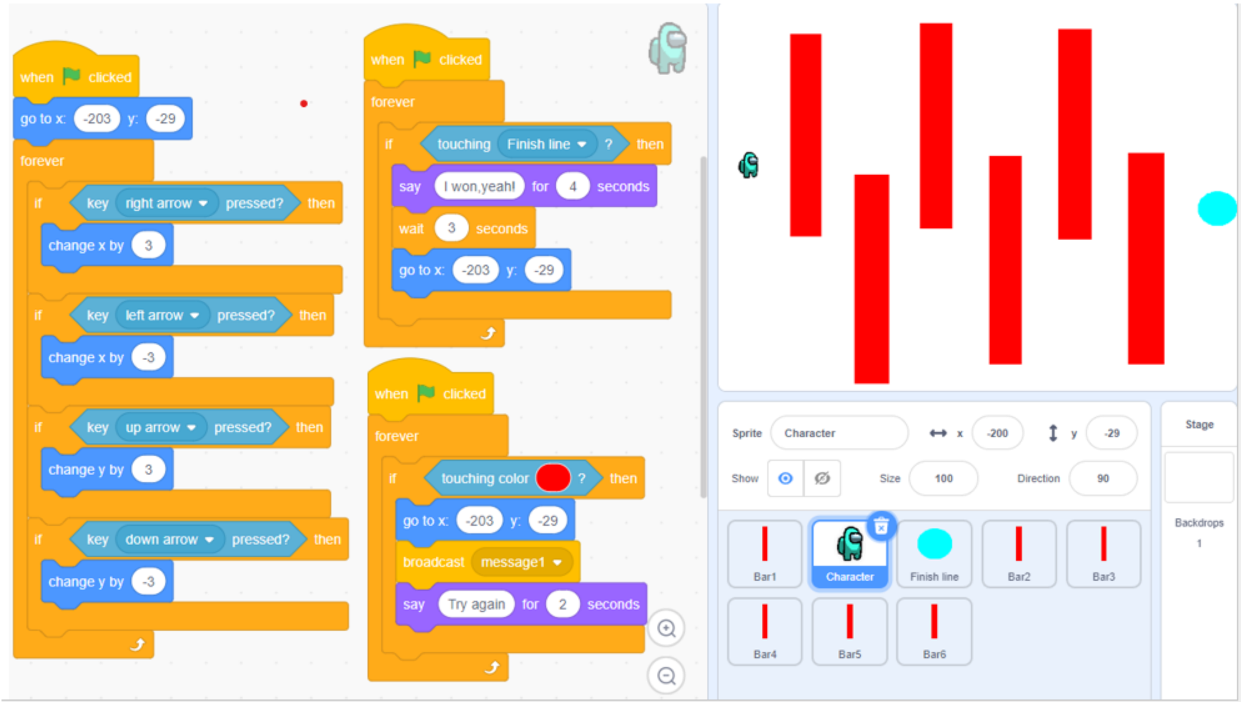

Figure 3 Workshop Scratch Interface Activity Challenge, Spring 2022.

Figure 4 shows an activity that required students to program a calculator using the available arithmetic blocks in the Scratch environment.

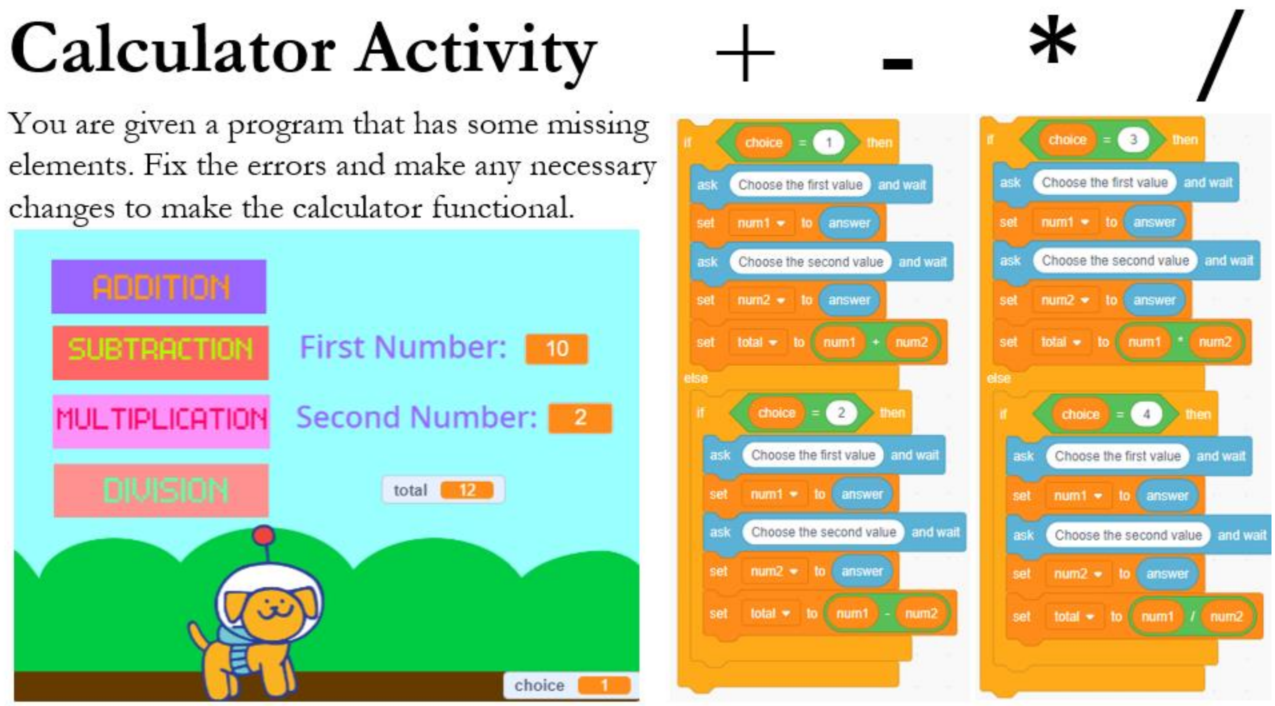

Figure 4 Scratch Activity Programming a Calculator with Arithmetic Blocks from Workshop, Spring 2022.

Subsequent workshops built upon the types of activities exemplified in Figures 1-4. The new activities slightly increased in difficulty each time students came to the workshops. Comparable activities were developed for the returning students who used Python.

Research Design of the Case Study

Participants

Wilson STEM Academy Participants In 2019, about 25 6th grade Wilson CS students nominated by their teachers as suitable for participation in the Partnership participated in the workshops. Wilson's Principal purposefully targeted 6th graders for the first cohort so that the Partnership could offer three years of supplemental instruction to the same youth before they moved on to high school. Similar nominations produced subsequent cohorts of 6th graders in the 2020-21 and 2021-22 school years. A total of 65 middle school pupils participated during the three years covered by this descriptive case study. Of these, one-third participated all three years.

Undergraduate Participants Initially, tutors were limited to the 16 undergraduate Scholars who received an academic scholarship for underrepresented CS students (Mickelson, Mikkelsen, Dorodchi, Cukic, & Horn, 2022). After two years of the Partnership's operation, word had spread among CCI's undergraduates about the Partnership and its associated service-learning courses. CCI undergraduates who were not Scholars expressed interest in being tutors (all CCI undergraduates' degrees required service learning). During the third year of the Partnership (Fall, 2021to Spring, 2022), enrollment in the service-learning course linked to the Partnership became available to any CCI junior or senior interested in it. Eight of the 16 Scholars participated throughout the Partnership, along with another 30 CS undergraduates, many of whom were also students of color and/or from low-income backgrounds. Overall, 46 undergraduates participated between one and six semesters in the Partnership.

<u>Data</u>

This case study employed several qualitative data sources. They included 15 sets of confidential open-ended surveys that were collected from middle school participants immediately after each workshop, formal interviews with undergraduate participants, CS teachers and staff; and approximately 220 reflective essays describing the Scholars' experiences preparing for and implementing the workshops. The reflective essays were assignments for their service-learning college course in which they were enrolled. Other sources of qualitative data collected by the first author included field notes from planning meetings, in-person observations of workshops, and exit interviews with Scholars who received their BS in computer science.

Data also included post-workshop surveys to assess the middle school pupils who attended each workshop. The open-ended surveys were designed and administered by Wilson's staff to ascertain pupils' perceptions of the workshop's influences on their attitudes about attending college, STEM, and CS. All student responses were identified only by a LSD student ID number. These data were shared with the researchers only after a Memo of Understanding was signed by both schools' legal teams and administrators (UNC Charlotte/CMS, 2022).

Researchers complied with all human subject ethical standards throughout the study. The lead researchers received UNC Charlotte's Institutional Review Board approval for the study and every undergraduate tutor received [delete ~~CITI~~] certification necessarily for working with human subjects. Signed parental permissions for student participants and informed content from interviewees were obtained by the researchers. Anonymous administrative data from publicly available files of the North Carolina Department of Public Instruction, the Charlotte-Mecklenburg School system, and the University of North Carolina at Charlotte were examined as well.

Analytic Strategies

Interviews, Observations, and Reflective Essays The authors used conventional methods to code all qualitative data (interviews with tutors and educators; undergraduates' reflective essays; observations; exit interviews with graduating Scholars) and identify themes (Miles, Huberman, & Saldaña, 2020). All qualitative data materials were coded and analyzed according to a coding schema developed from recurring patterns found in the data (Rubin & Rubin 2012). The analysis method involves an iterative process of data analysis and its relationship with prior research. Through this process the authors were able to identify participants' and interviewees' perceptions and attitudes.

Content Analysis of Post-workshop Assessments Three of the authors analyzed Wilson students' responses to assessments' open-ended survey questions. Following social science conventions for content analysis of text, three authors independently coded key words and phrases in pupils' responses to reveal patterns across individuals, workshops, and semesters. Next, they compared emergent themes and resolved by consensus any discrepancies in coding categories. Once themes were established, they independently coded all students' responses, conducted interrater reliability checks, and counted the instances where a word or phrase appeared as representations of themes. An example of the results of the content analysis procedures for one open-ended question appears in Table 1 in the Results section of this manuscript.

Triangulation Qualitative data were triangulated across various sources to ensure reliability of interpretations. They included reflective essays, observations, interviews, and survey responses of the middle school adolescent participants. To draw interpretations, researchers utilized data from more than one source. For example, evidence supporting Wilson students' use of computational thinking drew on teacher interviews, tutors' narrative reflections, and middle schoolers' answers to survey questions.

Anonymity and Reliability Checks Wilson students' words and responses are not attributed to any identified student. All undergraduates whose insights are quoted are identified by a chosen pseudonym to guarantee their confidentiality. Because of the salience of gender and race to the problematics examined in this study, the description of their gender and racial/ethnic characteristics reflect their actual backgrounds. Undergraduate participants and the middle school's faculty and administrators had the opportunity to verify, clarify, or correct attributions to them, any findings, and interpretations of results to enhance reliability of findings.

Findings

The case study's findings suggest that the workshops inspired a large portion of Wilson participants to attend college and/or consider a major in CS. The workshop's activities introduced, honed, and/or reinforced participants computational thinking skills; the mentors and tutors challenged negative stereotypes of who belongs in CS; and the overall experiences augmented adolescent participants' academic growth, their engagement, enthusiasm, and creativity in CS.

Table 1 presents middle schoolers' responses to the open-ended survey question *This Partnership is important to me because _______*, arranged by the themes that emerged from the content analysis of responses. They include college, coding, CS, mentors and tutors, fun, and the future. Responses that did not fit these themes were categorized as Other. Responses to the other open-ended questions were similarly content analyzed for these themes.

Table 1 Examples of Middle School Students Responses by Theme to Open-Ended Assessment Question *This Partnership is important to me because _______*, N Per Theme, 2021-2022

Themes	N of responses	Examples of responses arranged by themes
Going to College	25	It helps me learn what college is like; I want to go the University when I grow up;
Learning to Code	88	It makes me happy to learn more about coding; I love to learn about coding;
Computer Science	26	I like computers and would LOVE to learn more about them; I get to know about computer science;
Tutors and Mentors	27	I get to bond with older people and talk about computer science; I like how all the college students explain stuff
Having Fun	64	It's fun to work with computers and also educational; It is very fun and cool.
CS in My Future	35	I love STEM and art and I want to make them my future; It [CS] can help me in the future.
Other	16	I get to make friends; The workshops take me away from science [class]

Inspiration for going to college and majoring in CS Available responses to assessments indicate that the workshops inspired many middle school students to think about college and studying technology. As Table 1 indicates, the most common responses referred to learning to code or program (N=88) and how computer science may be in the student's future (N=35). Twenty-six responses mentioned that the workshops stimulated the student to wonder about going to college and studying technology (N=26). Some responses straddled two categories. For example, one student declared, "I want to be an architect, but I think about having a minor in computer science." Reflecting on the experiences with the workshop, another student stated, "I learned how to be myself... and explore the field of computer science."

University mentors' reflective essays echoed Wilson students' survey responses with respect to the workshops' salutary effects on middle schoolers' aspirations to attend college and study technology.

> The idea [is] that we are giving middle schoolers a chance to explore computer science early on in their life, allowing the students to grasp the very basic ideas, ... [and this] creates new opportunities that they did not know existed in the beginning.
>
> Melanie, Asian female.

> It is clear that they are interested in computer science content and in the Python programming language as well. Most of them said that they were planning to study computer science in college.
>
> Nate, Black male.

Several Wilson pupils acknowledged that time with their tutors and mentors was one of the key reasons why they now were considering technology careers. Lena, an undergraduate tutor/mentor, reported that "At the end of the [semester's workshops], one girl said that we made her want to be a computer scientist and actually join the field."

Tutors embody expanded gender and race/ethnic norms of who belongs in CS. As mentioned, Wilson students indicated they want to learn coding, study computer science, and aspire to pursue these goals in college where they, following their mentors, will major in CS. Results from the post-workshop surveys indirectly link tutors' own gender and race/ethnic diversity to students' challenging norms that suggest underrepresented youth do not belong in CS. Although no survey question asks if the diversity of the tutors undermined stereotypes, almost every Wilson students' responses embraced studying CS despite negative stereotypes. For example, as Table 1 indicates, working with the tutors was cited as an important facet of the workshops. The students also mentioned nine tutors/mentors by name a total of 27 times, praising them for the ways they taught the supplemental material and explained concepts to them. Given the majority of the middle school participants' interest in CS and tutors' diverse race/ethnic and gender identities, it is reasonable to posit the latter's role as mentors disabused the former of the stereotype implying White and Asian males are the people best suited for CS.

Computational Thinking Tutors' reflective essays described how they built computational thinking into their lessons and the perceived successes of their instructional strategies with Wilson students.

> Although each activity varies from lesson to lesson, we provide [the participants] with a consistent format for their program [....with computational thinking infused into activities].

> First, the tutors will demo the completed version of the program while we provide the Wilson scholars with the uncompleted version of the program. The uncompleted version contains errors, missing blocks, sprites, or variables. When we [demonstrate] the program, it allows the students to practice their pattern recognition and algorithmic thinking skills to figure out how they can fix the program to look like what we demo-ed. Once they work on the activity, they will use their abstraction skill to eliminate anything that is unnecessary and finally their decomposition and pattern recognition again to study each block of the algorithm to solve the broken code.
>
> Zoe, Asian female

> The turning point during the class ... [was] when we asked the kids to apply computational thinking to their favorite video games, so a lot of kids related computational thinking to how they would win a game of Call of Duty or Fortnite for example.
>
> Ron, Black male

> My group did animation and animating [their] name using Scratch sprites. The students used pattern recognition in order to follow the demonstration as well as to recreate an example given. Decomposition was used in figuring out what letters they wanted to animate since they could use other people's names (family, friends, pets, etc.). Algorithms were used to follow the code and instructions while abstraction was used to make the code simple, yet function as it needs to be.
>
> Mona, Black female

Interviews conducted with Wilson CS teachers confirmed that the workshops had a positive impact on workshop participants' computational thinking skills. When asked if the Partnership appears to enhance the computational thinking skills of his students, a computer science teacher responded,

> I would say yes. . . but, um, . . . this is pertaining the high flyers, the ones that are performing across the board, that they're, um, willing to help the others because they understand . . . .
>
> Mr. McCormack, computer science teacher

His colleague agreed, providing further evidence for a similar conclusion.

> . . . I would say, um, . . . maybe about 25% of them, um, that is a yes. Uh, I have had students who, as I'm teaching something in class, . . . it triggers a memory or some knowledge that they have gained through your program and they've even said, 'oh, we learned this with the University group.' And so, uh, I, they are learning something, and they are, um, applying that in my classroom. They're remembering it and they are, you know, tapping into that knowledge in my classroom.
>
> Ms. Johnson, computer science teacher

Post-workshop surveys did not directly assess computational thinking. Nonetheless, several middle schoolers' responses to the post-workshop surveys suggest the experiences developed their computational thinking skills. Survey responses that referred to tools students used, such as EDUblocks, Scratch, or Python, convey the mode through which they practiced computational thinking skills. Utilizing these tools develops students' ability to find solutions to complex problems while considering constraints, such as the instruction set of a programming language or tool. For example, one student mentioned completing a task to build a calculator, drawing squares in code, and enjoying "the challenging puzzle." The calculator activity (Figure 4), in particular, combines multiple facets of computational thinking, including the development and technical implementation of mathematical thinking, a fundamental skill of CS. One eighth grader affirmed their engagement in computational thinking, stating that the sessions "... help me get better at problem solving."

Other responses to the open-ended queries suggest pupils engaged in computational thinking. One assessment item asked what the students enjoyed most about the session. Several students responded with reference to using Turtles, specifying "mov[ing] the Turtle." Turtle is a common abstraction tool that allows students to employ complex code in their own programs without being required to understand the underlying code. Abstraction is a key tenet of computational thinking that allows students to critically assess and utilize the resources available without being hindered by the details of complex implementation. Another student expressed interest in knowing "what other things we can do with computers and coding" and "how much more I could learn," which suggests an interest in expanding computational thinking skills to other computing pursuits beyond what was taught in the session. For instance, undergraduate tutor Mona noted a few Wilson students used computational thinking skills when they went above and beyond the assigned activity to create a more advanced variation of the assignments their tutors had designed. Students got "creative" and changed some of the code to personalize it by making it more advanced than the original assignment.

Evidence of middle school wonder, engagement, enthusiasm, and growth. An unexpected set of findings emerged from several qualitative data sources. As each semester progressed, more Wilson students orally participated in the workshops. To be sure, they always laughed, joked, and whispered to each other during the didactic lectures and PowerPoint presentations of new material. As the semester unfolded, they began to quickly transitioned to answering questions about the new materials posed by their tutors and gave full attention to the hands-on activities that followed.

Several students stated the workshops left them wondering about concepts and experiences they had previously not encountered. Asked if the workshop caused them to wonder about anything, a student wrote, "It got me to wonder if I need to learn more of what the UNC Charlotte people are talking about." Another pupil wrote, " I wonder . . . if they [the tutors] ever struggle with binary." A seventh grader wondered "How can I get into UNC Charlotte ?"

Evidence of student engagement and enthusiasm manifested in question and answer sessions and students' concentration during the coding activities. After the last workshop in spring 2022, a graduating eighth grader commented, "this partnership program is important to me because I have been here since the start, and it makes me sad that this will be the last session of being in the program." Another graduating pupil wondered "if I will ever have a great opportunity like this one ever again." One student's comments captured his enthusiasm, engagement, and growth when he described the Partnership as ". . . a new experience and I'm glad I was open and available to it. I learned a lot about coding and met great people and got along better with some of my classmates."

Several University tutors described Wilson pupils' enthusiasm was meaningful to them as tutors.

> One thing that stood out to me was the kids' ability to retain and learn all the information that they have been taught. For kids their age to be able to code at a decent level is truly impressive and something to be proud of by both the students and us [University tutors] for teaching them.
>
> Arthur, Southeast Asian male.

> It was encouraging to see how enthusiastic they were about creating art with Python. You can tell when working with them that many of them have never seen anything like this before. Coding is a whole new world for many of them, and it is exciting and rewarding to watch them experience it and make connections.
>
> Nate, Black male

In fact, Wilson's CS teachers were pleasantly surprised to learn of the widespread enthusiasm and cooperation of workshop participants given that some middle schoolers' engagement in the workshops did not reflect the same students' frequently unfocused behavior in their CS classrooms.

An advantage of the case study's three-year window on the Partnership is the design's capacity to capture changes over time in the growth of the middle school students. Ella and other tutors reported that Wilson students displayed CS knowledge growth in multiple domains, enthusiasm, and more self-control than they showed when the workshops began. Steve, another tutor, commented, "I was very impressed with how engaged... and well-behaved the middle schoolers were." Mike, experienced in working with middle school youth, noted that the Wilson students seemed really happy to be there and were very excited when the undergraduates that had worked with them before remembered the Wilson students' names. He observed, "The engagement from them was much better than I was expecting since I've work with middle school [who]... normally aren't this enthusiastic." At the end of the sixth semester of workshops, another undergraduate observed,

> I have taught Python before . . . and the [7th grade] students at Wilson were both more interested and more knowledgeable than other students I have worked with.
>
> Nate, Black male

Discussion and Conclusion

Our findings offer tentative answers to the questions that motivated this case study. The first two questions concern the Partnership's effects on Wilson students' interests in learning computer science and attending college to pursue a major in technology. Both the middle school participants' post-workshop surveys and their mentors' observations provide substantial evidence that many participants were interested in pursuing CS and going to college, which they attribute, in part, to the workshops. Unfortunately, we have no information on baseline attitudes. The evidence for our findings relies on middle school students' statements and observations of their tutors. Neither do we have empirical indicators of enrollment in high school or college or technology classes. Nonetheless, in many cases intentions foreshadow future behavior.

The next question asks whether working with diverse UNC Charlotte mentors undermined stereotypes suggesting people like Wilson students do not belong in CS. Because the tutors/mentors were largely low-income students of color and 50% were females, the Partnership expected them to positively influence the middle schoolers' perceptions of who belongs in the field. Both the survey responses of the Wilson students and their candid and spontaneous interactions with mentors reported in the latter's reflective essays indicate that these adolescents shared the conclusion of a fellow learner who wrote, "If they [the Scholars who tutored them] can do it [major in CS], I can do it."

The final question concerned the workshop activities' possible effects on Wilson students' computational thinking skills. Our interpretation that activities taught and improved middle schoolers' CT skills is tentative. First, observations could not directly capture CT behavior. Thus, any interpretations that conclude workshops taught and improved students CT skills rest on our inferences made by linking indirect data across several sources. Wilson's CS teachers, assessment question responses, and the reflective essays all describe Wilson pupils employing elements of their computational thinking skills during their formal CS classes and the workshops' hands-on activities. Second, direct questions regarding computational thinking skills were not part of the post-workshop assessments. Thus, Wilson students' answers to assessments rarely addressed CT directly. The exception was one participant's statement that the sessions "... help me get better at problem solving."

Limitations Like all studies, this one has several limitations. The first limitation involves the absence of measures taken prior to the workshops of pupils' beliefs about going to college, majoring in CS, awareness of stereotypes regarding who belongs in CS, science identities, or their baseline computational thinking skills. The second limitation is the absence of empirical longitudinal outcome data to test the efficacy of the workshops. We do not know if participants were more likely to enroll in high school CS courses or other STEM subjects, or are more likely to go to college and major in CS compared with their otherwise comparable peers who did not participate in the workshops. This is a largely a consequence of the LDS's policies guaranteeing student confidentiality and the Partnership's research design, which did not include a post-middle school longitudinal component. Without these empirical pre- and post-workshop indicators our findings reflect only the impressions of their CS teachers and undergraduate tutors and the participants expressed aspirations. A final limitation concerns the selection bias of the sample involved in the Partnership. Participants decision to be involved in the workshops differentiates them from their peers who did not. These unique characteristics of this self-selected sample precludes generalizing the study's findings to other middle school students or other schools.

Significance of this Study Despite these limitations, this case study offers some encouraging findings that suggest the Partnership offers a model intervention that can potentially address the two dilemmas with which this article began: The demographic disproportionalities that characterize the CS undergraduate population and the projected labor force shortages for technology occupations. Specifically, the findings suggest that a significant number of the Wilson participants were inspired to go to college and pursue CS. Many of they appeared to be developing a nascent CS identity. Their CS teachers recounted how many participants attempted to integrate their new computational thinking skills into their formal CS classwork. Given the literature on STEM education clearly indicates that early inspiration and preparation are essential to later success in the field, the Partnership' results are encouraging even though they are far from conclusive. Case studies are not generalizable even without the design limitations discussed above. Future replications of the study that improve upon this study's research design are necessary to ascertain if there are, in fact, lasting effects from Partnerships like this one.

These issues notwithstanding, the study's findings are promising. Because the Partnership appears to increase marginalized middle school youths' readiness and interests in attending college and studying CS, this case study suggests a well-designed and implemented intervention has the potential to broaden participation in CS by youth from marginalized communities. The UNC Charlotte/ Wilson Partnership offers a model that may narrow the social class, gender, and race/ethnic disproportionalities in CS and, in doing so, also begin to address projected labor shortages in the technology sector as well. Equally if not more important, benefits of college educations extend far beyond preparation for careers. College educations shape youths' futures as informed and literate adults facing complex personal, national, and global issues increasingly related to technology.

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren’s constructions of science through the lens of identity. *Science Education, 94*(4), 617-639.

Brennan, K. & Resnick, M. (2012) New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American educational research association, Vancouver, Canada* (Vol. 1 p. 25)

Charlotte-Mecklenburg Schools. (2015). Fast Facts.

Csizmadia, A. Curzon, P. Dorling, Humphreys, S., Ng, T., Selby, . & Woollard, J. (2015). *Computational thinking: A guide for teachers. CAS*, https://www.computingatschool.org.uk/media/kscbloob/computationalthinking.pdf

Code.org, CSTA, & ECEP Alliance. (2021). *2021 State of computer science education: Accelerating action through advocacy*. https://advocacy.code.org/stateofcs

College of Computing and Informatics. (2018). *Reflections on the First Two Years of CCI’s Curriculum.* Author. White Paper. UNC Charlotte.

Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: Increasing girls’ interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology, 6,* 49. https://doi.org/10.3389/fpsyg.2015.00049

Chetty, R., Hendren, N., Jones, M., & Porter, S. (2019). Race and Economic Opportunity in the United States: An Intergenerational Perspective. *Quarterly Journal of Economics*, 135(2), 711-783

CSTA & ISTE (2011). Operational Definition of Computational Thinking for K-12 Education. https://cdn.iste.org/www-root/Computational_Thinking_Operational_Definition_ISTE.pdf

DeJarnette, N. (2012). America's children: Providing early exposure to STEM initiatives. *Education*, *133*(1), 77-84.

Deslonde, V. L. (2017). *Exploratory Case Study: On School Counselors' Perceived Influence on Low Socioeconomic Students' College Enrollment* (Doctoral dissertation, Grand Canyon University).

Dorodchi, M, A. Benedict, A. Rorrer, D. Pugalee, L. Cao. (2021), Broadening the Middle School Computational Thinking Interventions Beyond Block Programming. In *2021 ASEE Virtual Annual Conference Content Access*

Dorodchi, M., N. Dehbozorgi, A. Benedict, E. Al-Hossami, & A. Benedict. (2020). Scaffolding a Team-based Active Learning Course to Engage Students: A Multidimensional Approach. In *2020 ASEE Virtual Annual Conference Content Access*

Engberg, M. E., & Wolniak, G. C. (2013). College student pathways to the STEM disciplines. *Teachers College Record*, *115*(1), 1-27.

Fry, R., Kennedy, B., & Funk, C. (2021). STEM jobs see uneven progress in increasing gender, racial and ethnic diversity. *Pew Research Center*, *1*.

Grover, S., & Pea, R. (2013). ‘Computational Thinking’ in K-12: A review of the state of the field. *Educational Researcher, 42*(1), 38-43.

Grover, S., Pea, R., & Cooper, S. (2015). Designing for deeper learning in a blended computer science course for middle school students. *Computer Science Education, 25*(2), 19-237.
Hammack, R., Ivey, T. A., Utley, J., & High, K. A. (2015). Effect of an engineering camp on students' perceptions of engineering and technology. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5*(2), 2.
Hanson, S. (2008). *Swimming against the tide: African American girls and science education*. Temple University Press.
Justice, C., Sample, C., Loo, S., Ball, A., & Hampton, C. (2022, March). Future Needs of the Cybersecurity Workforce. In *International Conference on Cyber Warfare and Security* (Vol. 17, No. 1, pp. 81-91). Academic Conferences International Limited
McKillip, M. E., Rawls, A., & Barry, C. (2012). Improving college access: A review of research on the role of high school counselors. *Professional School Counseling*, *16*(1), 2156759X1201600106.
Meerbaum-Salant, O., Armoni, M., Ben-Ari, M. (2013). Learning Computer Science concepts with Scratch. *Computer Science Education*, *23*(3), 239-264.
Mickelson, R. A. (2015). The cumulative disadvantages of first-and second-generation segregation for middle school achievement. *American Educational Research Journal*, *52*(4), 657-692.
Mickelson, R., Mikkelsen, Ian, Dorodchi, Mohsen, Cukic, Bojan, et al. (2024) Inspiring and preparing underserved middle school students for computer science: a descriptive case study of the UNC Charlotte/Wilson STEM Academy Partnership, *School community journal,* May/June *School Community Journal*, 34, (1), 17-58. http://www.schoolcommunitynetwork.org/SCJ.aspx
Mickelson, R., Mikkelsen, I., Dorodchi, M., Cukic, B., & Horn, T. (2022). Fostering greater persistence among underserved computer science undergraduates: A descriptive study of the I-PASS Project. *Journal of College Student Retention: Research, Theory, & Practice.* https://doi.org/10.1177/15210251221086928
Miles, M., Huberman, M, & Saldaña, J. (2020). *Qualitative Data Analysis Sourcebook*. 4th Edition. Sage.
Morgan, S. L., Gelbgiser, D., & Weeden, K. A. (2013). Feeding the pipeline: Gender, occupational plans, and college major selection. *Social Science Research*, *42*(4), 989-1005.
North Carolina Department of Public Instruction. (2022). *Computer Science and Technology Education*.
Rainey, K., Dancy, M., Stearns, E., & Moller, S. (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. *International Journal of STEM Education,* 6(6), 1-13.
Rogers, M. E., & Creed, P. A. (2011). A longitudinal examination of adolescent career planning and exploration using a social cognitive career theory framework. *Journal of Adolescence*, *34*(1), 163-172.
Rubin, H., Rubin, I. (2012). *Qualitative Interviewing: The Art of Hearing Data*. 3d Edition. SAGE.
Settle, A., & Perkovic, L. (2010). Computational thinking across the curriculum: A conceptual framework. Technical Reports. Paper 13. http://via.library.depaul.edu/tr/13.
Settle, A., Franke, B., Hansen, R., Spaltro, F., Jurisson, C., Rennert-May, C., & Wildeman, B. (2012, July). Infusing computational thinking into the middle-and high-school curriculum. In *Proceedings of the 17th ACM annual conference on Innovation and technology in computer science education* (pp. 22-27).

University of North Carolina System. (2018). Insight Data Mart, Reports and Data Tables, Year 2018.

University of North Carolina at Charlotte & Charlotte-Mecklenburg School District. (2022). Memo of Understanding Regarding the UNC Charlotte/College of Computing and Informatics and Wilson Middle School STEM Academy Partnership.

U.S. Bureau of Labor Statistics. (2023).Occupational Outlook Handbook, Computer, and Information Research Scientists. https://www.bls.gov/ooh/computer-and-information-technology-research scientists.html (visited May 10, 2023)

U.S. Census Bureau (2018). American Community Survey (ACS), One-Year Public Use Microdata. Sample I-PUMS). https://census.gov/programs-survey/acs/cirodata.html

Vincent-Ruiz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education, 5*(1), 48. https://doi.org/10.1186/s40594-018-0140-5

Voskoglou, M. G., & Buckley, S. (2012). Problem solving and computational thinking in a learning environment. *arXiv preprint arXiv:1212.0750*.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Wing, J. M. (2011). Research notebook: Computational thinking—What and why. *The link magazine* 6 (2011): 20-23.

Woods, C. S., & Domina, T. (2014). The school counselor caseload and the high school-to-college pipeline. *Teachers College Record*, *116*(10), 1-30.

Zweben, S., & Bizot, B. (2022). 2022 Taulbee Survey. Computer Research Association. cra.org/crn/wp-contents/uploads/sites/7/2023/05/2022-Taulbee-Survey-final.pdf , Retrieved 28 May 2023.