IEEE STCBP
RESPECT
CONFERENCE

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Conference Proceedings

Portland, Oregon & Online Virtual Conference
March 11, 2020

with technical sponsorship by the
IEEE Special Technical Community for Broadening Participation

Christina Gardner-McCune, Nicki Washington, Edward Dillon, Gloria Washington, and Jamie Payton, editors

IEEE Catalog Number CFP20B73-USB
978-1-7281-7171-5

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

IEEE Catalog Number CFP20B73-USB
978-1-7281-7171-5

RESPECT 2020 | TABLE of CONTENTS

SHORT RESEARCH PAPERS

EXPERIENCE REPORTS

RPP FOR CS PAPERS

PANELS

LIGHTNING TALKS

POSTERS

RESPECT 2020 | CONFERENCE WELCOME

Welcome to **RESPECT 2020**, the fifth convening of the **Conference for Research on Equity and Sustained Participation in Engineering, Computing, and Technology!** RESPECT aims to build a strong community, theory, and foundation for broadening participation research. Our 2020 conference celebrates our fifth-year anniversary and this year's theme - "Learning from the past. Building for the future" - reflects on where we've come and where we're headed in the next five years. We are excited to partner with the RPPforCS community for a second year to continue expanding our reach into K-12 and evaluation communities to broaden research in these areas. The conference convened over 180 attendees from K-12 educators, administrators, and support; two/four-year university faculty, graduate students, and postdocs; research & evaluation firms; advocacy organizations, and corporations. This year, we continued to expand the reach of the conference to faculty at community colleges, teaching universities, and HBCUs.

As the entire world grappled with the onset of COVID-19, the RESPECT Organizing Committee faced growing concerns regarding the spread in the United States (especially in the state of Oregon) and its impact on conference attendance. It was ultimately determined that it was best to transition the conference from in-person in Portland to a virtual and live-stream format, thereby allowing for not only full participation of all advanced registrants, but also additional attendance by those who were previously limited due to travel funding. This virtual attendance option provided even more equitable access to the conference than would've been possible with the original onsite implementation.

The Organizing Committee was joined by an additional team of 15 researchers, practitioners, and graduate students who helped to quickly transition the full conference program (including all sessions and presentations) to Zoom within 48 hours. For those participants who still traveled to Portland, an onsite team traveled and managed technology and audiovisual setups for participation in the Zoom sessions.

The RESPECT 2020 research track includes research papers, experience reports, posters, and lightning talk presentations that (1) examine barriers to equity and inclusion that impact the representation of women, people of color, and people with disabilities across the entire CS education and workforce pipeline; (2) propose and evaluate interventions to promote inclusive in computer science classrooms, including through K-12 teacher preparation; and (3) describe approaches to making equity and inclusion a first principle for CS education strategies at the school and state levels.

This year's **plenary panel, "The Past, Present, and Future of RESPECT," features a conversation among panelists Gail Chapman, Rafi Santo, and Nicki Washington** about the values of our community and how to put those values into action through research and practice. Finally, the program includes a variety of thought-provoking panels, lightning talks, and posters on broadening participation - we hope that you'll be drawn into a lively discussion of new ideas and emerging results.

RESPECT 2020 had a total acceptance rate of 34% for full research papers, 19% for short research papers, 41% for experience reports, and 58% for posters. Each submission was carefully reviewed by at least three members of the Program Committee (PC), and recommendations were provided to the Program Chairs. Final acceptance decisions were based on reviewer scores and Program Chair recommendations, with careful consideration of novelty, relevance, and significance, and diversity of the program. As an inclusive community, we strive to give contributors a voice at the conference.

RESPECT 2020 | CONFERENCE WELCOME

Three papers across the full & short research papers and experience reports were recognized as RESPECT 2020 Best Papers:

- Full Research Paper: "Building Systemic Capacity to Scale and Sustain Equity in Computer Science: A comprehensive model of professional learning for teachers, counselors, and administrators"
  Julie Flapan, Jean Ryoo, and Roxana Hadad, University of California, Los Angeles

- Short Research Paper: "The iAAMCS Ecosystem: Retaining Blacks/African-Americans in CS PhD Programs"
  Jeremy Waisome, Jerlando Jackson, and Juan Gilbert, University of Florida

- Experience Report: "Using Black Music as a Bridge to Understanding Introductory Programming Concepts"
  David James and Lelia Hampton, Spelman College

RESPECT is supported by technical co-sponsorship from the IEEE Computer Society and IEEE Special Technical Community on Broadening Participation (STCBP). As attendees of the conference, we invite you to join the IEEE STCBP to continue to sustain the connections, ideas, and energy you discover at RESPECT!

With many thanks to the IEEE Program Committee for their thoughtful reviews and the RESPECT authors and panelists for their contributions to the RESPECT program and full participation in the virtual and live stream in Portland. We extend a special thanks to the many volunteers who responded to the call to move RESPECT 2020 online in 48 hours. We could not have made this monumental transition online without your initiative, leadership, and genuine concern for the RESPECT community.

CONFERENCE CHAIRS

Nicki Washington
Duke University

Christina Gardner-McCune
University of Florida

PROGRAM CHAIRS

Gloria Washington
Howard University

Edward Dillon
Morgan State University

STEERING COMMITTEE

Jamie Payton
Temple University

Tiffany Barnes
NC State University

PANEL & LIGHTNING TALK CHAIR

Siobahn Day Grady
North Carolina Central University

POSTER CHAIR

Aleata Hubbard Cheuoua
WestEd

RPPforCS

Alan Peterfreund
Stacey Sexton
Sagefox Consulting

RESPECT 2020 | ORGANIZING COMMITTEE

Conference Chairs
Christina Gardner-McCune, University of Florida
Nicki Washington, Duke University

Program Chairs
Edward Dillion, Morgan State University
Gloria Washington, Howard University

Panel & Lightning Talk Chair
Siobahn Day, University of North Carolina Greensboro

Poster Chair
Aleata Hubbard Cheuoua, WestEd

Volunteer Chair
Yerika Jimenez, University of Florida

RPPForCS Meeting Chairs
Alan Peterfreund, SageFox Consulting Group
Stacey Sexton, SageFox Consulting Group

Steering Committee Chairs
Tiffany Barnes, North Carolina State University
Jamie Payton, Temple University

Virtual Conference Committee
Raquel Boulware, Claflin University
Kirsten Peterson, Education Development Center (EDC)
Yihuan Dong, North Carolina State University
Sarah Dunton, ECEP Alliance
Pedro Feijoo-Garcia, University of Florida
Amanpreet Kapoor, University of Florida
Anne Leftwich, Indiana University
Melissa Perez, University of Michigan
Rose Pozos, Stanford University
Jean Salac, University of Chicago
Ryan Torbey, ECEP Alliance

Live Stream @ Portland Committee
Veronica Catete, North Carolina State University
Joseph Isaac, Jr., University of Florida
Nick Lytle, North Carolina State University
Melissa Perez, University of Michigan

Proceedings Chairs
Christina Gardner-McCune, University of Florida
Nicki Washington, Duke University
Jamie Payton, Temple University

RESPECT 2020 | PROGRAM COMMITTEE

Adesola Adebayo, Sterling Bank
Monica Anderson, The University of Alabama
Marvin Andujar, University of South Florida
Bushra Anjum, Amazon
Gonzalo Bello, University of Illinois at Chicago
Elodie Billionniere, Miami Dade College
Brianna Blaser, University of Washington
Gedare Bloom, University of Colorado, Colorado Springs
Julian Brinkley, Clemson University
Cassandra Broneak, Mobile CSP
Legand Burge, Howard University
Curtis Cain, Howard University
Martine Ceberio, University of Texas at El Paso
Amlan Chatterjee, California State University, Dominguez Hills
Radhouane Chouchane, Columbus State University
Merijke Coenraad, University of Maryland
Bojan Cukic, University of North Carolina, Charlotte
Hillaary Fleenor, Columbus State University
Tonya Frevert, University of North Carolina, Charlotte
Megean Garvin, University of Maryland, Baltimore County
Olga Glebova, Georgia State University
Lynne Grewe, California State University, East Bay
Jean Griffin, Google
Jason Hallstrom, Florida Atlantic University
Leshell Hatley, Coppin State University
David Heise, Lincoln University
Sepehr Hejazi Moghadam, Google
Thorna Humphries, Norfolk State University
Diane Igoche, Robert Morris University
Ketly Jean-Pierre, Howard University
Erin Johnson, CodeCrew
Erin Johnson, CodeCrew
Emmanuel Johnson, Institute for Creative Technology
Andrea Johnson, Spelman College
Elva Jones, Winston-Salem State University
Prasaun Joshi, Cisco
Zaina Kalyankolo, Kampala International University
Mary Ann Leung, Sustainable Horizons Institute
Lin Li, Prairie View A&M University
Na Li, Prairie View A&M University
Nicholas Lytle, North Carolina State University
Mani A., International Rough Set Society

RESPECT 2020 | PROGRAM COMMITTEE

Brandeis Marshall, Spelman College
Marlon Mejias, University of North Carolina, Charlotte
Terry Miller, Alabama A&M University
Alvaro Monge, California State University Long Beach
Deidra Morrison, Claflin University
Sarah Msaud, Redhat
Srinidhi Nandakumar, Vmware, Inc.
Deveeshree Nayak, University of Memphis
Ebel Nwafor, Villanova University
Jared O'Leary, BootUp PD
Imani Palmer, FNA
Dhaval Parmar, Northeastern University
Graciela Perera, Northeastern University
Enrico Pontelli, New Mexico State University
Yolanda Rankin, Spelman College
Yasmeen Rawajfih, Tuskegee University
Mimi Recker, Utah State University
Shanon Reckinger, University of Illinois at Chicago
Rosario Robinson, FocusGears
Navid Sabbaghi, Saint Mary's College of California
Paul Salvador Inventado, California State University, Fullerton
Akrati Saxena, National University of Singapore
Cheryl Seals, Auburn University
Stacey Sexton, SageFox Consulting Group
Rachna Shriwas, Cisco
Murali Sitaraman, Clemson University
Amber Solomon, Georgia Institute of Technology
Katharine St. John, City University of New York
Allison Sullivan, The University of Texas at Austin
Nargis Sultana, USPTO
Cheryl Swanier, Claflin University
George Thiruvathukal, Loyola University Chicago
Gloria Townsend, DePauw University
Jeremy Waisome, University of Florida
Janett Walters-Williams, Hampton University
Briana Wellman, The University of District Columbia
Dale-Marie Wilson, University of North Carolina, Charlotte
Rae Wright, ACTBLUE
Jinghua Zhang, Winston-Salem State University

A

B

C

D

RESEARCH PAPERS

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Portland, Oregon & Online Virtual Conference
March 11, 2020

Why is Data on Disability so Hard to Collect and Understand?

Brianna Blaser
DO-IT Center
University of Washington
Seattle, WA, USA
blaser@uw.edu

Richard E. Ladner
Paul G. Allen School of Computer Science and Engineering
University of Washington
Seattle, WA USA
ladner@cs.washington.edu

***Abstract*—This report explores why data on disability is so hard to collect and understand. There is a reluctance to collect data by the broadening participation in computing (BPC) community even though disability is a recognized demographic in broadening participation. As a result, much less is known about the participation of people with disabilities in computing education and careers than some other groups. The reasons for this reluctance are multi-faceted. Data about disability can vary significantly depending on how you ask the question, making it difficult to understand what the data is actually indicating. Questions about functional limitations may overinflate the numbers of some populations with disabilities while undercounting other groups. This report will help the BPC community move towards collecting and reporting data on disability. Advice is given on how to ask about disability status and resources are provided to find existing data sources about disability.**

Keywords—disability, data, survey questions

I. Introduction

Those of us who work on broadening participation in computing (BPC) are to a great degree data driven. We track the percentage of women and underrepresented minorities who are enrolled in and graduate from computer science programs, and who take high school computer science courses in order to see if our interventions are actually working. For disability, however, it is a different story. It seems that there is reluctance in our community to tracking the participation of students with disabilities even though approximately 15% of K-12 students and 11% of college students have a disability.

To drive this home, we recently examined the “2019 State of Computer Science Education” report, which reviews how states are doing in implementing K-12 computer science education [1]. Indeed, the report is subtitled “Equity and Diversity” to emphasize how the organizations sponsoring the report—the Code.org Advocacy Coalition, the Computer Science Teachers Association, and Expanding Computing Education Pathways—view the importance of BPC. The report is full of relevant data about women, underrepresented minorities, and rural students, but there is nothing about students with disabilities. The word “disability” does not appear in the report. It’s as if people with disabilities don’t exist or matter when thinking about BPC.

This report was created with the support of National Science Foundation Grants numbers CNS-1539179 and CNS-1738252.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

Other organizations that play a central role in BPC are also not collecting or reporting data on disability. The well-known Computing Research Association (CRA) Taulbee Survey on the state of computer science departments does not collect disability data, although it does collect data on gender, race, and ethnicity [2]. The College Board does not ask Advanced Placement exam takers if they have a disability. While they do have data about disability-related accommodations requests from exam takers, they do not publish that information despite the fact that they publish information about the participation of girls and underrepresented minorities [3].

Disability is mostly absent in broadening participation research, policy, and practice [4]. Quantitative efforts rarely ask about disability and if they do, they don’t analyze the data with respect to disability. [4, 5, 6]. Edlyn Vallejo Peña states “When scholars, researchers, and editors of top-tier journals do not engage in or include scholarship on students with disabilities, even if unintentionally, they communicate that understanding these needs and interests is less important than other issues in higher education” [6, p. 38]. We find this statement particularly powerful. When the BPC community does not engage on issues related to disability, it is problematic.

One notable exception is the CRA’s Data Buddies [7]. Data Buddies collects data from students and faculty members in computing departments nationwide and shares customized department reports with each institution about their students. Among the items on the survey, is a question about disability. Departmental reports include information about the number of students with disabilities in a department and the types of disabilities they have. Departments can also request to have their students’ data broken down by disability.

The Americans with Disabilities Act defines disability as “a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment” [8]. The social model of disability views disability as the “limit or loss of opportunities to take part in community life because of physical and social barriers" [9, pp. 103]. This is a heterogeneous group including individuals who are blind or visually impaired, who are deaf or hard of hearing, who are autistic or have learning disabilities, who have mobility-related disabilities, who have mental health disabilities, and more.

The purpose of this paper is to explore reasons why we are not collecting high quality data on disability and offer suggestions on how the BPC community can begin doing so, either by collecting that data directly or by employing various national data sources. We believe that all of us who are working in BPC do care and consider people with disabilities to be a group that is disadvantaged and worthy of receiving interventions to increase their participation. And indeed, there is evidence that people with disabilities are underrepresented in employment and in STEM education. The U.S. Department of Labor reports that in 2018 only 30.4% of persons aged 16 to 64 who have a disability are employed as compared to 74.0% for those without a disability [10]. The 2015-16 Civil Rights Data Collection STEM Course Taking Report (in their Figure 10) shows that students with disabilities are underrepresented in STEM courses taught in high schools around the nation [11].

We can think about disability data as existing on two levels: (1) large, publicly-available existing data collections and (2) data collected within a research project, department, or organization. Many existing data collections, such as the Survey of Earned Doctorates and the Census Bureau's American Community Survey, do collect information about disability. Beyond those datasets, those of us working in BPC should be empowered to collect information regarding disability within our projects, departments, or institutions and consider whether individuals with disabilities are successfully participating. For a particular project or institution, data can be obtained in a consistent manner to track progress at an institution or on a particular intervention.

In the following sections we cover reasons why disability status data is not collected, problems with existing data collections, operationalization of disability, and best practices in collecting disability status data.

II. Why Disability Status Data is Not Collected

Through our involvement in AccessComputing, one of the National Science Foundation's BPC Alliances, we have asked our colleagues in the BPC community why they aren't collecting data on disability. Answers vary, but include the following:

- We focus on increasing the number of women (or underrepresented minorities) in computing, so we don't ask for other demographic data.
- Asking about disability is more sensitive than asking about race or gender.
- Data about disability was not listed in our Institutional Review Board (IRB) application.
- IRB won't let us ask about disability.
- We don't know who to ask for the data: the school, the teacher, or the individual.
- Data on disability is considered to be confidential, so we don't ask.
- We don't know what to ask. There seems to be no standard definition of disability.
- Disability data is unreliable because people with a disability might not want to disclose due to stigma.
- Our institution doesn't systematically collect data about disability.
- Our institutional data isn't accurate because we know people don't disclose to disability services.
- The information is difficult to access when obtaining data from institutions.

These are not sufficient reasons to ignore disability altogether in our broadening participation efforts.

The technical notes of the National Science Foundation report *Women, Minorities, and Persons with Disabilities in Science and Engineering* echoes many of these issues, including an inconsistent definition of disability, lack of institutional records, difficulties with self-reported data, and issues with changing the questions asked on a variety of surveys [12].

III. Problems With Data Collections: A Case Study

The United Nations, governmental agencies, and educational institutions at all levels collect and report on disability. In the U.S., the Census Bureau, the National Center for Education Statistics (NCES), the National Center for Science and Engineering Statistics (NCSES), the Civil Rights Data Collection (CRDC) and the Bureau of Labor Statistics (BLS) all collect data on disability, although not always in the same way. In these data collections and elsewhere, the incidence rates of disability will vary depending upon how disability is defined and how questions related to disability are asked [13]. The World Bank has reports on problems with the consistency of disability data internationally [14].

Even though the word "disability" has been accepted nomenclature since at least 1990 when the Americans with Disabilities Act was passed, there is an international trend to not use the word "disability" itself in survey questions, but to ask instead about functional limitations. The consequences of moving from one nomenclature to another are apparent in the data from the Survey of Earned Doctorates (SED) prepared by NCSES. This survey has been given to all students graduating with a doctorate in the US every year since 1957 and reports are released annually. Figure 1 shows 14 years of data, tracking the percentage of doctorates in all fields who have a disability.

As you can see, the percentage of doctorates with disabilities rose from 1.5% in 2004 to 7.2% in 2017, a remarkable increase over such a short period. If you look more closely, there are two steps in increase, first in 2010 and again in 2012. Furthermore, the percentage was a fairly steady around 1.5% between 2004 and 2009, jumped in 2010, and rose steadily between 2012 and 2017. How can this chart be explained? The principal

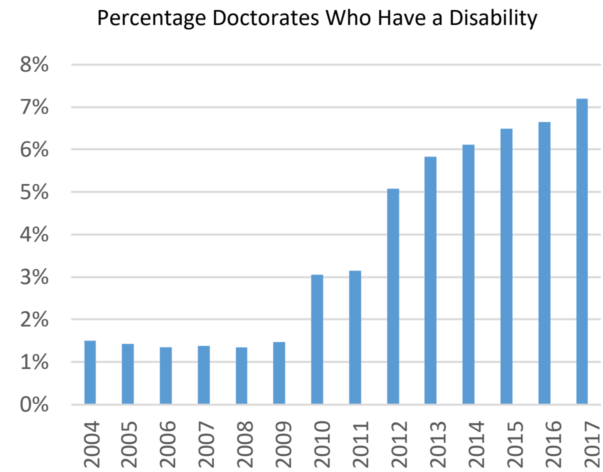


Fig. 1. Percentage of doctorates who have a disability between 2004 and 2017.

explanation is that the question about disability changed twice, first in 2010 and then again in 2012.

Figures 2, 3, and 4 have the questions asked between 2004 and 2009, in 2010 -2011, and between 2012 and 2017, respectively.

For the years 2012-2017, respondents were designated as disabled if the degree of difficulty of completing a task was moderate, severe, or unable to do. This question gathers data about functional limitations instead of disability identity, which is what was asked about in prior years.

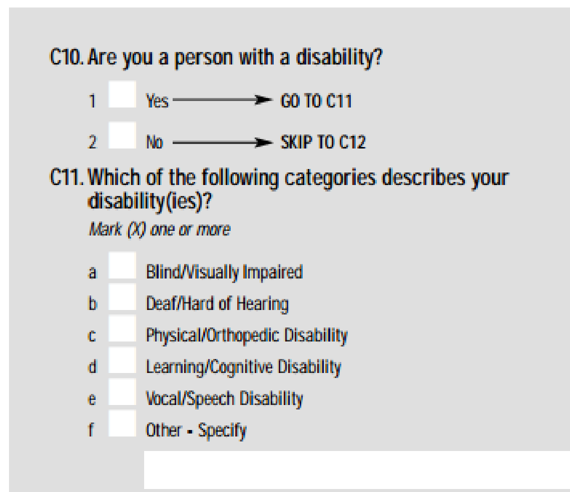
A closer look demonstrates the problem further. According to NCES (Table 204.30), about 0.1% of children age 3 to 21 students have a visual impairment [15]. According to the SED, in 2011, 0.6% of new doctorates were "blind/visually impaired" and in 2017, 3.1% of new doctorates had "visual limitations" from moderate to unable to do. How can 0.1% become 3.1%, more than a factor of 30, unless they are counting fundamentally different people? It should be noted that the SED is self-reported data, while NCES data is from schools who provide services through the Individuals with Disabilities Education Act (IDEA). As the IDEA students have to document their disabilities to receive services and it would be unlikely that there are people with visual impairments who are not receiving accommodations, this number should be fairly accurate.

This problem with using functional limitation questions is apparent when looking at people who are unemployed due to "chronic illness or permanent disability." In 2017 National Survey of College Graduates (NSCG) data 700,000 scientists and engineers who are unemployed due to chronic illness or permanent disability, 178,000 (25.4%) are identified as not having a disability because of the way they answered questions related to functional limitations [16]. The ADA definition of disability considers someone to be disabled if they have a condition that impacts a major life activity, including working. By that definition, 100% of people unemployed due to chronic illness or permanent disability have a disability.

IV. Understanding Existing Surveys on Disability

Many other surveys have moved away from the use of the term "disability" [17]. The SED and organizations such as the United Nations and the US Census Bureau's American Community Survey (ACS) all use questions that measure functional limitations rather than those that measure disability identity in their surveys. Unfortunately, there is no agreement on the functional limitation language. For blindness, the UN and ACS use the language "serious difficulty seeing," while SEC uses the range "moderate" to "unable to do." The situation is so confusing that the National Federation of the Blind simply reports all the different percentages on blindness on their web page addressing data [18].

We admit that we do not fully understand the movement away from "disability" nomenclature. It could be motivated by the word "disability" having a stigma attached. Indeed, the guidelines recommended by the UN explicitly state not to use


C10. Are you a person with a disability?

1 Yes → GO TO C11

2 No → SKIP TO C12

C11. Which of the following categories describes your disability(ies)?

Mark (X) one or more

a Blind/Visually Impaired

b Deaf/Hard of Hearing

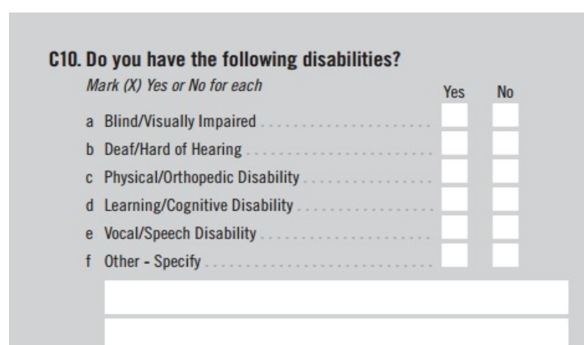
c Physical/Orthopedic Disability

d Learning/Cognitive Disability

e Vocal/Speech Disability

f Other - Specify

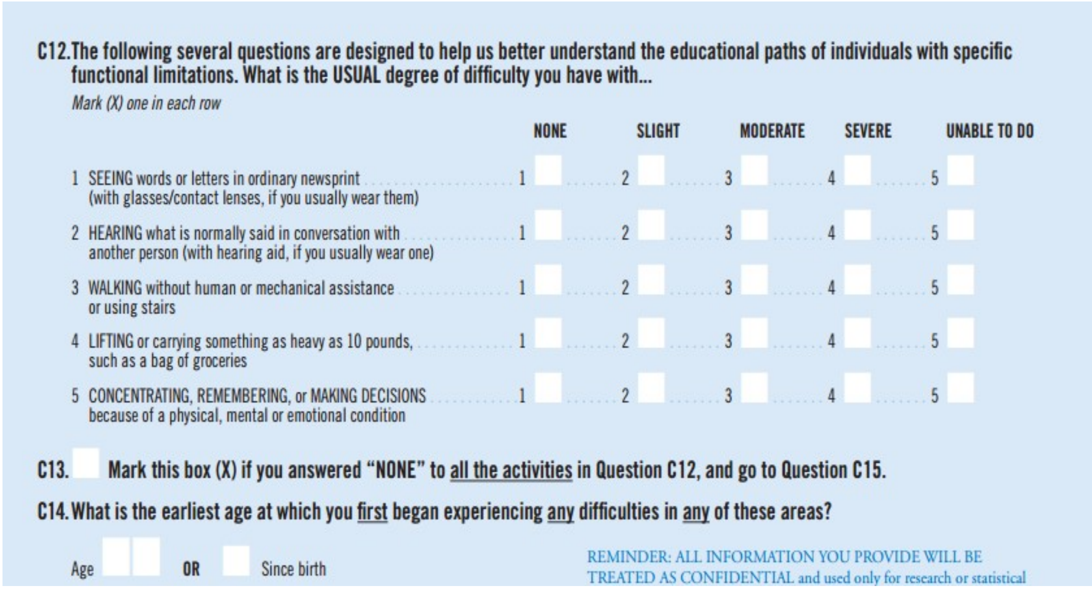
Fig. 2. Survey of Earned Doctorates disability question 2004-09


C10. Do you have the following disabilities?

Mark (X) Yes or No for each

	Yes	No
a Blind/Visually Impaired		
b Deaf/Hard of Hearing		
c Physical/Orthopedic Disability		
d Learning/Cognitive Disability		
e Vocal/Speech Disability		
f Other - Specify		

Fig. 3. Survey of Earned Doctorates disability question 2010-11



C12. The following several questions are designed to help us better understand the educational paths of individuals with specific functional limitations. What is the USUAL degree of difficulty you have with…

Mark (X) one in each row

	NONE	SLIGHT	MODERATE	SEVERE	UNABLE TO DO
1 SEEING words or letters in ordinary newsprint (with glasses/contact lenses, if you usually wear them)	1	2	3	4	5
2 HEARING what is normally said in conversation with another person (with hearing aid, if you usually wear one)	1	2	3	4	5
3 WALKING without human or mechanical assistance or using stairs	1	2	3	4	5
4 LIFTING or carrying something as heavy as 10 pounds, such as a bag of groceries	1	2	3	4	5
5 CONCENTRATING, REMEMBERING, or MAKING DECISIONS because of a physical, mental or emotional condition	1	2	3	4	5

C13. Mark this box (X) if you answered "NONE" to all the activities in Question C12, and go to Question C15.

C14. What is the earliest age at which you first began experiencing any difficulties in any of these areas?

Age OR Since birth

REMINDER: ALL INFORMATION YOU PROVIDE WILL BE TREATED AS CONFIDENTIAL and used only for research or statistical

Fig. 1. Survey of Earned Doctorates disability question 2012-17

the word "'disability' or other negative terms and phrases" [19]. Many people with disabilities would cringe at the assertion that "disability" is a negative term. The person-first language, for example using "person with a disability" instead of "disabled person," seems to imply that "disability" is a secondary trait that is stigmatized. Organizations of (not for) people with disabilities tend not to use person-first language because they do not believe that their disability is stigmatizing. Examples of such organizations are the National Federation of the Blind, National Association of the Deaf, and the Autism Self Advocacy Network. Increasingly, disabled people are embracing disability-first language, an indicator that "disability" is not as stigmatizing as it once was [20, 21, 22].

For a number of reasons, we do not recommend adopting the functional limitations measures. First, there is no agreement on how to ask the question. Is "moderate difficulty," "severe difficulty," or "serious difficulty" the standard for having a disability? What set of functional limitations do you focus on? Second, the concept of functional limitation is not one that people readily understand. It seems to apply nicely to seeing, hearing, and walking, but what about other disabilities such as learning disabilities, attention deficit, anxiety, and autism. The percentage rise from 2012 and 2017 in Figure 1 demonstrates the confusion about the question. Clearly, the understanding of this question by new doctorates changed during this period. Although the meaning of the word "disability" has changed over time, it is relatively stable and far less stigmatizing than it was in the past.

And yet, arguments for asking about functional limitations seems compelling. These disagreements are part of what make collecting data on disability difficult. Internationally, surveys that ask someone if they identify as disabled have the lowest rates of disability [17]. The UN Washington Group on Disability Statistics argues that even though it will miss some people with disabilities asking about functional limitations will identify the majority of them [19]. Furthermore, advocates for these questions argue functional limitation questions fit within a social model of disability that views disability as an interaction between environment and a person whereas a question asking about disability fits within a medical model of disability that views disability as a problem within the person [13].

Overall, there's a lack of clarity when examining the definitions of disability as used in theoretical models, legal terminology, and lay usage [23]. Indeed, sociologist Barbara Altman argues:

> Disability is a complex social phenomenon that involves the interaction of individuals with specific limitations, possibly due to a physical impairment, with their identity, their physical and social surroundings, and the societal culture and normative systems. Disability, then, is undefinable empirically unless one reduces the focus of the definition to a specific aspect of experience [23, p. 80].

In BPC research, we need to determine what aspects of disability we are interested in when constructing questions about disability status.

V. Defining Disability

There is a need to define disability in order to identify who should receive services or accommodations. As a result, in education and employment settings, conversations about the representation of people with disabilities and conversations about services or accommodations are necessarily intertwined. Generally, students and employees are identified as having a disability if they qualify for and receive accommodations like documents in alternative formats, extended time on tests, flexible work hours, or interpreting services. To qualify, a person must have documentation of their disability by a recognized professional. Many individuals who have a disability that do not register with disability services for a variety of reasons.

A. PreK-12 Education

In the PreK-12 education setting there is more uniformity with regard to what constitutes a disability than in other settings because of two laws: the Individuals with Disabilities Education Act (IDEA) [24] and Section 504 of the Rehabilitation Act of 1973 [25]. Students with a documented disability may receive accommodations under either law. Under IDEA, the student will have an Individualized Education Program (IEP) that includes specifics about the students' education goals and accommodations that a student will receive. The education goals and accommodations are designed to meet the individual needs of the student. The education goals may be different than those of other students in the same school. A student with a Section 504 Plan has the same education goals as other students, but may need some accommodations to help meet those goals. Accommodations may include extra time on exams because of a learning disability, screen reader access to computers because of blindness, or a sign language interpreter because of deafness. The student, their parents, teachers, and administrators all know if they are covered under IDEA or Section 504.

IDEA requires states to collect data about PreK-12 students with disabilities [26]. The number of students covered under IDEA and Section 504 has varied over time, but is relatively stable. One striking change has been the number of students with autism who have been identified over the past 10 years. In 2008-9 the number was 336,000 nationwide and in 2017-8 the number had almost doubled to 710,000 [14]. There is also some variation in the application of these laws by state. For example, in 2017-8, in Texas only 9.2% of students are covered under IDEA, while the percentage in Pennsylvania is 18.6% [14].

In addition to NCES, the Office for Civil Rights in the Department of Education maintains data in its Civil Rights Data Collection (CRDC) [27]. Reports are published annually on the student demographics, including disability status, of participation in STEM courses. Since 2017-2018, data on computer science courses has been collected, but has not yet been reported on.

As states implement policy related to PreK-12 computer science (CS) education, some are enacting laws that require data collection about computer science education in their state. In Washington State, HB 1577 requires data collection about CS education, including demographic data of students enrolled in CS courses starting in 2020 [28]. Specifically, the special education status of students enrolled in CS courses must be reported. We hope to see other states follow suit to collect data about all students with disabilities taking PreK-12 CS courses.

B. Postsecondary Education

Students with disabilities at the postsecondary level are guaranteed access by Section 504, but not under IDEA. The educational goals for these students are the same as for the rest of the student body. Colleges are required by law to provide accommodations for students with disabilities; however, unlike in K-12 education, students must request those accommodations from an office of disability resources for students (DRS). To receive accommodations the disability must be documented. Students who are employed as a teaching assistant, research assistant, or otherwise on campus and need accommodations for their employment may need to request those services from an office of disability resources for employees. In such situations, disabled students may have to deal with two offices.

Unlike PreK-12, there are no regulations requiring colleges to report on students with disabilities [26]. Typically, in their offices of institutional research, colleges track data about disability. There is likely data about whether a student received accommodations. Some colleges ask about disability in the college application, in which case that data is in a student's record as well. Naturally, an individual student's data is protected by the Family Educational Rights and Privacy Act (FERPA). Publishing of aggregate data, however, does not violate FERPA. Nonetheless, colleges rarely publish aggregate data about students with disabilities whereas they often do publish data about gender and minority status.

Regardless, aggregate data about disability may be available by request to the office for institutional research. Computing departments can track this data as part of the work they are doing related to BPC in their own departments. In working with partners at institutions across the country, we have found that many computing departments struggle to obtain and report on institutional data. Some institutions did not agree to provide information to faculty, while others blamed updates of databases, DRS records that did not include information about students' majors, or paper-based systems within their DRS office. Even if you are able to successfully obtain institutional data, it will necessarily undercount students with disabilities. Some students in postsecondary settings are unable to get adequate documentation, which can be costly to procure, in order to get accommodations [29]. Other students fail to disclose because of concerns around stigma [30, 31].

In 2016, 88% of students who participated in the Data Buddies survey disclosed disability information. 8% indicated that they have a disability [32]. The overwhelming majority (68%) had cognitive disorders (attention deficits, autism, or mental health disabilities). 12% of students had learning disabilities and 12% reported sensory disabilities (vision, hearing, or speech-related disabilities). In 2017 data from Data Buddies, students with disabilities were significantly more likely to report feeling like an outsider (32%) than majority men without disabilities (17%) [33]. Women with disabilities (46%) and underrepresented minorities with disabilities (45%) were the most likely to report feeling like an outsider. Findings such as this highlight the importance of including disability in conversations about BPC.

C. Employment

Section 504 and the ADA protect the rights of people with disabilities in employment. Employers must provide reasonable accommodations to employees with disabilities. Like in the postsecondary setting, to receive accommodations disabled people need to disclose their disability to their employer and provide documentation. Some people with disabilities may decide not to officially disclose to their employer because they do not require accommodations in a work setting.

The 2017 Survey of Doctorate Recipients found that among doctorate holders employed in universities and 4-year colleges working as computer and information scientists, 8.5% have a disability [34]. This is comparable to the 9.4% of doctorate holders that have a disability across all occupations. The 2017 NSCG found that 9.1% of employed computer and information scientists have a disability compared to 10.3% of all employed scientists and engineers [16]. Note that this survey uses functional limitation questions to ask about disability status.

Recent years have seen several large tech companies release diversity reports about their workforce. Until very recently, very few of these reports contained information about disability. A 2016 article from TechCrunch interviewed seven major companies, none of whom had included information about disability in their diversity reports [35]. Many companies pointed to inclusion efforts related to disability or their work in accessibility but refrained from talking about why they weren't reporting on disability representation in their companies. In the time since that article was written, more companies—including some interviewed for the TechCrunch article—have released disability-related data.

- Clover has reported that company-wide, 8% of their employees have a disability [36].
- Google has reported that of the 39% of global employees who self-identified, 7.5% have a disability [37].
- LinkedIn has reported that 1.6% of US employees had a disability [38].
- Slack has reported that 1.7% of their U.S. workforce identified as having a disability but notes that this statistic is based on the small number of employees who have chosen to disclose [39].

The variability between these data points to some of the difficulties with collecting this information. Different questions or different data sources could lead to wildly different data about the prevalence of disability within these companies.

Beyond data available from companies, Stack Overflow issues an annual survey of developers [40]. In 2019, they received 90,000 responses, 18.0% of respondents reported a mood or emotional disorder, anxiety disorder, concentration or memory disorder, or autism. In terms of physical disabilities, 1.5% blind or difficulty seeing, 0.8% deaf or hard of hearing, 0.3% difficulty walking or standing, and 0.3% difficulty typing. Because of the way this question is asked, it's not clear whether all of these individuals have a disability. For example, not everyone with an anxiety or mood disorder necessarily has a disability, although there are certainly some of them may have a mental health disability.

VI. Best Practices for Collecting Disability Data

We encourage computer science education researchers to ask about disability when they are collecting demographic data from participants. Recent work has explored best practices for asking about gender on surveys in the area of human computer interaction [41]; similar recommendations with regard to disability could move forward conversations about individuals with disabilities in computing education and employment. Using a variety of measures to inquire about disability status is problematic in that different measures will classify individuals differently [23, 42]. As a result, it's important that the BPC community adopt consistent measures.

When working with preK-12 students, researchers can ask whether a student has an IEP or 504 Plan or explore the use of institutional records to obtain this information. Teachers will know whether students in their classes have an IEP or 504 Plan. In the context of CS education, we are interested in asking about disability status in order to determine how a disability has impacted a student's education. Since most preK-12 students whose education is impacted by a disability should have an IEP or 504 Plan, asking about that is sufficient in identifying students with disabilities in preK-12.

When working with adults, whether looking at students in computing or teachers participating in professional development, the situation is a bit more complicated. As discussed, for a variety of reasons adults may not use accommodations in the context of postsecondary education or employment, so a similar measure wouldn't be sufficient. We feel strongly about avoiding functional limitation questions because of the potential to overestimate some populations, namely those with vision impairments, while also underestimating other populations, including autistic individuals.

Part of the difficulty of determining who has a disability and who does not is that there isn't a black and white line between the groups but rather a fair amount of grey area. Some individuals with mental health diagnoses may identify as disabled whereas others do not. Individuals who have age-related disabilities may hesitate to identify as disabled.

Based on our own experiences and conversations with other experts in disability, people with disabilities, and other stakeholders, we suggest using the following two questions when asking adults about their disability status:

1. Do you identify as having a disability or other chronic condition?
    a. Yes
    b. No
    c. Prefer not to disclose

2. How would you describe your disability or chronic condition?
    a. Attention deficit
    b. Autism
    c. Blind or visually impaired
    d. Deaf or hard of hearing
    e. Health-related disability
    f. Learning disability
    g. Mental health condition
    h. Mobility-related disability
    i. Speech-related disability
    j. Other (please specify)

We feel that addressing disability directly in the question is important. Asking the second question gives the research richer information for analysis. Alternatively, individuals could write-in their specific disability. In our experience, however, this approach can make it difficult to categorize disabilities that may affect individuals in multiple ways. Asking about disability-type is also less invasive than asking someone to specify their exact diagnosis.

A. Where to Find Data

National data on disability is scattered in various tables and reports some of which were mentioned earlier. Principal data sources include the following:

1. National Center for Education Statistics maintains data on PreK-12 education. [43]. NCES periodically publishes a report *The Condition of Education* that covers students with disabilities. They also publish a report titled the *Digest of Education Statistics* that has data about postsecondary students.
2. National Center for Science and Engineering Statistics maintains data on postsecondary education [44]. They administer the Survey of Earned Doctorates [45]. They also maintain an interactive tool for creating custom tables from their data [46]. Unfortunately, this tool is limited and doesn't allow access to disability data.
3. The Department of Education Civil Rights Data Collection (CRDC) includes information about students with disabilities taking various STEM courses nationally [27]. Starting in 2017 they are collecting data on computer science courses.
4. NSF Committee on Equal Opportunities in Science and Engineering has biennial reports to Congress that have data on disability [47].
5. Bureau of Labor Statistics has data on employment including data about disabilities [48].
6. Census Bureau's American Community Survey has general data on disability [49].
7. Centers for Disease Control and Prevention has some data and advice on how to ask about disability status [50].
8. Cornell University Disability Statistics reviews several resources of U.S. disability statistics [51].
9. Disabled World web site reviews disability statistics from a number of resources [52].

VII. Conclusion

Over the last couple of decades, the BPC and computer science education communities have spent a significant amount of time collecting data about and researching the involvement of women and underrepresented minorities in computing education. We'd like to move towards a future where people with disabilities are more substantively included in conversations about diversity in computing. To do this, we need more people to collect data about disability status. We hope this paper can start a discussion about ways to get this data and serve as a call to action to the community.

References

[1] Code.org Advocacy Coalition, Computer Science Teachers Association, and Expanding Computing Education Pathways Alliance, "2019 state of computer science education," USA, 2019. Accessed: Oct 1, 2019 [Online]. Available: https://advocacy.code.org/2019_state_of_cs.pdf

[2] Computing Research Association, "CRA Taulbee survey fact sheet." Accessed Oct 23, 2019 [Online]. Available: https://cra.org/wp-content/uploads/2018/07/CRA-Taulbee-Survey-Fact-Sheet-2018.pdf

[3] College Board, "Participation in AP Computer Science Principles more than doubles 3 years after launch," Jul 31, 2019. Accessed Oct. 23, 2019 [Online]. Available: https://www.collegeboard.org/releases/2019/participation-csp-nearly-doubles

[4] H. Metcalf, D. Russell, and C. Hill, "Broadening the Science of Broadening Participation in STEM Through Critical Mixed Methodologies and Intersectionality Frameworks," *American Behavioral Scientist*, vol. 62, no. 5, pp. 580-599, 2018.

[5] J. C. Garvey, "Demographic information collection in higher education and student affairs survey instruments: Developing a national landscape for intersectionality," in *Intersectionality and higher education: Research, theory, and praxis*, D. Mitchell, C. Simmons, and L. Greyerbiehl, Eds. New York, NY: Peter Lang, 2014, pp. 201-216.

[6] E. V. Peña, "Marginalization of published scholarship on students with disabilities in higher education journals," *Journal of College Student Development*, vol. 55, pp. 30–40, 2014.

[7] Computing Research Association. "The Data Buddies Project." CRA's Center for Evaluating the Research Pipeline. Available: https://cra.org/cerp/data-buddies/ (accessed Dec. 1, 2019).

[8] Americans With Disabilities Act of 1990. Pub. L. 101–336. 26 July 1990. 104 Stat. 328.

[9] B. Altman, "Disability definitions, models, classification schemes, and applications," in *Handbook of Disability Studies*, G. Albrecht, K. Sellman, & M. Bury, Ed., Thousand Oaks, CA: Sage., 2001, pp. 97–122.

[10] Bureau of Labor Statistics, U.S. Department of Labor, "Persons with a disability: Labor force characteristics—2018," News Release, Feb 26, 2019. Accessed Oct 1, 2019 [Online]. Available: https://www.bls.gov/news.release/pdf/disabl.pdf

[11] U.S. Department of Education, Office of Civil Rights. "2015–16 civil rights data collection: STEM course taking," News Release, Apr. 2018. Accessed: Oct 1, 2019 [Online]. Available: https://www2.ed.gov/about/offices/list/ocr/docs/stem-course-taking.pdf

[12] National Science Foundation, "Technical notes," *Women, Minorities, and Persons with Disabilities in Science and Engineering*, Alexandria, VA, USA, Mar. 8, 2019. Accessed: Oct. 1, 2019 [Online]. Available: https://ncses.nsf.gov/pubs/nsf19304/technical-notes

[13] G. T. Fujiura, and V. Rutkowski-Kmitta, "Counting disability," in *Handbook of Disability Studies*, G. Albrecht, K. Sellman, & M. Bury, Ed., Thousand Oaks, CA: Sage, 2001, pp. 69–96.

[14] D. Mont, "Measuring disability prevalence," SP Discussion Paper No. 0706, The World Bank, Mar. 2007.

[15] National Center for Education Statistics, "Table 204.30: Children 3 to 21 years old served under Individuals with Disabilities Education Act (IDEA), Part B, by type of disability: Selected years, 1976–77 through 2017–18," *Digest of Ed. Stats.*, USA, Dec. 2018. Accessed Oct. 1, 2019

[Online]. Available: https://nces.ed.gov/programs/digest/d18/tables/dt18_204.30.asp

[16] L. Milan, “National survey of college graduates,” National Science Foundation, National Center for Science and Engineering Statistics, 2017. Accessed Oct. 1, 2019 [Online]. Available: www.nsf.gov/statistics/srvygrads

[17] K. Miller, D. Mont, A. Maitland, B. Altman, and J. Madans, “Results of a cross-national structured cognitive interviewing protocol to test measures of disability,” *Quality & Quantity*, Vol. 45, Iss. 4, pp. 801–815, Dec. 2010, doi: 10.1007/s11135-010-9370-4.

[18] National Federation for the Blind, “Blindness statistics,” Resources. https://www.nfb.org/resources/blindness-statistics (accessed Oct. 1, 2019).

[19] Washington Group on Disability Statistics, “Disability measurement and monitoring using the Washington Group Disability questions,” Informational Flyer. Accessed Oct. 1, 2019 [Online]. Available: http://www.washingtongroup-disability.com/wp-content/uploads/2016/12/Disability-Measurement-and-Monitoring-Using-the-WG-Disability-Questions-July-2018.pdf

[20] R. W. Mackelprang, "Disability controversies: Past, present, and future," *Journal of Social Work in Disability and Rehabilitation*, vol. 2, no. 3, pp. 87-98, 2010.

[21] J. Sinclair, "Why I dislike person first language," *Autonomy, the Crit Journal of Interdisc. Autism Studies*, vol. 1, no. 2 Oct. 2013.

[22] M. Callahan, "'Autistic person' or 'person with autism': Is there a right way to identify people?" *News@Northeastern*, Jul. 2018. [Online]. Available: https://news.northeastern.edu/2018/07/12/unpacking-the-debate-over-person-first-vs-identity-first-language-in-the-autism-community/

[23] B. Altman, "Definitions of disability and their operationalization, and measurement in survey data: An update," in *Exploring Theories and Expanding Methodologies: Where we are and where we need to go (Research in Social Science and Disability, Vol. 2)*, S. Barnartt and B. Altman, Ed., New York: JAI, 2001, pp. 77–100.

[24] Individuals With Disabilities Education Act, 20 U.S.C. § 1400, 2004.

[25] Office of Civil Rights, “Frequently asked questions about Section 504 and the education of childrens with disabilities,” Protecting Students with Disabilities, USA, Sept. 25, 2018. Accessed Oct. 1, 2019 [Online]. Available: https://www2.ed.gov/about/offices/list/ocr/504faq.html

[26] D. Leake, "Problematic data on how many students in postsecondary education have a disability," *Journal of Postsecondary Education and Disability*, vol. 28, no. 1, pp. 73-87, 2015.

[27] Office of Civil Rights, “Civil Rights Data Collection,” USA, Sept 25, 2018. Accessed Oct. 1, 2019 [Online]. Available: https://www2.ed.gov/about/offices/list/ocr/data.html

[28] U.S. House, 116th Congress, 1st session, (2019, April 17). HB 1577 – 2019–20, Concerning K-12 computer science education data [Online]. Available: https://app.leg.wa.gov/billsummary?BillNumber=1577&Year=2019#documentSection

[29] R. L. Sparks and B. J. Lovett, “College students with learning disability diagnoses: Who are they and how do they perform?” *Journal of Learning Disabilities*, vol. 42, pp. 494–510, 2019, doi: 10.1177/0731948712472185.

[30] J. Martin, “Stigma and student mental health in higher education,” *Higher Education Research & Development*, vol. 29, pp. 259–274, 2010.

[31] K. C. Aquino and J. D. Bittinger, “The self-(un)identification of disability in higher education,” *Journal of Postsecondary Education and Disability*, vol. 32, iss. 1, pp. 5–19, 2019.

[32] B. Tamer, "Cognitive disorders are the most common disability reported by undergraduate students in computing," *Computing Research News*, vol. 29, no. 4, Apr. 2017. [Online]. Available: https://cra.org/crn/2017/04/cognitive-disorders-common-disability-reported-undergraduate-students-computing/

[33] B. Tamer, "Feeling like an outsider in computing? You are not alone!" *Computing Research News*, vol. 31, no. 2, Feb. 2019. [Online]. Available: https://cra.org/crn/2019/02/feeling-like-an-outsider-in-computing-you-are-not-alone/

[34] D. Foley, “Survey of doctorate recipients,” National Science Foundation, National Center for Science and Engineering Statistics, 2017. Accessed Oct. 1, 2019 [Online]. Available: www.nsf.gov/statistics/srvydoctoratework/

[35] S. O’Hear, “Tech companies don’t want to talk about the lack of disability diversity reporting,” TechCrunch, Nov. 7, 2016. Accessed Oct. 1, 2019 [Online]. Available: https://techcrunch.com/2016/11/07/parallel-pr-universe/

[36] J. Wusthoff, “Clover’s 2018 diversity report: Progressing toward best practices,” Medium, Nov. 12, 2018. Accessed Oct. 1, 2019 [Online]. Available: https://blog.usejournal.com/clovers-2018-diversity-report-progressing-toward-best-practices-dff43017cdcc

[37] D. Brown and M. Parker, “Google diversity annual report 2019,” Google. Accessed Oct. 1, 2019 [Online]. Available: https://diversity.google/annual-report/#!#_this-years-data

[38] R. Durruthy, “Creating a thriving community of diverse professionals in tech. Our diversity and inclusion strategy 2018,” Linkedin Careers, Nov. 14, 2018. Accessed Oct. 1, 2019 [Online]. Available: https://careers.linkedin.com/diversity-and-inclusion/workforce-diversity-report

[39] Slack, “Diversity at Slack,” Slack Blog, May 7, 2019. Accessed Oct. 1, 2019 [Online]. Available: https://slackhq.com/diversity-at-slack-2019

[40] Stack Overflow, "Developer survey results 2019." Accessed Dec. 1, 2019. Available: https://insights.stackoverflow.com/survey/2019

[41] K. Spiel, O. L. Haimson, and D. Lottridge, “How to do better with gender on surveys: a guide for HCI researchers,” *Interactions*, vol. 26, iss. 4, pp. 62-65, 2019, doi: 10.1145/3338283

[42] Mathiowetz, N. "Methodological issues in the measurement of persons with disabilities", Barnartt, S. and Altman, B. (Ed.) *Exploring Theories and Expanding Methodologies: Where we are and where we need to go* (*Research in Social Science and Disability*, S. Barnartt .and B. Altman, Eds., vol. 2, Emerald Group Publishing Limited: Bingley, 2001, pp. 125–143.

[43] National Center for Education Statistics, “Home page,” Institute of Education Sciences. https://nces.ed.gov/ (accessed Oct. 1, 2019).

[44] National Center for Science and Engineering Statistics, “National Center for Science and Engineering Statistics,” National Science Foundation. https://www.nsf.gov/statistics/ (accessed Oct. 1, 2019).

[45] K. Kang, “Survey of earned doctorates,” National Science Foundation, National Center for Science and Engineering Statistics, Dec. 2019. Accessed Oct. 1, 2019. Available: https://www.nsf.gov/statistics/srvydoctorates/

[46] National Center for Science and Engineering Statistics, “Introducing the new NCSES interactive tool,” National Science Foundation, ver. 1.4.5, Alexandria VA, USA, Aug 30, 2019. Accessed Oct. 1, 2019. Available: https://ncsesdata.nsf.gov/ids/

[47] Committee on Equal Opportunities in Science and Engineering, “Committee on Equal Opportunities in Science and Engineering,” National Science Foundation. Accessed Oct. 1, 2019. Available: https://www.nsf.gov/od/oia/activities/ceose/index.jsp

[48] United States Department of Labor, “Median weekly earnings of full-time wage and salary workers are $919 in 3rd quarter 2019,” Bureau of Labor Statistics. Accessed Oct. 1, 2019. Available: https://www.bls.gov/

[49] United States Census Bureau, “Data,” USA. Accessed Oct. 1, 2019. Available: https://www.census.gov/data.html

[50] Centers for Disease Control and Prevention, “Disability datasets,” USA. Accessed October 22, 2019. Available: https://www.cdc.gov/ncbddd/disabilityandhealth/datasets.html

[51] K. Lisa Yang and Hock E. Tan Institute on Employment and Disability, “Disability statistics,” Cornell University. http://www.disabilitystatistics.org/ (accessed Oct. 22, 2019).

[52] Disabled World, “Disability statistics: Information, charts, graphs and tables,” Disabled World. https://www.disabled-world.com/disability/statistics/ (accessed Oct. 22, 2019).

Examining Teacher Perspectives on Computational Thinking in K-12 Classrooms

Quinn Burke
Digital Promise
San Mateo, CA
qburke@digitalpromise.org

Jeremy Roschelle
Digital Promise
San Mateo, CA
jroschelle@digitalpromise.org

Cinamon Bailey
Clemson University, LSR
Clemson, SC
cinamob@g.clemson.edu

Colin Angevine
Digital Promise
Washington, DC
colin@digitalpromise.org

Josh Weisgrau
Digital Promise
San Mateo, CA
josh@digitalpromise.org

Kelly Mills
Digital Promise
Washington, DC
kmills@digitalpromise.org

***Abstract*— This paper examines K-12 teacher perspectives on the promise and challenges of computer science (CS) and computational thinking (CT) education for all students across three states and three school districts—one rural, one suburban, and one urban. Through a series of teacher survey and focus groups, this exploratory research presents the perspectives of K-12 teachers across three distinct vantage points: First, to what degree do these teachers see a clear value as to why CS and CT matter to their students' learning? Second (if the pathway is deemed valuable) who, in their estimates, are the crucial players to help develop a coherent CS/ CT K-12 pathway and what is their capacity? Third, how can such a prospective pathway be practically implemented? These elements of why, who, and how are essential to wider questions around equity of student access to high quality computing, and with this paper, they come from the perspectives of teachers—a group too often left out of early discussions around K-12 curricular design. Discussion section points to how these preliminary surveys and focus groups with teachers offer an early predictor in terms of how each district develops its own K-12 computing pathway, with the expectation that such focus groups offer a powerful research/ evaluation protocol that can be repeated annually among districts to gauge to what extent teachers' hope (and concerns) about comprehensive K-12 computing pathways are warranted.**

Keywords—computational thinking; competency-based education; educational infrastructure

I. Introduction

Recent studies [8, 12, 13] have emphasized how K-12 students are meeting neither college nor workplace expectations in an ever-growing computational world that relies upon the capacity to code and, even more importantly, the capacity to "think creatively and computationally" [3].

By implementing introductory computer science (CS) and computational thinking (CT) as early as elementary school and through secondary education, there is a strong argument that not only can students be better prepared for academic and career success, but also that such early exposure may also encourage more diversity and inclusivity in the CS field, which has long been troubled by a lack of racial, ethnic, and gender diversity [10]. *Crucial however to this call for more rigorous and equitable K-12 technology education are qualified and enthusiastic teachers*. While education policy-makers, pundits, and school administrators are seemingly never short on vernacular about the importance of CS education, this paper examines **teacher perspectives** on the promise and challenges of CS and CT education.

Working with three distinct school districts in the U.S. through a federally-funded research practitioner partnership (RPP) [6], this proposal presents K-12teachers' thoughts on whether they have (i) a clear sense as to **why** CS and CT matters to student learning?, (ii) **who** are the key players to help develop a CS/ CT K-12 pathway in their own schools and district?, and (iii) **how** such a Pathway can be practically implemented in K-12? The Results section is likewise structured around these three research questions.

II. Background

Since Jeannette Wing's [15] influential article on computational thinking (CT) as a K-12 educational imperative, a total of forty (40) states have enacted—or are in the process of enacting—computer science (CS) standards and frameworks for their K-12 schools [5, 7]. What was once consider an erudite (even arcane) technical skill a decade ago is now promoted as a fundamental 21st century literacy for all children, with steep implications in terms of equity of access and quality instruction [4]. A recent Google report [2] however points to a series of systemic obstacles for future growth. Perhaps most prominent of these obstacles—and one directly mentioned by all interviewees in the Google report—is scaling effective teacher professional development. The national teacher shortage [9] has only exacerbated the lack of qualified teachers in CS and CT. Remarkably, despite the tremendous economic need and states' growing efforts, still less than two-thirds of K-12 schools offer any computer science (CS) based curricula [9, 7].

There has been considerable rhetoric around generating a national "pipeline" of teachers for K-12 CS and CT education (and STEM, in general), but too little in terms of what teachers, themselves, see as a reasonable groundwork for such a pathway. Returning to the research questions above, this proposal represents a modest—yet important—early step to include a wider range of voices in this key conversation.

METHODS

A. Participants

A total of thirty (30) K-12 instructors and three (3) administrators participated in this study as part of the CT Pathways Research Practitioner Partnership (RPP, see Acknowledgement below). Participating teachers ranged from kindergarten through high school and came from range of geographies: A small, rural school district in Alabama (approx. 7,300 students); a mid-sized, urban school district in Iowa (approx. 14,000 students); and a large but decidedly suburban school district in Illinois (approx. 28,000 students). Gender, grade level, and geographic breakdown of these participants are listed in **Table # 1**.

TABLE I. TEACHER PARTICIPANTS FROM K-12 PROGRAMS

Region	# of Participants	Grade Levels/ Subjects Taught
Iowa (urban city; 14,000 students)	6 male instructors 6 female instructors 1 male administrator	5 elementary school teachers 3 middle school teachers (1 Science, 1 Math, 2 STEAM/Project Lead the Way [PLTW]) 4 high school teachers (1 Special Education, 2 Math, 1 Math/ CS, 1 CS/ PLTW)
Alabama (rural; 7,300 students)	1 male instructor 9 female instructors 1 female administrator	4 elementary school teachers 3 middle school teachers (1 Life Science, 2 STEAM/Project Lead the Way) 3 high school teachers (2 Science, 1 CS)
Illinois (suburban; 28,000 students)	3 male instructors 5 female instructors 1 male administrator	4 elementary school teachers 3 middle school teachers (Instructional Tech Support) 1 high school teacher (Business)

Each of the three districts (via their technology directors and superintendents) expressed a commitment to more equitable access to computing coursework for their students. Each district's commitment is listed here (as detailed at the outset of the research):

- **Iowa District:** "It is our desire to reach the specific population of Black and Latinx students in an effort to broaden their participation in computing…. These students face many barriers. Over 75% of our Black and Latinx students quality for Free/Reduced Lunch; and 25% and 45% of our Black and Latinx students, respectively, are English Language Learners. At the secondary level only 60% of Black students and 68% of Latinx students are proficient in math compared to 91% of our White students."
- **Alabama District:** "Our focus is on two specific populations, students from low socio-economic households and female students.
  - Of the high school students currently enrolled in a computer science or engineering course, 16% of our more affluent students are enrolled, while only 4% of our students in poverty are enrolled.
  - Of the high school students currently enrolled in a computer science or engineering course, only 30% of the students are female."
- **Illinois District:** "Providing computational thinking to these schools will help mitigate persistent barriers and support the students along this pathway. As a district, we're confident we can bridge the opportunity gap by providing all students with an effective, sequenced education in computational thinking and computer science."

B. Data Colletion & Analysis

In Winter 2018, each school district was asked to complete the Strategic CSforALL Resource & Implementation Planning Tool (SCRIPT) [14] to be used as a guide for the planning and/or expansion of each district's Computer Science (CS) and Computational Thinking (CT) program in their K-12 education setting. In March 2019, the research team conducted four teacher focus groups across K-12 grade levels in order to gain insight into the perspectives of CS and CT across these grade levels. The discussions were centered on (i) Why CS & CT?; (ii) Who are the key players in developing a CS/ CT K-12 Pathway?; and (iii) How such a Pathway can be practically implemented?

While these three components represented the central elements of the focus groups, these discussions were loosely-structured, with the intention to provoke free responses and wider discussion from participants. All four focus groups were recorded, and subsequently transcribed and analyzed using Dedoose Software. Utterances were divided into primary, secondary, and tertiary codes. Refer to **Table #2** for coding schema and **Table #3** below for examples.

FIGURE I. CODING SCHEMA

1. **Personal Understanding of the Computational Thinking Pathway**
   a. **Administrative**
      i. What is CT?
      ii. Why is CT important?
      iii. How does CT get implemented into the classroom?

   b. **Teachers**
      i. What is CT?
      ii. Why is CT important?
      iii. How does CT get implemented into the classroom?

2. **Perceived Stakeholder "Buy In" / "Pushback"**
   a. Parents
   b. Students
   c. Teachers

3. **Operationalizing Next Steps**

While the table above provides the basic schema, below are examples of utterances from participating teachers and how they were coded under the initial "primary" with a "secondary" sub-code offering more specific categorization.

TABLE II. CODING SCHEMA W/ SAMPLE PARTICPANT UTTERANCES

Example Utterance from Teacher Participant	Primary Code(s) of this Utterance	Secondary Codes of this Utterance
"I think when you're thinking about PD going forward, the how is really important but not as important as the why for teachers."	Teachers'/Administrators' Personal Understanding of the Computational Thinking Pathway	Teachers • Why is CT important? • How does CT get implemented into the classroom?
"That was kind of my question too is as I'm looking at this, especially the high school and what are some of the, the ways that students are going to demonstrate their knowledge here besides coding, Arduino, robotics, those kinds of things. What other things can they do to show mastery of this? You know what schools are successful in this right now and how are they showing it?"	Teachers'/Administrators' Personal Understanding of the Computational Thinking Pathway	Teachers • How does CT get implemented into the classroom?
"(T)o me that the more it can be integrated in multiple disciplines, the more sustainability you have in this district and I've seen it for 22 years, you know, as I love it, I love the idea."	Teachers'/Administrators' Personal Understanding of the Computational Thinking Pathway Perceived Stakeholder "Buy In" / "Pushback" Operationalizing Next Steps	Teachers • How does CT get implemented into the classroom?

III. RESULTS

A. WHY is Teaching CS & CT Considered Important?

Teachers from all three districts provided substantial reasons as to "Why?" for CS and CT programs within their schools. The top reasons, outlined in Table 4 below, include: (1) **Promotes skills needed for future academic and career success** (including critical thinking, critical writing, problem solving, and relatable career connections); (2) **Increases student productivity, interest, motivation, & engagement**; and (3) **Promotes equity/inclusivity/dissolution of stereotypes**.

TABLE III. WHY IS INSTRUCTIONAL CT IMPORTANT?: TOP REASONS GIVEN BY PARTICIPANTS

	% of participants in **Alabama**	% of participant s in **Iowa**	% of participants in **Illinois**	% of participa nts in **Overall**
Promotes skills needed for future academic and career success *(including critical thinking, critical writing, problem solving, and relatable career connections)*	***4/11*** *of respondents*	***5 /13*** *of respondents*	***8/9*** *of respondents*	***17/33 = 52%***
Increases student productivity, interest, motivation, & engagement	***4/11*** *of respondents*	***0/ 13*** *of respondents*	***3/9*** *of respondents*	***7/33= 21%***
Promotes equity/inclusivity/dissolution of stereotypes	***3/11*** *of respondents*	***1/13*** *of respondents*	***6/9*** *of respondents*	***10/33= 30%***

Teachers from all 3 school districts spoke to CT as having the ability to promote future academic and economic success for their students. This point was illustrated by a middle school STE(A)M instructor:

> *Because so many jobs of the future are still not even invented yet. We need to train her children, teach them how to think outside of the walls of the school and think further ahead so that they can be the problem solvers and things that they haven't even seen yet but they will face in their future."*

Teachers also focused on the soft skills students would be able to develop, including productivity, creativity, collaboration, and perseverance. The push for **earlier exposure to computing** was reiterated during all four focus groups as well, with one middle school instructor noting,

> *I think if the ultimate goal was to get them (the students) into computer classes in high school, then I think the effort should be put into elementary school. And the PD needs to be there...you know, we need to teach kids how to think, teach them not just to go through a textbook and do problems whether it's science or math.*

An elementary teacher emphasized starting early is important:

> *(S)o kids have just an idea of what could be out there for them. And so, it's not something you're just thrown into at the end of high school….*

The question of **equity** figured most prominently during the Illinois focus group discussion. One middle school technology teacher, who has used Scratch with her students, particularly addressed the equity issue, indicating the earlier children had an opportunity to code, the better:

> *I know this is a really important… I've had as many as 28 kids in the classroom and one girl and zero African Americans. And I'm like, 'But it's so much fun and it's middle school!' But it's still too late. So, I know it's important that we're pushing this down and showing kids even younger than middle school that this is cool because we teach it in sixth and seventh grade it's required and I've got my girls shutting down."*

It is worth pointing out here though that, as noted in the Methods section, equity was an expressed focal point for all three district's from administrator's perspectives; Illinois teachers' discussion of issues around equity in computing and CS education does not necessarily mean this element of equity was less of an issue within the other two districts, but rather less a talking point during the loosely-structured focus groups.

B. WHO are the key players to help develop a CS/ CT K-12 Pathway?

The stakeholders whom participants talked about included students, parents, teachers, and school administration. Here, conversations revolved around who are the optimal teachers to recruit and where there may be pushback from instructors. The top reasons provided by participants for potential stakeholder pushback are listed in Table 5 below:

TABLE IV: TOP REASONS PROVIDED BY PARTICIPANTS FOR STAKEHOLDE PUSHBACK POTENTIAL

	% of participants in **Alabama**	% of participant s in **Iowa**	% of participants in **Illinois**	% of participa nts in **Overall**
Teachers don't understand why this is important or how to measure it	***4/11*** *of respondents*	***2 /13*** *of respondents*	***1/9*** *of respondents*	**7/33= 21%**
Teacher workload/lack of time	***6/11*** *of respondents*	***8 /13*** *of respondents*	***2/9*** *of respondents*	**16/33= 48%**
Lack of resources	***0/ 11*** *of respondents*	***3 /13*** *of respondents*	***0/9*** *of respondents*	**3/33= 9%**
High performing students (OR parents of these students) in higher grades *(anxiety related to leaving forms of instruction with which they are already familiar)*	***5/ 11*** *of respondents*	***1 /13*** *of respondents*	***0/9*** *of respondents*	**6/33= 18%**
Fear of Accountability	***4/ 11*** *of respondents*	***1 /13*** *of respondents*	***1/9*** *of respondents*	**6/33= 18%**

In terms of how teachers perceived "buy-in" into a district-wide pathway, instructors from all 3 districts touched upon the same challenge of **time** (time for instructional PD, time to implement, and time to reflect). The question of time was a three-fold concern, with some instructors quickly pointing for the time to prepare lessons via professional development as well as preparatory time during the day. But the question of finding time during the school day was a deeper concern for many instructors, especially on the elementary school levels where teachers are often expected to be offering a wide range of subjects (and activities) in a single classroom. A female kindergarten teacher's concerns were echoed by several teachers throughout the districts:

> *It's really hard for me to think about these big (questions) ... giving them time to do these big things and to be creative, and I want to do that. That's what I want to do, but what my day actually consists of doesn't match this. Making this adjustment and still giving a reading block the allotted time it's supposed to have...I'm already struggling, I have an open mind. So that worries me about taking that back to kindergarten/first grade teachers.*

This sentiment was seconded by a kindergarten teacher from another district, who stated, *"We probably have less time for science than most other schools, less time for social studies because we have to do extra intervention....We have only so many hours in a day to accomplish a lot."*

This question of **time** is compounded by a wider question of how to **assess**, as a high school physical & environmental science instructor remarked: *"Where's your pushback gonna come? Well, aside from (teachers saying) "this is another thing that I have to do", the second one I feel like is going to be "How do I know when they've got it?"*

Interestingly, resources were not consider to be a major barrier by two of the districts (AL & IL) and only minimally so in Iowa, pointing to the long-held adage (and demonstrated research [Penuel]) that districts do not necessarily lack tools nor curricula but rather the time for teachers to learn about such tools and curricula in meaningful professional development and the time to enact such PD during an already-crowded school day.

C. HOW can a CT Pathway be implemented in K-12?

The question of how to enact comprehensive K-12 pathways was perhaps the most discussed question within teacher focus groups across all three districts. As evident in Table 6 below, it was also the question that saw the most consensus across all three districts.

As indicated in Table 6, what participants across districts felt is needed in order to successfully implement a comprehensive K-12 Pathway included: (1) Time (planning time for implementation, designated planning time while implementing, and time to educate parents/train teachers); (2) CT curricular/assessment tools across grade levels (how to implement in different subjects, cross curricular opportunities, and student performance metrics); (3) Resources (support staff; mentors; coaches; tech support; examples; and vocabulary to match/reflect grade level understanding, current standards (CSTA, NVSS, Alabama state standards, etc.), & most recent initiatives (PBL,etc.); and (4) Teacher training (developing metrics for teacher/curriculum success, helping teachers understand why this is important, showing teachers that they are already doing most of this already, observing other classes in which this is implemented, coaching, & allowing teachers to hands-on train).

TABLE III. WHAT DO TEACHERS/SCHOOLS/STUDENTS NEED IN ORDER TO SUCCESSFULLY IMPLEMENT PATHWAY?

	% of participants in **Alabama**	% of participants in **Iowa**	% of participants in **Illinois**	% of participants in **Overall**
Time (including planning time for implementation, designated planning time while implementing, and time to educate parents and train teachers)	***7/11*** *of respondents*	***8 /13*** *of respondents*	***4/9*** *of respondents*	**19/33= 58%**
CT curricular and assessment tools across grade levels (including how to implement in different subjects, cross curricular opportunities, and student performance metrics)	***8/11*** *of respondents*	***7 /13*** *of respondents*	***9/9*** *of respondents*	**24/33= 73%**
Resources (includes support staff; mentors; coaches; tech support; examples; and vocabulary to match/reflect grade level understanding, current standards (CSTA, NVSS, Alabama state standards, etc.), & most recent initiatives (PBL, etc.).	***6/11*** *of respondents*	***10 /13*** *of respondents*	***7/9*** *of respondents*	**23/33= 70%**
Teacher training (includes developing metrics for teacher/curriculum success, helping teachers understand why this is important, showing teachers that they are already doing most of this already, observing other classes in which this is implemented, coaching, & allowing teachers to hands-on train)	***5/11*** *of respondents*	***4 /13*** *of respondents*	***5/9*** *of respondents*	**14/33= 42%**

As indicated in Table 6, what participants across districts felt is needed in order to successfully implement a comprehensive K-12 Pathway included: (1) Time (planning time for implementation, designated planning time while implementing, and time to educate parents/train teachers); (2) CT curricular/assessment tools across grade levels (how to implement in different subjects, cross curricular opportunities, and student performance metrics); (3) Resources (support staff; mentors; coaches; tech support; examples; and vocabulary to match/reflect grade level understanding, current standards (CSTA, NVSS, Alabama state standards, etc.), & most recent initiatives (PBL,etc.); and (4) Teacher training (developing metrics for teacher/curriculum success, helping teachers understand why this is important, showing teachers that they are already doing most of this already, observing other classes in which this is implemented, coaching, & allowing teachers to hands-on train).

Across all four focus groups, 14 teachers (47%) and all 3 administrators indicated they are already applying aspects of this pathway in their classrooms in the form of computer/tech classes, music, robotics, design tasks, engineering design, data collection, data analysis, coding, creating, communicating digitally, and/or Scratch. This stated, teachers in IOWA definitely saw the need to integrate CS and CT across not only multiple grade levels but also across multiple subjects. *"To me,"* remarked one middle school teacher, *"the more it can be integrated in multiple disciplines-the more sustainability you have in this district...and giving people time to see the connections across the curriculum. That's how this initiative will be sustained."*

Still, this aspect of implementation is seemingly downright scary for several teachers from all districts as they struggle with the vocabulary and deciding how it will fit into the curriculum: *"I just immediately get a little overwhelmed with all the vocab and my brain just goes like "computer science" and I forget about how I'm applying it to my subject."* One teacher on the elementary level also pointed out the need for a common vocabulary as being essential to the question of "How?" to get more teachers and students on board with the initiative: *"If we're gonna start down here,"* she remarked about offering introductory CS and CT on the lower grade levels, *"and we wanna get kids up here, we need to identify common themes and a vocabulary that follows them through the grade levels."*

IV. Discussion

By looking at teachers' perspectives, we are able to discover some of the challenges and opportunities that present themselves when trying to implement computational thinking into K-12 curriculum. This may also reveal the practices and strategies teachers feel confident about utilizing within their classrooms. This data indicated challenges that were both extrinsic (resources, time, training, workload, etc.) and intrinsic (fear, uncertainty, anxiety felt by high performing students, etc.), while also revealing that these teachers would like to promote strategies that are multidisciplinary, cross curricular, and contextual-all of which supports earlier research on best strategies for implementing CT within the school system [3]

Of course, these initial focus group with instructors represent an early stage within this three-year research program. Currently (Fall 2019) we are entering the classroom "Pilot" stage of the research, in which a select group of instructors begin to offer preliminary computing coursework within their classroom over the 2019-20 academic year. On the elementary level, this coursework is largely to be integrated into existing coursework (largely math and science units); on the high school level, coursework across all three districts is strictly "stand-alone" and makes use of existing curricula (i.e., Exploring Computer Science and Computer Science Principles). On the middle school level, the three districts are taking different approaches, with Iowa and Illinois offering stand-alone coursework via existing programs such as Project Lead the Way (PLTW) and Code.org, while Alabama intends to integrate into science coursework via computational modeling and Next Generation Science Standards (NGSS). The intention is to repeat these teacher focus groups over the Winter of 2019-20 to investigate to what degree participating instructors' own hope s and concerns were warranted and to what degree there may be other considerations not initially considered from their perspectives. Here, we expect to collect more empirical data from teachers in terms of the **Why?, Who?** and **How?** of K-12 CS and CT education. These three questions, of course, are certainly not static in nature, but may very well represent a series of shifting points among educators based on effective professional development or the lack thereof.

Acknowledgment

The writing of this paper was supported through a National Science Foundation (NSF) Computer Science for All Grant to the first two authors. The views expressed are solely those of the authors of this paper and are not necessarily representative of the views of the NSF.

References

[1] M.U. Bers, L. Flannery, E.R. Kazakoff, and A. Sullivan, "Computational thinking and tinkering : Exploration of an early childhood robotics curriculum," *Computers & Education*, vol. 72, pp. 145–157, Nov. 2013.

[2] P. Blikstein, "Pre-college computer science education: A survey of the field," Mountain View, CA: Google LLC, 2018.

[3] Bureau of Labor Statistics, *Occupational Outlook Handbook*. , 2018 [E-Book]. Available at https://www.bls.gov/ooh/computer-and-information-technology/home.htm.

[4] Q. Burke, "Mind the metaphor: Charting the rhetoric about introductory programming in K- 12 schools," *On the Horizon*, vol. 24, issue 3, 2016.

[5] Q. Burke, C. Bailey, and P. Ruiz, "CIRCL primer: Assessing computational thinking," In *CIRCL Primer Series*, 2019. [Online]. Available: https://circlcenter.org/assessing-computational-thinking/.

[6] C.E. Coburn, W.R. Penuel, and K.E. Geil, "Research-practice partnerships: A strategy for leveraging research for educational improvement in school districts. New York, NY: William T. Grant Foundation, New York, NY, 2013.

[7] Code.org, "Landscape of CS action in states," Code.org, Seattle, WA, 2019. [Online]. Available: https://docs.google.com/document/d/1J3TbEQt3SmIWuha7ooBPvlWpiK-pNVIV5uuQEzNzdkE/edit.

[8] Digital Promise, "Computational thinking for a computational world," Digital Promise, San Mateo, CA, 2018. [Online]. Available: https://digitalpromise.org/wp-content/uploads/2017/12/dp-comp-thinking-v1r5.pdf.

[9] Economic Policy Institute "The teacher shortage is real, large and growing, and worse than we thought,". EPI, Washington, DC, 2019. [Online]. Available: https://www.epi.org/files/pdf/163651.pdf.

[10] J. Margolis, J. Goode, and J.J. Ryoo, J. J., " Democratizing computer science. *Educational Leadership,* volume 72, issue 4, pp. 48-53, 2015.

[11] H. Partovi, H, "Should computer science be a mandatory class in U.S. high schools?" Forbes, New York, NY, 2017. [Online]. Available: https://www.forbes.com/sites/quora/2017/04/11/should-computer-science-be-a-mandatory-class-in-u-s-high-schools/#38dff67d1e9f.

[12] D. Schaffhauser, "It's time to weave computational thinking into K-12, THE Journal, Woodland Hills, CA, January 2018. Available: https://thejournal.com/articles/2018/01/02/its-time-to-weave-computational-thinking-into-k12.aspx .

[13] M. Ventura, E. Lai, and K. DiCerbo, "Skills for today: What we know about teaching and assessing critical thinking," Partnership for 21st Century Learning, 2017. [Online]. Available: http://www.p21.org/storage/documents/Skills_For_Today_Series-Pearson/White_Paper_-_P21_-_Skills_for_TodayWhat_We_Know_about_Teaching_and_Assessing_Critical_Thinking_v5.pdf.

[14] S. Vogel, R. Santo, and D. Ching, *Visions of computer science education: Unpacking arguments for and projected impacts of CS4All initiatives*: *2017 Proceedings of the ACM SIGCSE Technical Symposium on Computer Science Education*, March 2017, pp. 609-614, 2017.

[15] J.M. Wing, "A vision for the 21st century: Computational thinking,". *Communications of the ACM,* volume 49, issue 3, pp. 33-35, 2006.

NYC CS4All: An Early Look at Teacher Implementation in One Districtwide Initiative

Cheri Fancsali
Research Alliance for New York City Schools
New York University
New York, U.S.A.
cheri.fancsali@nyu.edu

June Mark
Education Development Center
Waltham, MA, U.S.A.
jmark@edc.org

Leigh Ann DeLyser
CSforAll
New York, U.S.A.
LeighAnn@CSforAll.org

***Abstract*—Computer science for all initiatives have broadened the participation of students enrolled in elective computer science (CS) courses and introduced compulsory CS instruction in many areas of the United States. However, there is a shortage of K–12 teachers with the background, preparation, and experience necessary to teach CS. To build capacity to deliver this instruction, districts must provide teacher preparation that includes not only CS content, but also high-quality pedagogical approaches that will meet the needs of all students enrolled in a wide variety of school settings. In this paper, we explore teacher outcomes across multiple CS professional development opportunities, in one large urban district. The teacher outcomes were measured via a survey administered between eight months and two years after teachers received training to implement CS.**

Though our findings are from a single district, we believe these findings are relevant to other settings and provide useful information about the outcomes of teacher professional development for CS education, as well as supports and barriers to implementing CS, in a large, urban school system. The results offer insight into professional development quality, teacher confidence, the ability of teachers to implement CS in their classrooms, and supports and barriers to offering CS instruction (even in a district where CS education is a priority). They also shed light on how supports and barriers differ in schools serving students with high economic needs and lower academic performance compared with schools serving students with lower economic needs and higher academic performance. These differences underscore the importance of considering economic need and academic performance (in addition to race and gender) when developing and executing CS for all initiatives.

Keywords—CS4All, K–12 classroom implementation, Teacher survey, Evaluation, Assessment, Computational Thinking, Gender and Diversity, Teacher Development, K–12 Curriculum, K–12 Instruction, Non-traditional Students, Professional Practice

I. Literature Review

A. CS Education Landscape

The last ten years have been marked by an explosion of computing across almost every industry, as well as a dramatic increase in jobs that require computational skills, especially in Science, Technology, Engineering and Mathematics (STEM) fields. Over the next decade, the computer science industry is projected to grow by 13 percent—adding over half a million jobs—according to the U.S. Bureau of Labor Statistics [1]. That rate exceeds the average for all occupations. Furthermore, it is widely agreed that the use of computational concepts and methods—problem solving, designing systems, refining the steps in a process, and tinkering toward creative solutions—are relevant in nearly every discipline, profession, and industry [2]. Thus, there is a growing call, at district, state, and national levels, for all students to have opportunities to become proficient computational thinkers and be exposed to hands-on computer science (CS) curriculum and courses throughout their educational careers.

However, while most students, parents, and educators support and see the value in CS education, nationally only 60 percent of schools offer any CS courses to students, and even fewer schools (40%) offer classes that teach programming and coding [3]. In fact, just 15 states require secondary schools to offer CS, only 19 provide funding for teacher training in CS, and only 22 have established K–12 CS standards [4].

Compounding these challenges, some groups are systematically underrepresented in CS and CS education [5]. For example, Black, Latinx, and low-income students are much less likely than their White and more affluent counterparts to have access to CS learning opportunities in school or access to computers at home. Female students face additional social barriers: compared with male students, they report less interest in and awareness of CS opportunities, and they are less likely to report having ever learned CS in grades 7–12 [6, 7].

An increasing number of policymakers, business leaders, and educators see it as a both practical and moral imperative to confront these disparities. They seek to empower underserved students and communities to participate as creators—and not just consumers—in a digital world. Broadening participation in STEM and computer science can strengthen the workforce and arm students with skills to help solve important problems in society.

Funding for this study is provided by the NYC CS4All Founders Committee and the Fund for Public Schools.

978-1-7281-7172-2/20/$31.00

Answering the call for computer science expansion and equity, the New York City Department of Education (NYCDOE) launched its CS4All initiative in 2015, with the goal of providing meaningful, high-quality computer science education to all public school students in each grade band (i.e., K–2, 3–5, 6–8, 9–12) by 2025. New York City's CS4All is currently the largest districtwide effort in the country attempting to implement CS education at this scale, though there are similar efforts occurring in other districts, such as Broward County, FL, Chicago, Dallas, San Francisco, and San Diego, as well as statewide initiatives in Georgia, Alabama, Utah, Maryland, and elsewhere.

In New York City, CS4All is explicitly designed to increase access to CS education among historically underrepresented groups—in particular, girls and Black and Latinx students. The initiative aims to positively influence a range of outcomes, including CS knowledge and skills, computational thinking, problem solving, academic engagement, and eventually students' pursuit of CS-related college majors and careers.

B. *Preparing Teachers to Teach CS*

Nationally, the lack of teachers with the capacity to teach CS is widely cited as a barrier to offering CS instruction to more students [8, 9]. Most states do not offer teaching licenses specific to CS, although in 2018, New York State approved the creation of a CS certificate for teachers. Further, most educators and administrators believe teachers need extensive training or coursework in CS to successfully teach the subject [10, 11, 12]. Yet, on a national scale, the state of CS teacher preparation has been described as "deeply flawed" and inadequate to address growing demand [10]. While great strides have been made in preparing teachers to implement quality CS instruction, efforts to expand CS education will require much greater teacher capacity than currently exists [13]. Equally problematic, the training that is available is generally provided by institutions of higher education with little or no involvement from schools or districts. This disconnect between professional development (PD) opportunities and local context limits the extent to which training is aligned with and relevant to the needs of the district and its schools [14].

To address these barriers, the NYC CS4All initiative is providing PD to nearly 5,000 teachers over the course of ten years. To date, the initiative has offered a diverse selection of year-long programs to teachers in foundational and advanced CS curricula. These PD experiences last a minimum of 48 hours for foundational curriculum and 100 hours for advanced curriculum. The trainings are designed to prepare teachers to lead multi-year CS sequences of semester and year-long CS courses (ranging from introductory to advanced AP CS courses) and the integration of CS units into other courses.

These professional development options are guided by a set of principles described in the NYC CS4All Blueprint, an academic and implementation guide for teaching computer science in New York City public schools. The Blueprint articulates five key CS concepts (abstraction, algorithms, programming, data, networks) and a set of CS practices (analyzing, prototyping, communicating) around which the CS4All PD options are organized.

Sequences: The multi-year sequence PD options include the Software Engineering Program (SEP) and SEP Jr.

Software Engineering Program. The SEP program is a multi-grade comprehensive CS education sequence for grades 6–12. The PD for teachers includes a two-week summer institute, five Saturday follow-ups during the school year, and participation in "hackathons."

SEP Jr. The Software Engineering Program Junior is a CS program for kindergarten through 5th grade students that includes teacher-directed lessons and creative computing activities such as Scratch, robotics, and maker education. PD includes a five-day summer institute, as well as four optional and five mandatory Saturday follow-ups during the school year.

Courses: These PD options focus on half-year and full-year courses that range from introductory to advanced AP CS offerings.

During the 2019–20 school year, introductory CS courses include Computer Science Discoveries, Exploring Computer Science, Introduction to Physical Computing, Introduction to Computational Media, and TEALS Introduction to Computer Science. Teacher PD includes a two-week summer workshop and five Saturday follow-ups during the school year.

Advanced CS courses include Advanced Placement Computer Science Principles using either the Beauty and Joy of Computing, UTeach, or code.org Computer Science Principles curricula. PD for teachers includes a two-week summer institute, and five Saturday PD sessions during the school year.

Units: These PD options focus on meaningful CS units for grades K–8. These units include 10–15 hours of CS instruction for grades K–2 and 15–25 hours for grades 3–8, designed to be integrated into existing instruction or used as stand-alone units. These units introduce foundational computer science and computational thinking ideas to students using a creative computing approach. Units curricula include Computational Media and Creative Computing, among others. PD for teachers includes a five-day summer institute, and follow-up PD sessions during the school year. Teachers implementing units are also supported by CS education managers—locally placed district staff who provide on-site coaching and additional PD as needed.

The initiative targets teachers who have not previously received CS PD and schools that do not already have CS teachers or courses. PD experiences were designed to include key features of effective CS PD suggested by past research, including: engaging in active, inquiry-based learning, fostering teacher professional learning community; providing pedagogical and content knowledge in CS instruction; and developing teacher capacity to implement culturally-responsive CS through an inquiry- and equity-oriented approach [9, 12, 15]. In addition, the initiative is guided by research that shows that creating opportunities for teachers to collaborate in planning CS instruction and integrating opportunities for reflection are both important [15, 16, 17], as well as growing recognition of the role that in-classroom support and coaching can play in improving and scaling CS instruction [18, 19].

This paper presents findings from multiple years of a survey of teachers who participated in the district's year-long CS PD programming. There is very little prior research on efforts to increase capacity to teach CS on a wide scale, as required by the NYC CS4All efforts. This research contributes important information about implementation challenges and successes, as well as the early outcomes of a large-scale district-wide effort to develop teacher capacity and implement CS for all students.

II. Methods

A. Research Questions

The teacher survey was administered online in the spring of 2017, and again in spring of 2018. All teachers received the same survey regardless of the professional development they attended. The primary research questions guiding the survey include:

- How do teachers rate the quality of the CS PD they received?
- How confident do teachers feel about their knowledge of and ability to provide instruction in CS?
- To what extent and how are teachers implementing the CS training they received?
- What challenges do teachers report as barriers to implementation? What supports for implementation do teachers find helpful?
- What variations in implementation are there for teachers with different CS backgrounds, who attended different PD types (e.g., for units, courses, or sequences)?
- What variations in implementation are there for teachers in schools that serve students with different economic status and prior achievement?

B. Study Sample and Response Rates

In 2017, we surveyed 225 teachers (representing a 50% response rate) from 159 schools; these teachers had attended CS4All PD programs in 2015–16 or 2016–17. In 2018, we surveyed 536 teachers (representing a 66% response rate) from 446 schools; these teachers had attended CS4All PD programs in 2015–16, 2016–17, or 2017–18. Teachers could have taken surveys in both 2017 and 2018. The surveys were administered online between April and July of each year.

C. Data Measures

The survey asked teachers about their experience with the PD, as well as subsequent implementation of CS in their school. Through primarily closed-ended questions, the survey addressed issues related to the quality of the PD teachers had received and teachers' attitudes and beliefs regarding CS instruction. The survey also asked teachers about supports and barriers to implementing CS in schools and in the classroom. Most items were asked in both years of the survey, though some new items were added in 2018 (e.g., about the extent to which teachers reported covering specific CS concepts and practices in their instruction), and a few of the 2017 items were dropped in an effort to shorten the survey or because they had become less of a priority for the initiative.

D. Data Analysis

We conducted descriptive analyses of the closed- and open-ended survey questions. For closed-ended items, we ran frequencies and cross-tabulations by key subgroups of interest, including grade band taught (elementary, middle, high), whether or not the teacher had implemented CS in their classroom, and school characteristics, such as students' economic need and academic performance. To analyze differences in responses across teacher groups, we ran regression analyses controlling for teacher characteristics (gender, teaching experience, CS expertise), school level, and PD program attended.

The surveys contained a few open-ended items, mostly to allow teachers to specify and describe an 'other' option. For open-ended items, we conducted a content analysis using an iterative coding process. First, the team inductively developed a set of codes for each open-ended question using the initiative's theory of action and other documents to anticipate possible answers. Then, the team refined and added codes based on respondents' actual answers. Finally, team members discussed the coding scheme and its application to ensure consistent and accurate coding, revising the codes as necessary. Themes that emerged from the open-ended questions were reviewed in conjunction with the close-ended results, providing additional context and detail.

III. Findings

Below we present core findings from the 2018 survey, noting key differences and similarities in relation to findings from the 2017 survey.

A. How Did Teachers Rate the CS4All PD?

The CS4All PD offerings are aimed at helping teachers learn new programs and pedagogies in CS education, as well as methods for integrating CS into existing courses. CS4All then expects teachers (with support from school administrators) to put this training to use—helping students learn CS concepts, practices, and perspectives, and helping students connect their CS learning across subject areas and grade bands, as well as to their personal interests in and out of school. For that learning and connection-making to occur, teachers must be adequately prepared and supported to integrate CS knowledge with their existing areas of content expertise, and to help students build CS experiences into academic and career pathways over time. Ensuring the quality and depth of the PD that teachers experience will be crucial to the success of the CS4All initiative.

Our surveys were designed to gather information about teachers' perspectives on the quality and utility of the PD they received. Well over half of teachers (60%) surveyed in 2018 reported that they did not have a CS-related degree or certification or prior experience in the CS profession, confirming that many teachers participating in CS4All PD have limited CS knowledge. Given this, and because the initiative's PD offerings require a year-long commitment, it is critical that teacher engagement and commitment are high. If teachers' experiences are positive, they will be more likely to be engaged in the PD and committed to implementing what they learned when they return to the classroom.

Overall, teachers rated the CS4All PD highly, with a majority agreeing or strongly agreeing that it increased their CS knowledge (90%), that facilitators helped them understand how to implement their learning in the classroom (88%), and that the PD was tailored to meet their needs as a learner (86%). Agreement with statements about the PD quality were high regardless of the type of PD teachers attended (i.e., units, courses, or sequences).

B. How Confident Are Teachers in Their Ability to Teach CS?

Because CS is a new content area for many teachers, we sought to assess their level of confidence in teaching CS, following their participation in the CS4All PD. Beyond learning essential content knowledge and relevant pedagogical approaches, the CS4All PD offerings aim to increase teachers' confidence in their ability to engage their students in CS concepts and practices. Teachers who are confident in their capacity to teach computer science are better positioned to implement what they have learned in PD—and to help their students see computer science as an interesting and exciting field [4, 5]. Furthermore, to meet CS4All's goals, teachers must feel confident in their abilities to teach CS well to a wide range of students, especially students who historically had limited access to CS (e.g., girls, Black and Latinx students, students with disabilities, and others).

The majority of teachers responding to our survey reported feeling somewhat confident in their abilities to teach computer science. Teachers were asked the extent to which they agreed with statements like, "I know how to teach important computer science concepts effectively," and "I know how to facilitate students' interest in computer science." Teachers were asked to report their agreement with each statement on a 5-point scale: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree.

Overall, teachers' confidence in their ability to deliver CS instruction following PD fell between the "neutral" and "agree" categories (3.45 out of a 5-point scale). There were very few differences by grade level. Teachers receiving PD for the first time in 2017–18 had slightly lower scores on the teacher confidence scale than teachers receiving PD in 2016–17 (3.48 vs. 3.84), perhaps suggesting that teachers gain confidence with experience. Teachers implementing CS and trained to deliver stand-alone sequences and courses had slightly higher average scores (3.51 and 3.58 respectively) than teachers who were implementing CS and trained to deliver CS units integrated into other classes (3.46). This may be an indication that integrating CS units into other subjects is more difficult for teachers and requires a larger pedagogical shift from their typical practice.

Despite the moderate levels of confidence reported, 48 percent of respondents agreed or strongly agreed that they wished they had a better understanding of the CS concepts they teach. High school (48%) and especially middle school teachers (54%) were more likely to strongly agree with this statement (see Figure 1 below). This suggests that even after substantive PD experiences lasting 50 hours or more, many teachers may need more and different training and support to effectively implement CS instruction.

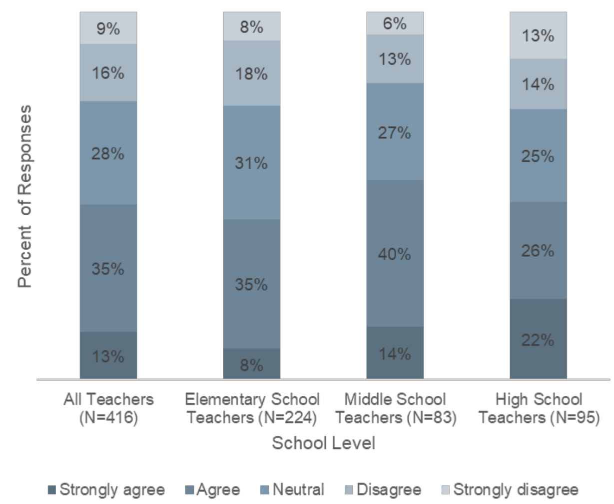


Fig. 1. Teachers' agreement with statement: "I wish I had a better understanding of CS," by school level, 2017–2018 school year

C. Are Teachers Who Received CS PD Implementing It in the Classroom?

Three fourths of the teachers surveyed (75%) in 2018 reported teaching CS in the 2017–18 school year,[1] either as a stand-alone course or integrated into other subject areas. This is slightly higher than the percentage reporting implementing CS in the prior year (70%). Teachers with prior CS experience were somewhat more likely to report implementing CS than teachers with no prior CS experience (80% versus 71%).

Elementary teachers reported implementing CS at higher rates (81%) than middle school (72%) or high school (63%) teachers. However, teachers who attended PD focused on teaching CS courses (e.g., AP CS) and CS sequences (e.g., SEP and SEP Jr.) were more likely to report implementing CS (86% and 81% respectively) than teachers who attended PD focused on CS units (70%). This suggests that stand-alone courses are more likely to be implemented in schools than units that require integration with existing courses, and may be related to the fact that teachers implementing stand-alone courses had higher confidence in their ability to do so than teachers integrating CS into other subjects.

Among the teachers who were not implementing CS, we heard several prominent themes in their responses to an open-ended question about why they were not doing so. These included a lack of ability to teach or integrate CS, competing academic priorities, lack of support to implement CS, and that they were not the designated CS teacher in the school.

[1] Teachers who did not respond to this question on the survey were counted as not implementing CS. If we take non-responders out of the denominator, the percent implementing CS in 2018 increases to 84 percent.

D. What Factors Support or Hinder Teachers' Efforts to Implement CS?

Our teacher survey examined factors that support or hinder high-quality CS implementation in schools and classrooms. Teachers were asked about the extent to which a list of individuals or resources supported their ability to implement CS in their classrooms. They were also asked about the extent to which they faced a number of specific challenges to implementation. Their responses to these questions may suggest strategies that districts can use to provide additional and more effective support to teachers, thereby increasing the initiative's odds of success.

Supports: In implementing CS in their classrooms, teachers reported drawing support from a variety of sources. The most commonly identified supports were professional development providers, administrators at their own school, and other teachers in the school. A total of 68 percent of survey respondents indicated that PD providers were a support to a "moderate" or "large" extent, while 57% said school administrators were supportive, and 41% said other teachers in their schools were. There were no notable differences in findings by grade band.

Challenges: The challenges to implementing CS cited by surveyed teachers were similar to those found in other studies (see for example [6]). In our study, the most frequently reported classroom-level challenges were lack of preparation time and lack of instructional time. The most frequently reported school-level challenges were competing priorities, the need to prepare students for high-stakes tests, and lack of time in student schedules (see Figure 2). For example, teachers' comments included.

"With focus on reading, writing and math, CS is viewed as a third-class citizen."

"Other academic classes are given priority, and CS classes are seen as less important."

It is interesting that—in a district that has articulated CS for all as clear priority—a substantial portion of teachers nonetheless reported challenges related to competing priorities (44% said it was a challenge to a large or moderate degree).

While there were few large differences by grade band, elementary and middle school teachers were more likely to report being challenged by a lack of instructional time and a lack of time in student schedules, compared with their high school counterparts. This may be related to the fact that high school students have more choice in their schedules, whereas elementary and middle school students often have set schedules. It also may be related to the additional challenge of finding time to integrate CS into existing courses and instruction, which is more prevalent in the elementary and middle grades. Teachers who participated in PD designed to implement CS units reported fewer supports and greater challenges than teachers who attended PD designed to implement multi-year CS sequences and year- or semester-long courses. Not unexpectedly, teachers who were trained in CS for the first time in 2017–18 reported more challenges and less confidence in their teaching than teachers who were trained in prior years and had more years of implementation.

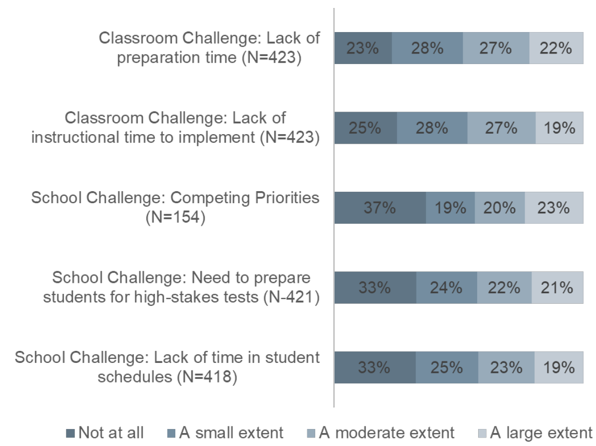


Fig. 2. Teacher-reported challenges to implementing CS, 2017–2018 school year

E. How Do Supports and Challenges Differ for Schools with High Economic Need and Low Academic Performance?

Because CS4All is committed to increasing access to CS instruction for historically underrepresented groups, we explored whether there were differences in the levels of support and challenges that teachers reported in the 2017 survey, depending on the economic need[2] and academic performance of their schools (as measured by standardized test scores and graduation rates). For each variable, we divided the schools of responding teachers into two groups: 1) high-economic-need and low-economic-need schools, and 2) high-performance and low-performance schools. About three quarters of high-economic-need schools are also low-performance schools.[3] Broadly, teachers from high-need and low-performance schools reported less support and more challenges in implementing CS instruction. Five out of the seven supports we asked about fit this pattern, as did 11 out of the 13 challenges. Figure 3 shows the supports and challenges that were statistically significantly different by school economic need. Compared to teachers from schools with low economic needs, teachers from schools with high economic needs were less likely to report receiving support from their administrators, school or network technology specialists, or other teachers in their schools. In a similar vein, teachers from schools with high economic needs were more likely to report challenges to implementing CS, including a lack

[2] Economic need is based on the NYC DOE's economic need index, a measure of students who are in poverty based on indicators such as homelessness, having a home language other than English and entered the NYC DOE for the first time within the last four years, and the percentage of families (with school-age children) in the student's census tract whose income is below the poverty level. Schools at or above the median economic need index for this sample were grouped into the "high economic need group" (N=86) and those below the median were grouped into the "low economic need group" (N=86).

[3] Schools were grouped into the "high performing schools" category if they were at or above the sample median proportion of students proficient in elementary and middle school math and ELA or at or above the sample median high school graduation rate (N=74). Schools were grouped into the "low performing schools" category if they were below the sample median on these indicators (N= 84).

of parental support, a lack of administrative support, and a lack of student interest in CS.

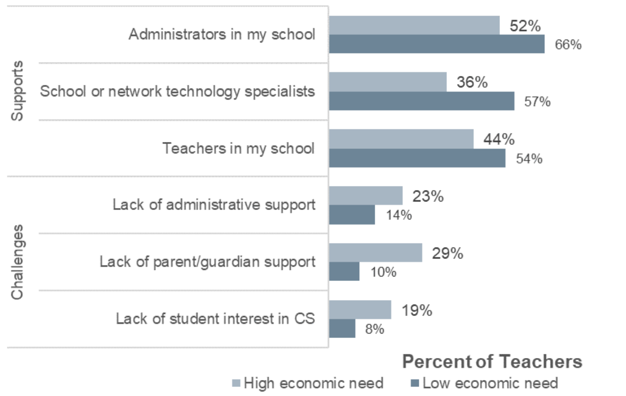


Fig. 3. Selected supports and challenges by school economic need, 2016-2017 school year. High-economic-need group N=86, low-economic-need group N=86. Differences were statistically significant at the 0.05 level.

As with schools with high economic needs, teachers from low-performance schools reported less support and more challenges, though in a few different areas (see Figure 4). In particular, teachers from low-performance schools were less likely to say that teachers from outside their school were supportive. They were also more likely to report a number of challenges, including a lack of expertise in CS education pedagogy and instructional strategies, a lack of expertise in CS content, a lack of parent/guardian support, and a lack of student interest in CS.

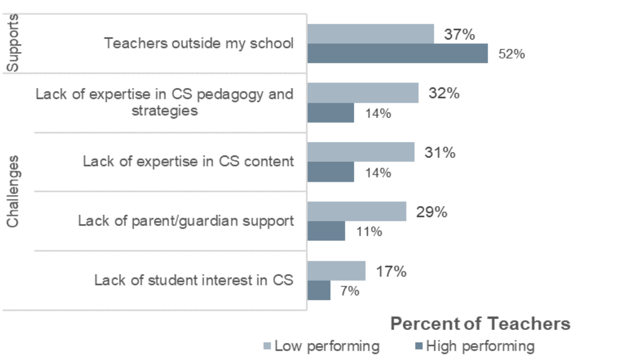


Fig. 4. Selected supports and challenges by school performance, 2016–2017 school year. High-performing schools N=74, low-performing schools N= 84. Differences were statistically significant at the 0.05 level.

IV. Summary and Implications

The survey findings presented here demonstrate that NYC's CS4All initiative has provided large numbers of teachers with CS professional development opportunities that they highly value. Most of them reported implementing CS in their classroom in the following school year. They also reported moderately high levels of confidence in their ability to deliver CS instruction, although many (especially in middle and high school) wish they had a better understanding of the CS concepts they teach. This suggests that in addition to intensive PD, teachers may need other enrichment opportunities and supports to extend their understanding of critical CS concepts and pedagogies. They may also benefit from PD opportunities and supports that are differentiated by grade level, specific content, and teachers' prior CS knowledge and experiences.

Another resource for extending learning about CS is the larger community of CS4All teachers. Among the supports teachers reported accessing were other teachers at their school. The initiative may want to expand its focus on mechanisms (e.g., interest- or need-based meetups, local affinity groups, etc.) to increase opportunities for teachers to connect with other teachers for further learning and support. Local colleges and universities may also be sources of opportunities for certification, continuing education credit, and badges. Our survey revealed that teachers in schools serving lower-performing and higher-economic-need students are less likely to find support for implementation from their peers—possibly because there are no other CS education colleagues in the building. In light of this finding, increasing opportunities for CS teachers to connect with other CS educators could be an important strategy for increasing equity.

The surveys explored both classroom- and school-level challenges to implementing CS. Teachers most frequently reported lack of preparation time and lack of instructional time as classroom-level challenges. For school-level challenges, they most frequently reported competing priorities, the need to prepare students for high-stakes tests, and a lack of time in student schedules. These time and priority challenges are not ones that teachers can necessarily manage themselves. They often require reconsidering priorities, schedule changes, and other structural changes that need the input, direction, and often approval of school administrators.

Because it is clear that administrators are a critical support and can potentially remove barriers to CS instruction, CS4All's efforts to engage school leaders are particularly important—and may be a way to address the school-based challenges teachers identified. Strengthening engagement with and professional development for school leaders will likely enhance CS implementation and help sustain CS4All over time. Further, given that teachers from more advantaged schools (serving students with higher performance and lower economic need) reported more support from their administrators, this is another strategy that can promote equity in CS.

Along similar lines, expanding efforts to coordinate with district superintendents[4] who supervise school principals may help ensure that the importance of CS is being effectively communicated throughout the district. Superintendents may be able to help school leaders balance competing priorities (e.g., by including CS-related initiatives in each school's educational plan). It is possible that priorities are somewhat different at schools with low versus high levels of economic need and performance. At high-economic-need schools, for instance, staff may be focused on meeting students' basic needs; at low-performance schools, staff may prioritize traditional academic subjects—particularly those with accountability stakes for

[4] New York City has 46 superintendents, including 32 who oversee the 32 geographic school districts, nine who oversee high schools, and five who oversee special populations, such as students with disabilities.

students, teachers, and the school as a whole—over computer science. Teacher reports on the survey that implementation of CS is challenged by competing priorities suggests this may be the case. Providing administrator training and support and working with superintendents could help increase understanding of how CS education can support school improvement efforts, rather than detract from them. For example, CS instruction may increase students' engagement in school. Sharing this perspective, along with concrete strategies to balance competing priorities, could result in greater buy-in and prioritization of CS in schools.

In sum, the significant differences that emerged in teacher-reported barriers and supports, based on students' economic need and achievement, create a picture of how school demographics and context influence CS implementation and the support that teachers need. Most commonly, CS for all efforts focus on equity in terms of race/ethnicity and gender. Findings from this study highlight the importance of considering economic need and academic performance in addition to race/ethnicity and gender as key equity factors to attend to in a CS for all initiative.

Finally, we note that as NYC's CS4All initiative moves forward, it will be important to consider how needed supports and challenges may differ for schools that adopt CS later on (and who perhaps are less likely to have a 'champion' or strong staff and parent buy-in for the efforts), or that serve students with higher needs and fewer resources (e.g., lower-performance, higher-poverty schools).

While these findings are from a single district, we believe they point to challenges and supports that are similar to those found in other districts attempting to implement CS for all students. The lessons learned and implications for policy and practice are therefore relevant to other settings.

V. Limitations

As noted earlier, we obtained a 50 percent response rate to the 2017 survey and a 66 percent response rate to the 2018 survey. Conclusions drawn from these surveys are limited by the fact that we do not know if the teachers who responded to the survey are representative of teachers overall. It is possible that teachers who did not respond were systematically different from those who did. Perhaps non-respondents were less likely to have implemented CS in their classroom, or faced additional or different types of challenges. In addition, as with all surveys and self-reported measures, teachers' answers may have been influenced by social desirability—the tendency to give answers that respondents believe are more desirable. Given that other data collected for our larger study of the NYC CS4All initiative, such as interviews with teachers and PD providers, largely corroborate these findings, we do not believe social desirability biased the findings to a significant degree.

Acknowledgment

This study would not have been possible without the generous support of the NYC CS4All Founders Committee and the Fund for Public Schools. In addition, we are grateful for the NYC Department of Education's CS4All team who contributed their time to speak with the research team and provided valuable feedback on our findings. We would also like to thank our current and former colleagues Edgar Rivera-Cash, Rachel Cole, Ethan Crasto, Wendy Castillo, Chelsea Farley, Zitsi Mirakhur, Ben Schwab, Kayla Stewart, Linda Tigani, and Adriana Villavicencio at the Research Alliance for NYC Schools, and Wendy Martin at EDC, for their many contributions to this study. Finally, we are grateful to the administrators, teachers and students involved in the larger NYC CS4All evaluation.

References

[1] U.S. Bureau of Labor Statistics. Office of Occupational Statistics and Employment Projections. Retrieved from https://www.bls.gov/ooh/computer-and-informationtechnology/home.htm.

[2] S. Grover and R. Pea, "Computational Thinking: A competency whose time has come." Computer Science Education: Perspectives on teaching and learning in school. London: Bloomsbury Academic, 19–37, 2018.

[3] Google Inc. & Gallup Inc. Trends in the State of Computer Science in U.S. K–12 Schools. Retrieved from http://goo.gl/j291E0, 2016.

[4] Code.org Advocacy Coalition. 2018 State of Computer Science Education.

[5] Google Inc. & Gallup Inc. Diversity Gaps in Computer Science: Exploring the Underrepresentation of Girls, Blacks and Hispanics. Mountain View, CA: Google Inc. & Gallup Inc., 2016.

[6] Google Inc. & Gallup Inc. Searching for Computer Science: Access and Barriers in U.S. K–12 Education. Mountain View, CA: Google Inc. & Gallup Inc., 2015.

[7] J. Margolis, R. Estrella, J. Goode, J. Holme and K. Nao. Stuck in the Shallow End: Education, Race, and Computing, 2017.

[8] U. S. Department of Education. Office of Postsecondary Education. Teacher Shortage Areas. Retrieved from http://www2.ed.gov/about/offices/list/ope/pol/tsa.html, 2014.

[9] J. Margolis and J. Goode. "Ten Lessons for CS for All." ACM Inroads Magazine, Special Issue on Broadening Participation in Computing. Vol. 7, No. 4, 2014.

[10] Computer Science Teachers Association. Bugs In The System: Computer Science Teacher Certification In The U. S. New York, NY: The Association for Computing Machinery, 2013.

[11] J. Margolis, J. Goode, and K. R. Binning. "Expanding the Pipeline: Exploring Computer Science: Active Learning for Broadening Participation in Computing." Computing Research News, Vol. 27, No. 9, Oct. 2015.

[12] J. Ryoo, J. Goode and J. Margolis. "It takes a village: supporting inquiry- and equity-oriented computer science pedagogy through a professional learning community." Computer Science Education, DOI: 10.1080/08993408.2015.1130952, 2016.

[13] J. Margolis, J. Goode, and G. Chapman. "An Equity Lens for Scaling: A Critical Juncture for Exploring Computer Science." ACM Sept. 2015, Vol. 6, No. 3. Pp. 58-66, 2015.

[14] J. Century, M. Lach, H. King, S. Rand, C. Heppner, B. Franke and J. Westrick, J. Building an Operating System for Computer Science . Retrieved from http://outlier.uchicago.edu/computerscience/OS4CS/, 2013.

[15] J. Goode, J. Margolis, and G. Chapman. "Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model ." In Proceedings of the 45th ACM Technical Symposium on Computer Science Education, pp. 493-498, 2014.

[16] A. Milliken, C. Cody, V. Catete, and T. Barnes. “Effective Computer Science Teacher Professional Development: Beauty and Joy of Computing 2018” ITiCSE ’19 Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education, pp. 271–277, 2019.

[17] T. Price, V. Catete, J. Albert, T. Barnes, and D. Garcia “Lessons Learned from “BJC” CS Principles Professional Development.” SIGCSE 2016.

[18] J. Margolis, J. Goode, J. Ryoo, and D. Bernier. “Seeing Myself Through Someone Else’s Eyes: The Value of In-classroom Coaching for Supporting Exploring Computer Science Teaching and Learning.” Retrieved from http://www.exploringcs.org/wp-content/uploads/2014/04/SeeingMyselfArticle.pdf, 2014.

[19] R. Morelli, C. Uche, P. Lake, and L. Baldwin. “Analyzing Year One of a CS Principles PD Project.” SIGCSE, 2015.

Building Systemic Capacity to Scale and Sustain Equity in Computer Science through Multi-Stakeholder Professional Development

Julie Flapan
CS Equity Project, Center X
University of California, Los Angeles
Los Angeles, CA, USA
flapan@gseis.ucla.edu

Jean J. Ryoo
CS Equity Project, Center X
University of California, Los Angeles
Los Angeles, CA USA
jeanryoo@ucla.edu

Roxana Hadad
CS Equity Project, Center X
University of California, Los Angeles
Los Angeles, CA
rhadad@ucla.edu

***Abstract*—The CSforALL movement has made great strides preparing teachers in computer science (CS) with professional development (PD) toward broadening participation in computing. These opportunities develop teachers' understanding of CS content, alongside culturally-relevant practices and equitable access. However, while a focus on teachers is necessary, it is not sufficient for systemic, scalable, and equitable implementation. Comprehensive PD programs need to include teachers, school counselors, and administrators. This paper uncovers a statewide research-practice partnership's approach to a replicable multi-stakeholder PD model that addresses the following research question: How can a comprehensive CSforALL model effectively engage teachers, counselors, and administrators to work in unison to ensure equity sits at the heart of scaling and sustaining CS education for all students? A university-district research-practice partnership developed a week-long professional learning experience for teachers, counselors, and administrators that linked equity at the classroom, school/district, and policy levels. With the intentions of iteratively improving on the PD and learning about attendees' CS education interests and experiences, the RPP collected and analyzed observations, interviews, and surveys. Findings reveal (1) a multi-stakeholder comprehensive PD model has positive impacts for the capacity-building of CS education leaders; and (2) a focus on equity across all strands of the PD program develops a better understanding of why equity needs to be at the center of CS implementation, allowing different stakeholders to work together to recognize collaboration is needed to respond to the challenges faced at each level of implementation.**

Keywords—equity, computer science education, professional development, teachers, counselors, administrators, research-practice partnership

I. Introduction

A. Computer Science Education

Computer science is power. As computing and digital media touch every aspect of our lives—from what we eat to what we buy to who we vote for—it is crucial that all youth gain an understanding of computer science (CS) and the possibilities it presents regardless of race/ethnicity, gender, sexual orientation, socioeconomic status, or disability. The CSforALL movement has focused its efforts on building capacity of teachers to expand learning opportunities for students. While teachers are key for scaling CS, more actors in the education system need to be part of this broader effort: specifically, school counselors and school leaders/administrators. A focus on classroom instruction and curricula alone will not be enough to ensure long-term sustainable change as educators can only do so much with low funding, school-day scheduling conflicts, and limited pathways for underrepresented students. The support of counselors and administrators is key to making CSforALL a reality, and the CS education community needs to intentionally include them in a collective effort to ensure equitable outcomes for CS in schools.

This is especially true in California. The state has one of the largest economies in the world and one of the most diverse populations in the country—a "majority-minority" state of 6.2 million students who are over 60% Latinx, African American, and Native American [1]—yet students of color, low-income students, females, and English Learners are extremely underrepresented in computing due to disparities in learning opportunities falling along race, gender, and socioeconomic lines [2]. Only 0.5% of the state's 1.9 million high school students took Advanced Placement Computer Science in 2016, and while 53% of these students are Latinx, 50% female, and about 5% African American, only 15% of AP CS A test-takers were Latinx, 27% female, and 1% African American [3].

B. Goals of this Paper and Research Question

This paper uncovers a statewide research-practice partnership's approach to addressing equity and access to computer science education by seeking to answer the following research question: How can CSforALL efforts at the classroom, counselor, and district/county levels work in unison toward ensuring equity sits at the heart of scaling and sustaining CS education for all students?

What follows is a description of a summer five-day professional development (PD) model titled "Summer of CS" developed by a research-practice partnership to scale teacher PD, build education leaders' capacity for local implementation, and contribute to the research base to expand access to equity-minded CS teaching and learning opportunities across the state. The goal of this project was to create an evidence-based model that both builds capacity and can be replicated, thereby serving as an effective, cost-efficient approach to meet the diverse needs of this geographically expansive state. Without data-informed equity-minded implementation, efforts to expand CS may not only be short-lived, but they could have the unintended consequence of simply increasing opportunities for students who already have access to this knowledge. This paper will

This material is based on work supported by the National Science Foundation under Grant # 1837780.

978-1-7281-7172-2/20/$31.00

describe the value of a multi-stakeholder approach to PD as indicated by teachers, counselors, and administrators, as well as why it is crucial to center equity at such PD events.

II. Literature Review

This work is informed by research that examines equitable implementation, various stakeholders' impact on instructional improvement, as well as work that has explored what models are effective in CS PD and PD in general.

Scott, Martin, McAlear, and Madkins [4] describe the various "complex" and "interconnected" barriers to maintaining inequity in CS as 1) structural (disparities in access to rigorous, engaging, and relevant curriculum; lack of diverse role models and peer networks; implicit bias affecting recruitment and placement), and 2) social/psychological (misconceptions about what is CS; perceptions of CS as lacking cultural relevance; stereotype threat; stereotypical cues in classroom environments) [4]. In order to avoid reinscribing the inequities that have been denying large numbers of students of color, low-income students, English Learners, students with disabilities, and females access to quality CS education [2, 5], there needs to be intentional and strategic development of resources and supports that target the individual barriers, while being effective in the overall educational system in which they work [6].

Teachers are the focus of a majority of the studies examining CS PD because their ability to implement and encourage effectively has had significant impact on students' attitudes towards computing [7, 8]. Teachers are on the front lines of broadening participation in computing and their advocacy is imperative in diversifying CS. With effective PD that establishes CS in a way that is culturally relevant and generates a broader understanding of what constitutes CS, teachers can act as change agents to ensure historically underrepresented students are fully included [9].

However, teachers do not work in isolation and cannot do this work alone. Counselors also play a role in serving as gatekeepers to computing courses, encouraging or discouraging students based on implicit biases, rather than students' abilities and interests [2, 10, 11]. As such, counselors must also understand ways to make CS a more equitable field [12].

Administrators are also essential in CSforALL efforts by providing instructional support and leadership. Teachers and counselors rely on principals, superintendents, and curricular leads to develop strong learning environments where teachers feel supported. Education leaders are responsible for carving out time for teachers to collaborate and create a school culture where continuous improvement is prioritized. These leaders need to make data-informed decisions about how to structure school schedules toward expanding equal opportunities for learning by well-prepared teachers [13, 14]. Ongoing collaboration and communication with school leadership and district administration are critical for the effectiveness and long-term sustainability of PD programs. Even PD programs with all other core features sometimes do not have long-term effects on teaching practices and student learning when there is no support from school leadership [e.g. 15]. Administrators need to work closely with teachers and counselors to get effective training that is of sustained duration, focused on CS content, and supports an ongoing professional learning community [13, 16], while promoting the appropriate pedagogical and social-emotional practices that create a healthy learning environment for all [6].

PD can only affect student learning if it involves the entire school community [17]. Because teacher pedagogy is heavily influenced by the school and district contexts in which they work [18], success cannot be measured only by how effective individual teachers and counselors are in promoting CS, but by how all of the factors that play a part in the implementation of equitable CS instruction interact with one another [17]. Research on teaching and learning often analyzes teacher practice outside of district policies [18], but for CS to truly be for all, it is imperative to examine how the system that involves the classroom, the counselor's office, and the county work together.

III. Methods: Research-Practice Partnership as a Networked Improvement Community

Research-practice partnerships (RPPs) are long-term collaborations that foster an equitable partnership with a focus on problems of practice that produce unique analyses [19] toward the improved use of research in decision making [20], and educational outcomes [21]. As such, our RPP builds on several existing collaborations between local education agencies and university researchers who have been engaged in CS expansion efforts for several years; the RPP includes district administrators, county office of education leaders, teachers, and education researchers representing diverse geographic regions across this state.

This RPP chose to form a Networked Improvement Community (NIC) that meets regularly to identify issues impacting CS teachers and district leaders in real time, while discussing how data across regions can help address those issues in different regional settings toward advancing understandings about what works where, when, and under what conditions [19, 22, 23, 24]. The partnership was guided by the following six core principles of NIC improvement science methods focused on implementing research findings in everyday settings [22]: 1) making the effort problem-specific and user-centered; 2) focusing on variation in performance toward advancing efficacy reliably at scale; 3) looking at how local conditions shape practice toward making clearer hypotheses for change; 4) measuring outcomes and processes, including those that are unintended; 5) engaging in rapid cycles of research, feedback, and iteration; and 6) quickening improvement by working across the networked community [25].

The initiating members of the RPP began by identifying the following **problems of practice** with the objective of broadening participation in computing on across the state:

- How can the preparation of CS teachers for broadening participation of computing and capacity building best be scaled, supported, and sustained?
- How can education leaders from districts and county offices of education guide and support the implementation of CS education to ensure that it is equitable, scalable, and sustainable?

To address these problems of practice, the RPP identified a complex web of factors that must be disentangled and responded to with PD and policies to support teachers', counselors', and administrators' efforts to broaden participation in computing.

Our partners felt that isolated teacher PD's are often seen as one-offs, with limited follow-up and lacking connection to larger structural inequalities. In order to address these factors, the partnership has focused on the following goals:

- Build the capacity and preparation of the state's high school CS teachers through equity-focused PD;
- Build education leaders' (school principals, administrators, counselors, school board members) leadership capacity to keep an equity focus on all CS initiatives;

In an effort to address the goals listed above, the partnership organized a "Summer of CS" CSPdWeek during the summer of 2019—modeled after other successful evidence-based CSPdWeeks in Colorado and Indiana [26] that brought together teachers and counselors. What lacked in these other PD models, was a focus on school administrators and leaders responsible for making key decisions that affect the entire school community. These positions include school principals, CS coordinators, and county and district-wide CS or technology administrative leaders. One of the concerns expressed by the RPP founding partners was the sustainability of such a large and expensive PD. They had participated in other regional approaches to PD, but were unable to replicate these models at scale. Therefore, the RPP intentionally designed this CSPdWeek to serve as a model and inspire districts to take what they learned and custom design and implement similar PDs at scale on a local or regional level. The Networked Improvement Community aspect of our RPP allowed the partners to design features of Summer of CS that could be replicated in regions across the state.

This specific 2019 Summer of CS included the following PD programs: CS Fundamentals, CS First, CS Discoveries, CS Principles, Exploring CS, Counselors for Computing, as well as a newly developed Administrator Workshop. The Administrator Workshop and accompanying CS Equity Implementation Guide for Administrators were created by our RPP. All of these PD programs are actively involved in the broader national CSforALL movement, and share a commitment to broadening participation in computing. The classroom-based curricula for teachers are also standards-aligned with Common Core, NGSS, and/or CS standards. Attendees were encouraged to register as 3-person teams representing their specific local education agency (including at least 1 teacher, 1 counselor, 1 district administrator). Additionally, a high-profile lunch panel with an elected official was organized to highlight the perspectives and experiences of educators, counselors, administrators, students, researchers, and policy makers, while collectively wrestling with what is needed across their different areas of expertise for broadening participation in computing.

Data sources from the Summer of CS included quantitative data generated from a Qualtrics survey administered to teachers and counselors, as well as a separate Google Forms survey completed by administrator workshop attendees. Reports and visualizations generated from Qualtrics and Google Forms assisted in the analysis of the data.

Qualitative data from interviews and open-ended survey items were also collected and analyzed. Interviews were recorded with the permission of participants and then transcribed. Researchers noted the prevalence of different responses, group differences in responses, and any outliers from the majority of respondents. Key findings were summarized, and example responses are provided to support quantitative findings.

IV. Findings

A. The Importance of Multi-Stakeholder PD

The driving research question—How can CSforALL efforts at the classroom, counselor, and district/county levels work in unison toward ensuring equity sits at the heart of scaling and sustaining CS education for all students?—helped shine a light on whether or not a multi-stakeholder approach would be effective in promoting equitable CS education practices that were scalable and sustainable. Given their many different commitments and responsibilities, would teachers, counselors, and administrators, as well as invited policymakers, students, and researchers, find the time spent at Summer of CS valuable?

The top-line findings from the surveys were shared with the RPP partners during a video meeting and in a draft report. Together, we made sense of that data and reached the following conclusions. The findings across surveys and interviews reveal that people highly valued this multi-stakeholder approach to CS PD. Analyses of post-surveys completed by 206 attendees of Summer of CS revealed that 15% (n = 31) came to the event specifically to connect with other teachers, counselors, and administrators interested in implementing CS in their schools. This finding suggests that people across the state are seeking out opportunities to connect with other teachers, counselors, and administrators in the CSforALL movement. The post-survey included this agreement/disagreement rating on the likert-scale statement "I found it beneficial to come to a professional development opportunity at the same time and place as professional developments for other educational stakeholders (i.e., teachers, administrators, counselors)," the majority of respondents either agreed (48.57%) or strongly agreed (48.57%). This suggests that while not all came to the gathering with the goal of meeting other educational stakeholders, the majority found it useful to do so, realizing the value of meeting other stakeholders by the end of the week. Furthermore, 40 of the 43 people who reported attending social events designed to create community-building opportunities across stakeholders (e.g., bowling, baseball game, etc.), agreed that they valued these specific contexts for spending time with others in the CS education landscape. All of these data support the fact that CS educational stakeholders find value and desire opportunities to engage with others in CS education.

On this same post-survey, when asked to specifically articulate what people learned from others in this multi-stakeholder learning community (and, therefore, the value of bringing multiple stakeholders together during the same event), people shared how having a multi-stakeholder event helped: 1) clarify the range of roles people must take on in the larger CSforALL movement, as well as 2) counter the feeling of isolation people felt when trying to implement CS.

The ways that people gained new understandings of the range of roles different stakeholders must assume were shared in statements such as:

- "I got to hear first-hand experiences with CS, student perspectives and also to see student created artifacts. **I learned about a struggle around CS that I never knew existed and how people are fighting to ensure that CS exists for all**."

- “I learned about how **counselors can impact** which students are in classes by advocating for them. I learned about the **legislation** going around about CS and how much this is needed in our schools and **how we need to advocate** for these learning opportunities for all of our students.”
- “I learned a great deal about the **perspective of a Computer Sci support person's isolation yet sense of being overwhelmingly needed**.”

Statements such as these illustrate how important it was for various stakeholders to learn about each other’s struggles and achievements, which could inform their own responsibilities and roles while implementing CS.

The importance of challenging one’s isolation by connecting with other stakeholders in the CSforALL community was visible in comments such as:

- “**CS teachers tend to be alone** (I certainly am). This collaboration with other teachers is invaluable. In addition, working with other stakeholders at other levels during informal times has made for an interesting experience and **makes the whole greater than the sum of the parts**.”
- “I learned that **I am not an island onto myself**. The challenges are mostly the same (big or small schools, types of population served, etc.)”
- “We are all in this together.”

Statements such as these reflect the larger sentiment from post-survey takers about how important it was to bring multiple stakeholders together for CS PD.

PD facilitators echoed these ideas in interview as well. All six facilitators who were interviewed agreed that bringing together multiple stakeholders at the Summer of CS was incredibly important. For example, one PD facilitator noted:

> I think it is very important for all educators to interact with each other in regards to **CS education and equity** in the workforce. **Too often we work in a bubble**, on our own. There are **numerous ways that teachers, counselors, administrators, and support staff can help in getting more access to CS education**. These include; access to funds for training and computers, making room the school’s schedule to offer these courses, making the course material engaging and inclusive, recruiting a diverse group of students to take courses, encouraging after school clubs, field trips, and competitions.

Similarly, another facilitator explained:

> I do think it’s **important for teachers to interact with other stakeholders, largely because of the equity issues that are present in CS**. Teachers are essentially the face to the community for CS. **It’s important for them, as the first contact in CS, to be in contact with various stakeholders**: students, teachers, maybe industry leaders, other school admin, community college CS program coordinators, and so forth, so that they can help not just communicate an equitable message to all subgroups of the population, but also to **help develop an equitable strategy for recruitment to help balance out the inequities that we see**.

Interestingly, these PD facilitators were very explicit about how multi-stakeholder PD was crucial to keeping equity at the center of CSforALL. More specifically, facilitators saw value in the ways people could learn about new perspectives across roles in the CSforALL movement, as well as create opportunities for collaboration toward equitable implementation. For example, a different facilitator explained, “**The more people involved, the more people they have to work with, to fall back on, to plan with, to run ideas by**” and that people need to “work together” toward equity in CS. Yet another facilitator shared, “The most beneficial is usually when they can **collaborate with each other and form an informal Professional Learning Network with each other to support each other as they go forward**.” This is best facilitated by gaining access to diverse perspectives among CS education stakeholders. As articulated by the fifth facilitator, bringing together multiple stakeholders:

> **gives teachers new perspectives, provides resources, and helps in networking**...We often don't know problems/issues districts, counselors, and other stakeholders face in hiring CS educators or offering CS courses. On the other hand these stakeholders often don't understand what CS is about and problems CS teachers face in the classrooms. **Bringing them together gives both sides opportunities to get a different perspective and talk about issues**. I also feel we learn a lot about the political issues involved in K-12 CS education - role of [universities] and the state government...These PDs have helped me learn about what is happening at the state level in CS education.

As stated by a sixth facilitator interviewee, just as “**diversity matters in computer science**,” so too should there be diversity of stakeholders present at professional development gatherings: “**teachers should interact with administrators, counselors, parents, among many others.**” This, in turn, can ensure that “[CS education] implementation can be informed by counselors, admin, [and] parents’ needs and wants.” Only by bringing together multiple stakeholders can the conversation begin around how to sustain equity across varying needs and wants, roles and responsibilities in the CSforALL movement.

Beyond discussing issues of equity across multiple stakeholders and creating opportunities for collaboration, one facilitator appreciated how bringing together multiple stakeholders helped her **feel part of a larger movement across the state**. She explained, “I saw that California cares deeply about diversifying their courses and opportunities from the discussions I had in my session as well as discussions over lunch. **My dream conference includes time where stakeholders are mixed together in smaller groups to talk to each other more about how they can work together**.” As another facilitator explained, when educators were able to have contact with other stakeholders in the CS education movement, “They were able to hear and work with each other and learn those different ways. All of that helped change their perspective about **‘hey, this isn’t just teaching another course at my school … it’s much more than that.’**” This was echoed by yet another facilitator who described how coming together across responsibilities and roles helped gel “the idea that **we’re all in this together, we all have a common goal to bring CS to our**

kids. And there's not these people up here and these people down here, but we're all a cohesive group with the same goal."

Data collected following the administrator portion of the workshop revealed how administrators also appreciated the multi-stakeholder approach to Summer of CS. Of 24 administrator survey-takers, **11 administrators explained that they came to the workshop in order to connect with other teachers, counselors, and administrators**. Across the survey-takers, 62.5% strongly agreed and 37.5% agreed with the statement "I found it beneficial to come to a professional development at the same time and place as professional developments for other educational stakeholders (i.e., teachers, administrators, counselors)." Furthermore, 61% strongly agreed and 39% agreed with the statement, "I found information from other Summer of CS attendees valuable for my work." Administrators appreciated PD networking opportunities, stating: "**It was good to sit in a room with other professionals that were talking about the same subject**, talking about the importance of it, and learning about where they were in that process and what pitfalls that they had experienced….I think the **networking part was really, really good**."

In these ways, a multi-stakeholder context for PD proved invaluable to the experience of teachers, counselors, administrators, and facilitators alike, who all recognized their participation and commitment to the larger effort to bring CS education to the entire state.

B. The Importance of Focusing on Equity Across All Strands of Professional Learning

One of the guiding philosophies of the RPP is a commitment to the equitable design and implementation of CS education programs. This commitment was mirrored by the interests of the attendees for Summer of CS. In the post-workshop survey administered to the teachers and counselors who attended the Summer of CS, the most commonly selected answer out of nine options for "What are your top three reasons for attending Summer of CS?" was "I want to find ways to implement more equitable CS programs in my district or school" (n=35). All administrator workshop survey respondents agreed that they understand what equity means in the context of CS education (65% strongly agreed) and why equitable access to CS instruction should be a priority (83% strongly agreed).

In response to the question: "During Summer of CS, what new perspectives or experiences did you learn about from other education stakeholders present during the week who play different roles in California schools than you do?" attendees described learning about equitable implementation from other stakeholders. This ranged from understanding the differences in vocabulary and mindset ("equality vs equity"), to learning about barriers to equitable CS implementation for special populations, including access to calculus and CS existing only in Advanced Placement tracks. Several teachers reported getting ideas for how to bring equitable practices into the classroom (e.g., "I learned computer science concepts and strategies to **make the curriculum equitable and accessible for all students**," and "I hope to use this class as a way to **understand what my [special education] students are doing out of my class and how to help them better.**")

Beyond the classroom, attendees reported on getting a better understanding of the need for an organized CSforALL movement from other stakeholders. They learned about legislation aimed at making CS equitable throughout the state, as well as the need for their role to include advocating for equitable CS education. As one administrator explained, "I developed a greater sense of urgency to promote equity in CS."

Some of the attendees learned about the inequity that existed in the state by learning about the challenges other stakeholders faced in comparison to their own situation. This led to feelings of gratitude for what they did have (e.g., "My district has a stronger commitment to equitable CTE and CS education and has progressed farther into implementation than many other districts and regions") and surprise at what others had to deal with ("e.g. **I learned that other schools have CS as an elective with different availabilities** due to other classes being offered at the same time or other reasons.")

Conversations in the administrator workshop revealed that education leaders are particularly concerned about equity in relation to economic opportunity. Leaders from districts that were large and small, rural and urban, wanted to make sure that their students had promising job prospects and careers once they graduated. As one administrator said:

> I think there is a changing landscape in K-12 ed … [we are] asking K-12 to be more mindful of opportunities after HS. Before was just "get kids to graduate and you were doing your job," but now "have discussions about career-tech ed, what does industry need, the labor-tech demand." **We're here because we don't have enough people who code or go into CS in our state**; that awareness, and maybe responsibility if you see it that way, has filtered down into K-12, not just post-secondary. As admin, we have a different role to play than just one year ago.

They saw CS as a force for equity, as a way for students to get out of poverty, and they were concerned that the schools were not providing them with this opportunity. One administrator said, "We're graduating our kids, but we're preparing them to work at Walmart—70% of them—**but if they could learn CS they could be anywhere and do anything**." It was therefore frustrating to them that their students' current financial situation was preventing them from ever accessing the economic potential CS provided, due to lack of access to transportation, hardware, or even WiFi.

To many administrators, equity was not just about reach or access, but also about quality and rigor. One administrator lamented that the technology class her students took focused on word processing, slide presentations, and spreadsheets, and that students did not have access to "engaging or rigorous curriculum" related to computing. Another administrator was uncomfortable with the disconnect between what the teachers taught in CS and what was needed in the workforce ("**If you have no industry experience, what do you really know?** Don't you think the kids deserve that?").

The need to collect and use data to inform equity-centered CS implementation was also a common theme in the administrator workshop. Administrators spoke of collecting data from local employers to understand where their needs are and from their own districts to determine where gaps exist. More often, however, administrators in the workshop mentioned the power of data as a tool for advocacy. They saw data as a way to underline the importance of the need to disrupt the status quo in order to provide more opportunities to more students. For them, data serve as a way to educate and communicate more effectively with teachers, the school board, or funding agencies regarding "**how the labor market is connected and how we can have an impact on how we're feeding the labor market** with what we're doing in high school programs and PreK-8" or "students who take one CS class are more likely to graduate."

Administrators commented that the session made them realize they had to be "proactive and intentional about recruitment efforts," and discussed using peer mentoring models where existing underrepresented CS students could mentor and attract others, or using marketing material with logos on buttons or t-shirts to create buzz in a school.

Notably, the attendees of the administrator workshop left the session wanting more guidance. Only 36% of respondents strongly agreed that they understood barriers that stand in the way of an equitable CS education program. Similarly, only 43% of respondents strongly agreed and 13% of respondents disagreed that they had ideas and resources for overcoming barriers to equitable CS education. In response to a question about how to improve the workshop, one participant called for "more actionable steps around breaking down equity barriers, beyond just identifying them." While this workshop opened up many opportunities for education leaders to explore ways they can support equity in computer science, there is still more guidance needed to develop concrete action plans to take their learning back to their local contexts.

V. Discussion & Conclusion

A. The Importance of Multiple Stakeholders Participating in High Quality PD at CSPD Week

The findings above highlight the fact that teachers, counselors, and administrators alike highly valued the opportunity to meet other CS education stakeholders, learn about the varying roles people play and efforts they were engaged in, and feel a sense of community within the larger CS movement to ensure *all* students gain access to quality and rigorous CS education. Across the board, people attending the Summer of CS found significant value in the time they spent with other stakeholders, learning about their perspectives and priorities from different professional roles and activities that they did not realize before the PD. By seeing themselves as part of a larger community with a shared goal of equity in computer science, participants did not feel as isolated as they once did. Participating in a comprehensive professional learning experience like Summer of CS, the diverse stakeholders began to understand the different challenges each role faces in scaling and sustaining equitable computer science. These findings reflect the value of bringing leadership together with teachers and counselors during PD opportunities. Furthermore, this research confirms that professional learning for teachers cannot occur in a vacuum. To increase effectiveness, PD must include conditions for learning both within schools and across the system level.

The Summer of CS is a prime example of a PD model that aims to incorporate the individual indicators of high quality professional learning along with supports for systemic implementation more broadly. By incorporating professional learning opportunities for teachers, counselors, and school leaders, models like Summer of CS help build capacity with numerous stakeholders at the school level while building broader capacity at a systems level, thereby resulting in widespread scalable and sustainable equity-minded CS learning in its relevant context.

Such findings suggest that, in order to continue supporting the CSforALL movement across contexts, it will be important to continue designing PD opportunities that support multiple stakeholders to learn together, as was organized during the Summer of CS. However, simply bringing people together to the same place is not enough. Close attention must be paid to ensuring that multiple stakeholders engage in authentic and meaningful interactions with one another. In the case of Summer of CS, a policy panel discussion and luncheon was organized for people to meet and hear from varying perspectives across the CS education landscape. To build community and collaboration across roles, social events during the evenings where various stakeholders could interact with one another in a relaxed environment. Social events can help foster a sense of community with time set aside for productive networking and interaction, both during the time assigned for professional development working hours, as well as after-work hours. This way those who work across varying levels of effort are aware of each other's roles toward building equitable and sustainable CS education.

Relatedly, the effort to bring multiple stakeholders together cannot end after the PD is over. As found in prior research [e.g., 16], educators in the world of CS highly value contact with others in the field because they often feel isolated as the only CS teachers on their school campuses. Building opportunities for educators to interact with counselors and administrators during a CSPdWeek can help counter that feeling of isolation within school campuses, allowing for educators to find other CS champions from their school communities. Building these opportunities for multi-stakeholder interaction allows for bonds to be built across different regions in the state, so that people can learn from each other's varying approaches to implementing CS education. As expressed in open-ended survey responses and interviews described above, multiple stakeholders coming together allow for new bridges to be constructed between varying roles in the CS education landscape.

As Darling-Hammond, Hyler, and Gardner, [13] emphasize, professional learning is most effective when it is of sustained duration and provides ongoing support and continued coaching. Unfortunately, it is often in the hands of individual motivated teachers, counselors, and administrators to make the most of those connections and plan continued learning opportunities. In addition to each of the PD providers offering important and ongoing learning opportunities to connect, Summer of CS helps connect educators to national networking and capacity building communities such as the Computer Science Teachers Association and CSforALL Teachers. More intentional follow-up can be done to sustain newly formed relationships across stakeholders. An important area for further research involves figuring out ways to allow continued networking and interaction to occur among multiple CS education stakeholders beyond a comprehensive CSPdWeek. How can conversations continue beyond the intensive time spent together during the summer? While individuals may exchange contact information and reach out to one another for advice or support, more is needed to institutionalize such interactions and better ensure the networks continue after the initial CSPdWeek.

B. Keeping Equity at the Center of CS PD Efforts

The findings above emphasize how various stakeholders attending the Summer of CS shared a commitment toward equity in CS. There was a collective belief that equity should sit at the center of PD experiences. Educators, administrators, and counselors alike recognized that youth are receiving differential access to computing education based on race/ethnicity, class, gender, home language, immigration status, and more. These same educators, administrators, and counselors want to support CS education that counters such inequity, ensuring that *all* students have access to rigorous and meaningful computing learning experiences and they want to learn actionable steps for how to make that happen.

As such, efforts must be made in CSPdWeeks to prioritize communities that do not have resources or access to quality CS education. As emphasized by administrators, examining localized data is an important way to inform an equitable approach to implementation. A critical component of Summer of CS is the commitment of administrators to gather CS education related data (number of courses in their schools, number of students, demographics of their students, pass rates etc.) from their own districts. These data help ground educators in the reality of their schools and districts and the inequities that may exist, as well as provide evidence for why they need financial and institutional support in expanding their CS efforts. The intention of Summer of CS was to foreground the workshops through reflection on the data and what it suggests in terms of equity in CS education in their schools and how teachers, counselors, and administrators can expand access to students who currently don't have these opportunities.

In selecting PD providers to replicate Summer of CS, it is recommended that equity guides the direction of CS PD experiences for all stakeholders; PD providers must be chosen who focus on equity explicitly. PD providers and resources should not be companies seeking to sell their latest gadgets or technological tools, but instead be providers who are authentically driven by the shared equity values in CSforALL. In addition to explicitly shared values of equity and expanding access to underrepresented students in CS, providers must move beyond access and diversity, and attend to inclusion and engagement of students in high quality CS [27]. This includes culturally responsive teaching practice to engage students of color, girls, students with special needs and others who are underrepresented in CS [4]. How are they considering ways to address the funds of knowledge [28, 29] that youth are bringing into learning spaces, and ways to connect computing to the interests, needs, and desires youth have toward positively impacting their communities [30, 31]?

Furthermore, are the PD providers chosen during the CSPdWeek paying attention to rigor and quality of educational content? Are the PD providers aligning their curricula with state CS, ICT, and NGSS standards? PD providers need to be explicit about their approach to computer science; including computational thinking, problem solving, and creativity in their curricula and instruction in ways that support more equitable but also rigorous CS learning experiences for students. Relatedly, data indicators should be inclusive of access and also indicators of learning CS. For example, it is not enough to look at the increase of numbers of AP test takers, but take into account the disaggregated data on pass rates to ensure equal opportunities and outcomes for both teaching and learning rigorous CS.

For equity to truly be at the heart of CSPdWeek efforts for teachers, counselors, and administrators, PD conversations should be informed by current and accurate data. Real-time data are needed to ensure that multiple stakeholders in the CS education landscape are clear about where their efforts are missing the mark, as well as where their efforts are meeting success at closing equity gaps.

Because of the systemic and complicated nature of issues that have an effect on equitable implementation of CS, teachers, counselors, and administrators can feel overwhelmed by the task at hand. PD participants need to be provided with tools to address the equity gaps found in the data. Educators need further support to develop actionable steps that all stakeholders can take when they return to their schools and districts.

The Summer of CS model effectively incentivizes small teams from districts, schools, or counties to attend the PD so that upon return, teachers, counselors and administrators will have a team to further develop their vision for CSforALL. Building capacity for teachers, counselors, and administrators is a systemic approach to ensure that multiple levels in the education system are attending to issues of equity and addressing opportunity gaps from various vantage points. More research is needed to compare the outcomes of teacher-only approaches to multi-stakeholder approaches to PD, in order to affirm the value of counselors and administrators in discussions around equity, access, and inclusion in computer science.

CS cannot be viewed in isolation of the complex demands and ever-changing constraints and unequal structures of the broader school system. Local education agencies face herculean challenges of managing school budgets, staffing, and competing demands of the broader K12 system. Adding to the mix is figuring out where CS belongs in the curriculum, how to prepare teachers to teach it, and how to incentivize students to take it. The Summer of CS comprehensive PD program brings together stakeholders to collectively respond to these challenges and share a commitment to an equitable approach to ensure access and inclusion for all students at all schools in the system.

The systemic approach offered by Summer of CS to build capacity among teachers, counselors, and administrators helps build an ongoing community of practice to respond to these challenges while advancing a collective vision for CSforALL.

Educators and policymakers alike share a concern for scaling and sustaining equitable CS. The Summer of CS is intended to serve as a replicable model to inspire districts, counties, and other statewide systems of support to customize similar PD programs at the local level. As a proof-of-concept, it is a goal that state budgets will support this model with funding so that local education agencies will work together to replicate this model with a sustainable cost-sharing structure to provide equitable, scalable, and sustainable computer science teaching and learning opportunities at all schools in California.

ACKNOWLEDGMENT

This material is based on work supported by the National Science Foundation under Grant # 1837780. We would like to thank our RPP partners Jared Amalong and Louise Stymeist of Sacramento County Office of Education; Steve Kong, Steve Dunlap, and Jessie Gurbada of Riverside Unified School District; Bryan Twarek of San Francisco Unified School District; Sophia Mendoza of Los Angeles Unified School District; and Michele Dawson and Dylan Lira of Compton Unified School District. We would also like to thank our research partners at AIR: Joel Knudson, Julie Kochanek, and Joey Wilson.

REFERENCES

[1] CSBA Analysis: California Department of Education, DataQuest. 2018-19 enrollment by ethnicity. Retrieved on October 24, 2019, from https://bit.ly/361GSJg.

[2] J. Margolis, R. Estrella, J. Goode, J. Jellison-Holme, and K. Nao. Stuck in the Shallow End: Education, Race, and Computing. Cambridge, MA: MIT Press, 2008/2017.

[3] A. Scott, S. Koshy, M. Rao, L. Hinton, J. Flapan, A. Martin, and F. McAlear. Computer Science in California's Schools: An Analysis of Access, Enrollment, and Equity. Oakland, CA: Kapor Center and CSforCA, 2019.

[4] A. Scott, A. Martin, F. McAlear, and T.C. Madkins, "Broadening Participation in Computer Science: Existing Out-of-School Initiatives and a Case Study," ACM Inroads, 7(4), 2-16, pp. 84-90.

[5] K. Bobb, "Unifying Equity and Access in Computing," Medium, 2018.

[6] J. Goode, J. Flapan, and J. Margolis. 2018. Computer Science for All: A School Reform Framework for Broadening Participation in Computing. In W. G. Tierney, Z. B. Corwin, & A. Ochsner, ed. *Diversifying Digital Learning: Online Literacy and Educational Opportunity*. Baltimore, MD: Johns Hopkins University Press, 45–65.

[7] L.J. Barker, C. McDowell, and K. Kalahar, "Exploring factors that influence computer science introductory course students to persist in the major." In ACM SIGCSE Bulletin, vol. 41, no. 1, 2009, pp. 153-157.

[8] H.K. Tillberg, and J.M. Cohoon, "Attracting women to the CS major," Frontiers: a journal of women studies, 2005, pp. 126-140.

[9] J. Goode, "If You Build Teachers, Will Students Come? The Role of Teachers in Broadening Computer Science Learning for Urban Youth" Journal of Educational Computing Research, vol 36, no 1, 2007, pp. 65-88.

[10] J. Oakes, Keeping Track: How Schools Structure Inequality. New Haven: Yale University Press, 1985.

[11] J. Oakes, J. "Opportunities, Achievement, and Choice: Women and Minority Students in Science and Mathematics," Review of Research in Education, vol 16, 1990, pp. 153-222.

[12] A. Munson, B. Moskal, A. Harriger, T. Lauriski-Karriker, and D. Heersink, "Computing at the high school level: Changing what teachers and students know and believe," Computers & Education, vol 57, no 2, 2011, pp. 1836-1849.

[13] L. Darling-Hammond, M.E. Hyler, and M. Gardner. Effective Teacher Professional Development. Palo Alto, CA: Learning Policy Institute, 2017.

[14] L. Sutcher, A. Podolsky, and D. Espinoza, D. Supporting Principals' Learning: Key Features of Effective Programs. Palo Alto, CA: Learning Policy Institute, 2017.

[15] L.M. Desimone, A.C. Porter, M.S. Garet, K.S. Yoon, and B.F. Birman, "Effects of professional development on teachers' instruction: Results from a three-year longitudinal study." Education Evaluation and Policy Analysis, vol 24, no 2, 2002, pp. 81-112.

[16] J.J. Ryoo, J. Goode, and J. Margolis, "It takes a village: supporting inquiry-and equity-oriented computer science pedagogy through a professional learning community." Computer Science Education, vol 25, no 4, 2015, pp. 351-370

[17] G. Diaz-Maggioli, Teacher-Centered Professional Development. ASCD. 2004.

[18] P. Cobb, K. Jackson, E.C. Henrick, T.M. Smith, and MIST team. (2018). Systems for Instructional Improvement: Creating Coherence from the Classroom to the District Office. Cambridge, MA: Harvard Education Press, 2018.

[19] C.E. Coburn, W.R. Penuel, and K.E. Geil, Research-Practice Partnerships: A Strategy for Leveraging Research for Educational Improvement in School Districts, New York, NY: William T. Grant Foundation, 2013.

[20] V. Tseng. Partnerships: Shifting the Dynamics Between Research and Practice, New York, NY: William T. Grant Foundation, 2012.

[21] B.J. Fishman, W.R. Penuel, A.R. Allen, and B.H. Cheng (Eds), Design-based Implementation Research: Theories, Methods, and Exemplars. New York, NY: Teachers College Press, 2013.

[22] A.S. Bryk, "Support a Science of Performance Improvement," Phi Delta Kappan, vol 90, no. 8, 2009, pp. 597-600.

[23] A.S. Bryk, L.M. Gomez, and A. Grunow, Getting Ideas Into Action: Building Networked Improvement Communities in Education, Stanford, CA: Carnegie Foundation for the Advancement of Teaching, 2010.

[24] D.M. Berwick, "The Science of Improvement," The Journal of the American Medical Association, vol 299, no 10, 2008, pp. 1182-1184.

[25] A.S. Bryk., L.M. Gomez, A. Grunow, and P.G. LeMahieu, Learning to improve: How America's schools can get better at getting better. Harvard Education Press, 2015.

[26] T. Camp, E. Schanzer, J. Goode, O. Astrachan, and E. Campos. 2017. CSPd Week: A Scalable Model for Preparing Teachers for CS for All. In Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE '17). ACM, New York, NY, USA, 645-646. DOI: https://doi.org/10.1145/3017680.3017681

[27] Microsoft and NCWIT. Guide to Inclusive Computer Science Education. Retrieved October 1, 2019 from https://www.ncwit.org/resources/guide-inclusive-computer-science-education-how-educators-can-encourage-and-engage-all

[28] L.C. Moll, C. Amanti, D. Neff, and N. Gonzalez, "Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms." Theory into Practice, vol 31, no 2, 1992, pp. 132-141.

[29] N. González, L.C. Moll, and C. Amanti, C. (Eds.), Funds of Knowledge: Theorizing Practices in Households, Communities, and Classrooms. New York, NY: Routledge, 2006.

[30] J.J. Ryoo, C. Estrada, T. Tanksley, and J. Margolis, Connecting Computer Science Education to Students' Passions: A critical step toward supporting equity in CS education. University of California, Los Angeles, Center X: Computer Science Equity Project, 2019.

[31] S. Vakil, Ethics, Identity, and Political Vision: Toward a Justice-Centered Approach to Equity in Computer Science Education, Harvard Educational Review, vol 88, no 1, 2018, pp. 26-52.

Centering the Identities of Girls of Color in Computational Thinking Programs

Patricia Garcia
School of Information
University of Michigan
Ann Arbor, USA
garciapg@umich.edu

Ashley Jackson
School of Education
University of Michigan
Ann Arbor, USA
jacksash@umich.edu

Laura-Ann Jacobs
School of Education
University of Michigan
Ann Arbor, USA
lxjacobs@umich.edu

***Abstract*—Efforts to broaden participation in computing have revealed the need for a deeper theoretical and empirical understanding of how girls of color form computing identities. In this paper, we use the concept of identities-in-practice as an analytical frame to examine how girls of color engage in computational thinking practices. Our research investigates how the identities of girls of color can be leveraged as funds of knowledge in learning spaces and asks the following research question: How does centering the identities of girls of color impact their engagement with computational thinking practices? We provide a program overview of CompuGirls, describe our curricular design approach, and share results from pilot implementations of the program offered at public libraries in Michigan, Arizona, and California. Results from our pilot year demonstrate that integrating identity exploration into a computational thinking curriculum results in a mutually reinforcing relationship where girls of color experience reflective identity development while simultaneously increasing their understanding of computational thinking. We present our approach as a promising avenue for connecting computing knowledge and skills to girls' identities and lived experiences. By focusing on the girls' identities, the program re-imagines computational experiences by fostering interactions with computational thinking from a personal perspective. Ultimately, we argue that centering girls' identities should be viewed as an integral part of the learning process and not tangential.**

Keywords—computing education, computational thinking, gender

I. Introduction

Despite numerous efforts to broaden participation in computing, disparities in participation among underrepresented minorities continue to persist across all educational levels. While we acknowledge that the barriers to diversifying participation in computing are varied and complex, we argue for the urgent need to deeply examine the social and cultural barriers that result in differential learner participation and stratification along racialized, gendered, and classed lines [1]. For girls of color in particular, scholars [2] have explicitly advocated for a greater theoretical and empirical understanding of how the social and cultural aspects of learning environments impact the formation of computing identities [3] and how the intersections of gender and race shape their educational experiences [4].

Motivated by research that has demonstrated the pedagogical utility of centering girls' identities in curriculum materials [5], this study draws from sociocultural theories of identity to examine girls' experiences reflecting on their identities throughout the course of engaging in computational thinking practices. We define the concept of "identity" as a form of self-understanding that is complex and negotiated across contexts and in relationship with others [6] [7]. As such, our study addresses the following research question: How can identity exploration can be leveraged to promote computational thinking (CT) practices among girls of color, ages 13-16?

This paper presents preliminary findings from an informal STEM program designed in collaboration with library partners. The program includes the development of a 20-hour computational thinking curriculum implemented across three geographically-dispersed public libraries in Michigan, Arizona, and California. Results from our pilot year suggest that integrating identity exploration into a computational thinking curriculum results in a mutually reinforcing relationship where girls of color experience reflective identity development while simultaneously increasing their understanding of computational thinking practices. By focusing on the girls' identities, the program re-imagines computational experiences by fostering interactions with computational thinking from a personal perspective. We present our approach as a promising avenue for connecting computing knowledge and skills to girls' identities and lived experiences. Ultimately, we argue that centering girls' identities should be viewed as an integral part of the learning process and not tangential.

II. Background

A. Social and Cultural Barriers in Computer Science Education

Participation in computer science education continues to be unevenly distributed, resulting in educational inequalities that further contribute to diversity gaps, particularly among underrepresented minorities such as women and students of color. For female students of color specifically, some of the most embedded and harmful contributors to diversity gaps in computer science are social and cultural factors that result in unwelcoming learning environments. These social and cultural factors include racialized and gendered stereotypes of their

This project is funded by IMLS award LG-80-16-0116-16

STEM abilities and interests [8] and positioning of female students of color as lacking motivation, unable to master challenging STEM course content, and missing the social supports necessary to fully participate in an academic culture [9].

Thus, in order to persist in learning environments like computer science courses, female students of color are faced with navigating a learning environment and institutional culture that often does not honor or legitimize their identities, interests, and abilities. The result of learning environments that privilege dominant language and literacies are pedagogical approaches and course content that are mistakenly perceived as "neutral" [10]. Within this paradigm, computational thinking is often taught using presumably "neutral" approaches that emphasize the mastery of task-based skills such as correctly applying the syntactic and semantic rules of programming languages.

B. Computational Thinking Practices

The concept of "computational thinking" continues to undergo definitional and conceptual debate [11] [12] [13]. Computer science education researchers have proposed and studied a variety of thought processes including abstraction, pattern generalization, systematic processing of information, algorithmic thinking, decomposition, parallel thinking, conditional logic, among others [12]. In our own work, the focus on computational thinking practices aligns with efforts to create an actionable definition of computational thinking that can be studied qualitatively and quantitatively [14]. Rather than focus on abstract thought processes or mental syntheses that are difficult to identify due to their conscious or unconscious nature, this research focuses on computational thinking practices, or what learners "do" as they engage in computational problem solving within the larger context of STEM learning [15] [16].

Within K-12 contexts, research has largely focused on teaching computational thinking via programming [17] [18]. Researchers have focused on developing tools that make programming more accessible to K-12 students; for instance, several studies have examined the effectiveness of using visual programming tools such as Scratch [19] [20] [21] and MIT App Inventor [22] to teach computational thinking and programming skills. While these approaches have yielded successful results, there remains a knowledge gap on how the practices of computational thinking are connected to students' cultural and social experiences and their future career goals and interests.

III. Conceptual Framework

Research in STEM education has broadly demonstrated how grounding learning in students lived experiences and identities promotes academic achievement [23] [24]. We utilize the concept of identities-in-practice [25] to examine how girls engage in computational thinking practices through identity work and in relationship with peers and facilitators. The concept of "identities-in-practice" examines identity development in situ as learners participate and learn the practices of a community [26]. In designing the curriculum, we focused on providing girls opportunities to enact disciplinary literacies related to computing via computational thinking practices. Moje [27] defines disciplinary literacies as "the different knowledge and ways of knowing, doing, believing, and communicating that are privileged" in particular domains. By focusing on computational thinking practices, we provided opportunities for the girls to participate in the "doing" and "communicating" that are privileged within computing contexts.

IV. Research Design

A. Context

The data used for this study was drawn from a pilot implementation of CompuGirls, a computational thinking program offered in public libraries in Michigan, Arizona, and California from June 2017 to June 2018. Research has demonstrated that informal learning environments are a promising forefront for engaging students in STEM [28] [29]. We partnered with libraries because they have a long history of providing youth services, are embedded in communities, often work directly with families and community partners, and represent safe settings that provide public access to resources [30].

We recruited three library partners by considering the following factors: demographic makeup of library patrons and communities, geographic location of branches (e.g. rural and urban), and institutional availability of resources, such as staff and funds devoted to young adult programming. These selection criteria allowed us to recruit a racially, ethnic, socioeconomically, geographically, and institutionally diverse set of partner sites. The three partnering sites are library systems located in an urban city in Southeastern Michigan, a rural town in Southern California, and an urban city in Central Arizona. In total, we collaborated with eight library professionals, which included youth services librarians, paraprofessionals, and branch managers.

B. Curriculum

The pilot program utilized a curriculum that combined computational thinking and identity-based activities. The curriculum includes ten modules that covered computational thinking practices drawn from the AP Computer Science Principles Curriculum Framework [31] (see Table I for examples of practices). The curriculum was co-developed by the research team and the eight participating librarians through a series of in-person and remote meetings. The librarians provided feedback on the content and pacing of the activities, as well as suggestions for ensuring that the curriculum could be feasibly implemented across a range of library systems.

TABLE I. Computational Thinking Practices

Practice	Definition
Analyzing problems and artifacts	Analyzing complex problems by breaking them down into smaller units
Creating computational artifacts	Designing a solution for a problem by developing a process or set of rules
Using abstraction and models	Removing extraneous details to identify general principles or models

Each module consisted of 2-hours of computational thinking activities (20 hours total) that utilized low-cost materials such as batteries, LEDs, paper, and colored markers. The majority of the activities (sixteen hours) were ”unplugged” activities that did not require a computer and two modules (four hours) were Arduino activities that were completed at a local makerspace. ”Unplugged” efforts aim to teach computational thinking skills and practices using methodologies that do not require access to computers [32] [33] [34]. The research team and participating librarians made a joint decision to create a predominately unplugged curriculum in order to accommodate future library partners with limited computer and internet access. In addition to focusing on computational thinking practices, each module offered identity-based activities that were intentionally designed to center student identity and experience within the learning process. While each of the modules follows the breakdown described below in Table II, we will discuss two illustrative lessons in this paper.

TABLE II. INDIVIDUAL MODULE BREAKDOWN

Lesson Section	**Description**
Supporting Identity Exploration	Girls engage in individual or group activities that facilitate an exploration of personal or collective identity
Anchoring Computational Thinking	Facilitator introduces CT skill by making an explicit connection to the identity-based activity
Promoting Knowledge Transfer	Facilitator guides girls in transferring their identity-based understanding of CT to a STEM context such as circuitry
Facilitating Reflection	Facilitator prompts girls to reflect on their understanding of CT from an identity-based and STEM-based perspective

C. Participants

Due to the personal nature of the identity exploration and the availability of resources, the program enrollment was capped at ten girls per implementation. Recruitment efforts targeted girls from diverse racial, ethnic, and socioeconomic backgrounds between the ages of 13-16. Given the focus on serving girls of color, participants from diverse ethnic and racial backgrounds were given priority enrollment. The enrollment percentages broken down by race (Table III) did resemble the overall demographics of the community. The recruitment was conducted by the librarians who hosted “open houses” where girls were invited to learn about the program and engage in hands-on activities similar to those they would experience if enrolled in the program, such as constructing simple circuits using copper tape, LEDs, and coin cell batteries. Additionally, the librarians presented at junior high schools, contacted local organizations such as chapters of Women in Science and Engineering (WISE), and advertised the program on library and city government websites. In total, 64 girls were recruited to participate in the program (Table 2).

TABLE III. PARTICIPANT DEMOGRAPHICS

Site	Start Date	No.	Racial/Ethnic
AZ	06/17	3	67% Latina 33% Asian
	10/17	9	33% White 33% Multiracial 11% Latina 11%African American 11% Native American
	03/18	10	60% White 30% Multiracial 10% Asian
	06/18	9	56% White 44% Multiracial
CA	7/17	4	100% Latina
	4/18	4	100% Latina
MI	06/17	9	77% African American 22% White
	03/18	7	71% African American 29% White
	06/18	9	78% African American 22% White height

D. Data Collection

The pilot program was offered over summer, fall, and spring breaks and held in “teen zones” or other youth-oriented spaces within the three libraries. The data for this study was collected during nine pilot implementations of the CompuGirls program offered from June 2017 to July 2018. Given the complex nature of learning, we implemented a protocol that allowed for the collection of varied data types that captured participants’ behaviors, actions, and artifact creation related to identity expression and demonstration of computational thinking practices.

Two researchers attended each program session and collected participant observation data. One researcher focused on taking field notes and the second researcher on collecting audiovisual recordings and student-created artifacts. Participant observation activities included co-facilitating icebreaker activities that focused on personal and group identity, helping participants troubleshoot during STEM activities, engaging in whole group reflection activities, and debriefing with librarian facilitators after daily sessions. In total, the observational data collection approach yielded systematic field notes, audiovisual recordings of program activities, and photographs of student-created artifacts such as journal entries, group projects, and expressive artwork.

E. Data Analysis

We used an inductive and emergent process to develop codes by directly examining the data in relationship to three broad interest areas [35]. The broad interest areas included girls’ behaviors and actions related to: 1) participation in a community of practice such as engaging in a collaborative learning process; 2) development of “identities-in-practice” through engaging in activities and tasks related to computational thinking; and 3) negotiations of “identities-in-practice” in relationship to peers, facilitators, and self-positioning. Based on these broad interest areas, three members of the research team analyzed a subset of the data and created codes through the process of verbal consensus-building. The codes were applied to the entire data set by two members of the research team. The two members coded blindly (meaning they could not see each other's code applications) in the qualitative data analysis software Dedoose. After all data was coded the research team members ran a code application comparison and created analytic memos for disagreements. Each analytic memo included a rationale for the code(s) application in order to facilitate a larger group discussion with all seven members of the research team. The entire research team engaged in the process of verbal consensus-building to resolve instances of disagreement; however, in order to honor the interpretive process, we did not aim to reach complete agreement and allowed for variance in interpretation.

The analysis process included cross-checking interpretative claims using data and investigator triangulation. Data triangulation occurred by converging information gathered across the textual, audio, and visual forms of data. Investigator triangulation occurred through the use of multiple researchers in the process of data collection and analysis to "balance out the subjective influences of individuals" [36]. Thematic analysis of the coded raw data occurred through a collaborative process where there was a "joint focus and dialogue" among the three researchers "regarding a shared body of data, to produce an agreed interpretation" [37]. The agreed interpretations were used to create themes and interpretive claims that were representative of all three sites. While we did note variance across the three sites, we did not conduct a comparative analysis and instead report on themes that surfaced across sites.

V. Findings

Given the paper's focus on exploring how identity exploration can be leveraged in the learning process, the findings from this paper will focus on how identity exploration was used as an entry point to computational thinking. Thus, rather than focus on quantitative measures of computational thinking gains, we present a detailed analysis of a particular activity that highlights how girls were able to transfer their understanding of decomposition (e.g. analyzing complex problems by breaking down them into smaller units) as grounded in their personal identities to a STEM-related context.

A. Anchoring activities in girls' identities offered a personal entry point to computational thinking practices.

The girls in the program participated in an "I Am" activity that was designed to bridge computational thinking practices with self-knowledge through an exploration of one's complex identity using the practice of breaking down complex concepts into smaller units, also known as decomposition. The librarians facilitated a discussion of social identity groups that prompted the girls to reflect on the complexity of their identity and multi-group membership. In order to encourage reciprocal sharing, the librarians used a list of identity categories provided in girls' journals (Figure 1) to share examples of their own complex identity.

Fig. 1. Sample journal page listing identity groups.

For example, Kendra, a teen services librarian, shared, "I am an adult woman who identifies as white and middle class." The librarians encouraged girls to use the practice of decomposition to gain a deeper understanding of their complex identities by asking them to "break down who they are" into discrete social identity groups and further reflect on their position as a member of multiple social identity groups.

For instance, Jasmine (all names are psuedonyms) used the social categories listed in the journal activity to reflect on her personal identity. While she had many social identity categories to choose from, she chose those that described her age, race, gender, class, religion, and language. When asked why she chose these personal identifiers, she paused, giggled, and then responded, "I guess these are the one's that most people probably notice about me." Her response revealed her process of breaking down her complex identity into smaller units included reflecting on how others saw her. Her response demonstrated that she was able recognize how her identity is complex and often negotiated in relationship to others.

B. Anchoring activities in girls' identities offered a personal grounding to return to when applying computational thinking in other contexts.

Since we were interested in capturing data on their "identities-in-practice," we followed up identity-based activ-

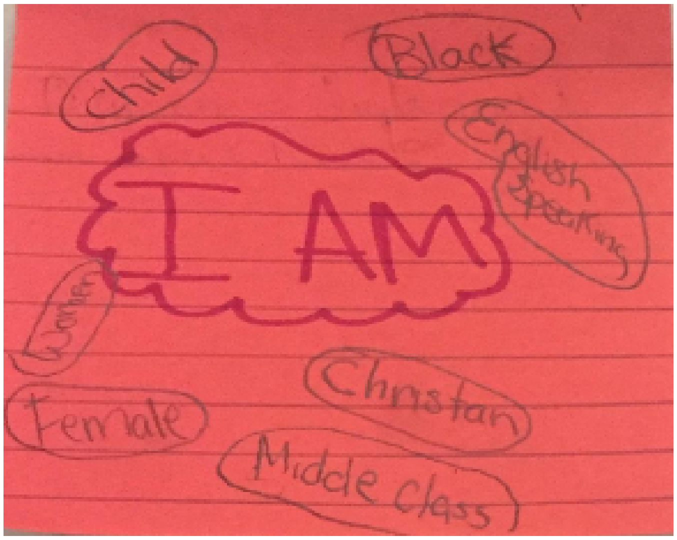


FIG. 2. BREAKING DOWN COMPLEX IDENTITY INTO SOCIAL IDENTITY GROUPS.

ities with STEM activities that incorporated computational thinking and provided girls opportunities to participate in the ways of "doing" and "communicating" that are privileged within computing contexts. For example, after decomposing their identity, the girls were asked to apply the same skill to the creation of circuit. Most of the girls were creating circuits for the first time which resulted in nervousness. However, the librarians facilitating the activity reminded the girls that they could decompose the circuit in the same way they had decomposed their identity in order to understand how it worked. The girls worked together to decompose the circuit they were creating by first listing all the components and then describing the relationship between them (Figure 3).

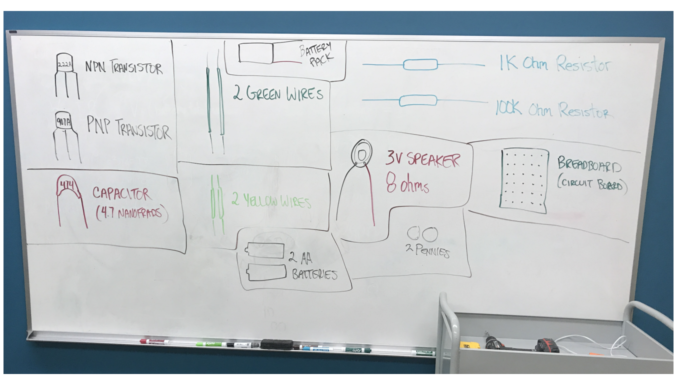


FIG. 3. DECOMPOSING A COMPLEX CIRCUIT ON THE BOARD.

As a knowledge checkpoint, girls were asked to reflect on how they used decomposition throughout the identity and circuitry activities. As demonstrated in Figures 3, reflecting on identity and decomposition led girls to make connections between their self-knowledge and the practice of disentangling complex concepts such as personal identity. Sarah shared how decomposition helped her both identify three personally salient identity categories, as well connect the act of breaking down her identity to the creation of a circuit.

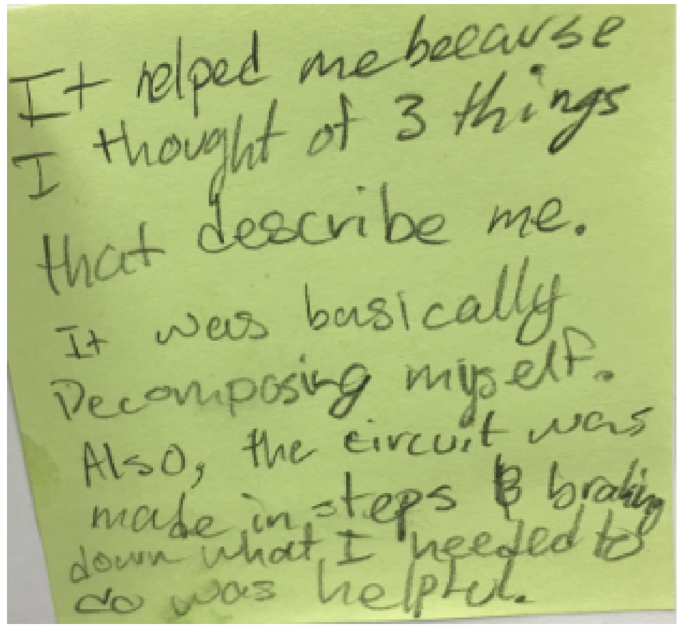


FIG. 4. CONNECTING BREAKING DOWN COMPLEX IDENTITY TO BREAKING DOWN PARTS OF A COMPLETE CIRCUIT.

The remainder of the activity continued to increase in complexity and introduced controlling physical outputs by combining their circuitry knowledge with Arduino code, such as creating the circuits and sketches to make buzzers, speakers, and lights turn on. With the introduction of programming via Arduino sketches, the librarians were able to once again build on the girls' previous knowledge of decomposition that was grounded in the identity-based activity to explain how to break down complex code into small chunks that could be tested.

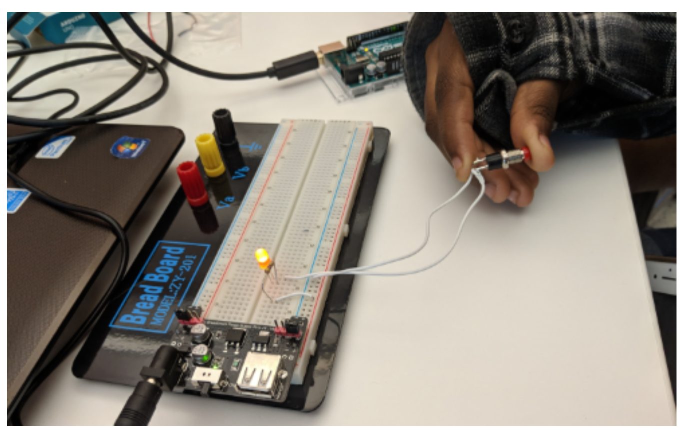


FIG. 5. COMBINING CIRCUITRY KNOWLEDGE AND CODE.

Ultimately, our analysis found that the girls were able to begin practicing decomposition within a context that they know intimately – the self. By grounding initial decomposition practices in their personal identity, the curriculum afforded librarians an anchor point to return to when the introduction of new and more complex skills began to feel overwhelming.

For our next steps, we plan to iterate on the design of the curriculum and conduct further implementations across all three sites. While this iteration predominately focused on racialized and gendered experiences, we are specifically interested in further incorporating experiences from a broader spectrum of identity categories, such ability, sexual orientation, and the intersection of these categories.

VI. Discussion

The act of learning science and engineering practices has been described as a cultural process that requires students to "cross borders" [38]. As girls of color are learning computational thinking practices, they are often interacting with discourses that may align or differ from their own. Research in science education has pushed for science educators to imagine a space where students' learning and identities can come together to form a learning experience that does not force them to leave behind their cultural knowledges and lived experiences for the sake of learning science [39] [40]. Results from pilot implementations of CompuGirls demonstrate that centering girls' identities in process of learning computational thinking practices is a promising avenue for connecting computing knowledge and practices to girls' lived experiences.

Interestingly, while the focus on identity was originally proposed as an entry point to computational thinking practices, our study found that an emerging theme of identity exploration serving as more just an entry point; instead, integrating identity exploration into a computational thinking curriculum resulted in a mutually reinforcing relationship where girls experience reflective identity development while simultaneously increasing their understanding of computational thinking. As shown in the "I Am" activity, identity exploration helped girls understand computational thinking practices, and through the practice of computational thinking they began to understand their own identities at a deeper level and in more complex ways.

We analyzed identity development as a negotiated process that includes community membership and participation in shared practices. Thus, we found that fostering a sense of community was integral to creating an environment where girls could feel safe to explore their identities. In order to foster a sense of community, the research team and librarian facilitators encouraged the girls to develop a set of shared practices. In the first group activity, girls are invited to participate in norm-setting by creating guidelines for their learning environment through a "Safe Space" activity. For this activity, girls are asked, "What do you need to feel safe here?" First, girls reflected on these questions individually and identified their own individual needs on sticky notes. We urge researchers and practitioners to ensure that they have created a safe and affirming learning environment before asking girls of color to share personal information that may make them feel vulnerable.

VII. Limitations

In line with other forms of interpretivist work, the goal of this study is to highlight the experiences of this particular set of girls to illustrate the potential of merging identity exploration and computational thinking practices. Additionally, since identity exploration and reflection is an intimate and personal experience, the sharing of girls' experiences may raise ethical concerns regarding privacy and disclosure in research processes and reporting. Thus, as a research team, we mindfully reflected on how to safely represent aspects of the girls' personal experiences. We mitigated privacy and disclosure risks by anonymizing the data presented and carefully selecting data that did not disclose potentially identifiable experiences.

VIII. Conclusion

Research [41] has emphasized the need for curriculum materials and classroom pedagogy to take into consideration girls' interest, experiences, and ideas. In our study, we aimed to address the need to discuss racialized, gendered, and classed experiences more explicitly in learning environments [9]. By honoring girls' complex identities in the process of learning computational thinking practices we sought to make space for their multiple subjectivities in the process of science learning and allowed for diverse entry points to computing knowledge and practices. From our work, we found that identity exploration provides multiple entry points to learning computational thinking practices through personal self-reflection. We do not view learning computational thinking practices through identity exploration as a replacement for other effective strategies such as visual programming; rather, we present our approach as a complementary and alternative avenue for connecting computing knowledge and skills to girls' lived experiences. By focusing on the girls' identities, the curriculum re-imagines computational experiences by fostering interactions with computational thinking from a personal perspective. Ultimately, we argue that centering girls' identities should be viewed as an integral part of the learning process and not tangential.

Acknowledgment

We would like to thank our collaborator Dr. Kimberly A. Scott and the rest of the research team at the Center for Gender Equity in Science and Technology at Arizona State University. As well as the public librarians who serve as invaluable research partners on this project.

References

[1] D. Fields and N. Enyedy, "Picking Up the Mantle of 'Expert': Assigned Roles, Assertion of Identity, and Peer Recognition Within a Programming Class," Mind, Culture, and Activity, vol. 20, no. 2, pp. 113–131, Apr. 2013, doi: 10.1080/10749039.2012.691199.

[2] N. Akkuş Çakır, A. Gass, A. Foster, and F. J. Lee, "Development of a game-design workshop to promote young girls' interest towards computing through identity exploration," Computers Education, vol. 108, pp. 115–130, May 2017, doi: 10.1016/j.compedu.2017.02.002.

[3] A.-K. Peters and D. Rick, “Identity Development in Computing Education: Theoretical Perspectives and an Implementation in the Classroom,” in Proceedings of the 9th Workshop in Primary and Secondary Computing Education, New York, NY, USA, 2014, pp. 70–79, doi: 10.1145/2670757.2670787.

[4] S. L. Rodriguez and K. Lehman, “Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory,” Computer Science Education, vol. 27, no. 3–4, pp. 229–247, Oct. 2017, doi: 10.1080/08993408.2018.1457899.

[5] N. Pinkard, S. Erete, C. K. Martin, and M. M. de Royston, “Digital Youth Divas: Exploring Narrative-Driven Curriculum to Spark Middle School Girls’ Interest in Computational Activities,” Journal of the Learning Sciences, vol. 26, no. 3, pp. 477–516, Jul. 2017, doi: 10.1080/10508406.2017.1307199.

[6] A. Calabrese Barton, H. Kang, E. Tan, T. B. O’Neill, J. Bautista-Guerra, and C. Brecklin, “Crafting a Future in Science: Tracing Middle School Girls’ Identity Work Over Time and Space,” American Educational Research Journal, vol. 50, no. 1, pp. 37–75, Feb. 2013, doi: 10.3102/0002831212458142.

[7] D. C. Holland, D. Skinner, C. Cain, and C. Cain, Identity and Agency in Cultural Worlds. Harvard University Press, 2001.

[8] M. Ong, C. Wright, L. L. Espinosa, and G. Orfield, “Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering,and Mathematics,” Harvard Educational Review, vol. 81, no. 2, pp. 172–209, 2011.

[9] C. D. Allen and M. Eisenhart, “Fighting for Desired Versions of a Future Self: How Young Women Negotiated STEM-Related Identities in the Discursive Landscape of Educational Opportunity,” Journal of the Learning Sciences, vol. 26, no. 3, pp. 407–436, Jul. 2017, doi: 10.1080/10508406.2017.1294985.

[10] M. Bang, B. Warren, A. S. Rosebery, and D. Medin, “Desettling Expectations in Science Education,” HDE, vol. 55, no. 5–6, pp. 302–318, 2012, doi: 10.1159/000345322.

[11] M. D. DeSchryver and A. Yadav, “Creative and Computational Thinking in the Context of New Literacies: Working with Teachers to Scaffold Complex Technology-Mediated Approaches to Teaching and Learning,” Journal of Technology and Teacher Education, vol. 23, no. 3, pp. 411–431, Jul. 2015.

[12] S. Grover and R. Pea, “Computational Thinking in K–12 A Review of the State of the Field,” Educational Researcher, vol. 42, no. 1, pp. 38–43, Jan. 2013, doi: 10.3102/0013189X12463051.

[13] J. Wing, “Computational thinking,” Communications of the ACM 49, 3: 33–35, 2006.

[14] D. Weintrop et al., “Defining Computational Thinking for Mathematics and Science Classrooms,” J Sci Educ Technol, vol. 25, no. 1, pp. 127–147, Feb. 2016, doi: 10.1007/s10956-015-9581-5.

[15] K. Brennan and M. Resnick, “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, 2012, pp. 1–25.

[16] S. Grover and R. Pea, “Computational Thinking: A Competency Whose Time Has Come,” Computer Science Education, p. 21, 2017.

[17] F. Buitrago Flórez, R. Casallas, M. Hernández, A. Reyes, S. Restrepo, and G. Danies, “Changing a Generation’s Way of Thinking: Teaching Computational Thinking Through Programming,” Review of Educational Research, vol. 87, no. 4, pp. 834–860, Aug. 2017, doi: 10.3102/0034654317710096.

[18] S. Y. Lye and J. H. L. Koh, “Review on teaching and learning of computational thinking through programming: What is next for K-12?,” Computers in Human Behavior, vol. 41, pp. 51–61, Dec. 2014, doi: 10.1016/j.chb.2014.09.012.

[19] K. Lawanto, K. Close, C. Ames, and S. Brasiel, “Exploring Strengths and Weaknesses in Middle School Students’ Computational Thinking in Scratch,” in Emerging Research, Practice, and Policy on Computational Thinking, P. J. Rich and C. B. Hodges, Eds. Cham: Springer International Publishing, 2017, pp. 307–326.

[20] M. Resnick et al., “Scratch: Programming for All,” Commun. ACM, vol. 52, no. 11, pp. 60–67, Nov. 2009, doi: 10.1145/1592761.1592779.

[21] A. Ruthmann, J. M. Heines, G. R. Greher, P. Laidler, and C. Saulters II, “Teaching Computational Thinking Through Musical Live Coding in Scratch,” in Proceedings of the 41st ACM Technical Symposium on Computer Science Education, New York, NY, USA, 2010, pp. 351–355, doi: 10.1145/1734263.1734384.

[22] B. Xie and H. Abelson, “Skill progression in MIT app inventor,” in 2016 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), 2016, pp. 213–217, doi: 10.1109/VLHCC.2016.7739687.

[23] J. Thompson, “Engaging Girls’ Sociohistorical Identities in Science,” Journal of the Learning Sciences, vol. 23, no. 3, pp. 392–446, Jul. 2014, doi: 10.1080/10508406.2014.888351.

[24] M. Varelas, D. B. Martin, and J. M. Kane, “Content Learning and Identity Construction: A Framework to Strengthen African American Students’ Mathematics and Science Learning in Urban Elementary Schools,” HDE, vol. 55, no. 5–6, pp. 319–339, 2012, doi: 10.1159/000345324.

[25] J. Lave, “Teaching, as Learning, in Practice,” Mind, Culture, and Activity, vol. 3, no. 3, pp. 149–164, Jul. 1996, doi: 10.1207/s15327884mca03032.

[26] Y. Kanno and C. Stuart, “Learning to Become a Second Language Teacher: Identities-in-Practice,” The Modern Language Journal, vol. 95, no. 2, pp. 236–252, 2011, doi: 10.1111/j.1540-4781.2011.01178.x.

[27] E. B. Moje, “Foregrounding the Disciplines in Secondary Literacy Teaching and Learning: A Call for Change,” Journal of Adolescent Adult Literacy, vol. 52, no. 2, pp. 96–107, 2008.

[28] L. A. Bricker and P. Bell, “‘What comes to mind when you think of science? The perfumery!’: Documenting science-related cultural learning pathways across contexts and timescales,” J Res Sci Teach, vol. 51, no. 3, pp. 260–285, Mar. 2014, doi: 10.1002/tea.21134.

[29] J. Rahm and J. C. Moore, “A case study of long-term engagement and identity-in-practice: Insights into the STEM pathways of four underrepresented youths,” Journal of Research in Science Teaching, vol. 53, no. 5, pp. 768–801, doi: 10.1002/tea.21268.

[30] “IMLS Focus Summary Report: Learning in Libraries,” Institute of Museum and Library Services, 25-Aug-2015. [Online]. Available: https://www.imls.gov/publications/imls-focus-summary-report-learning-libraries. ations/imls-focus-summary-report-learning-libraries

[31] “AP Computer Science Principles Including the Curriculum Framework,” College Board, 2017.

[32] T. Bell, P. Curzon, Q. Cutts, V. Dagiene, and B. Haberman, “Introducing Students to Computer Science with Programmes That Don’T Emphasise Programming,” in Proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education, New York, NY, USA, 2011, pp. 391–391, doi: 10.1145/1999747.1999904.

[33] P. Curzon, “Cs4Fn and Computational Thinking Unplugged,” in Proceedings of the 8th Workshop in Primary and Secondary Computing Education, New York, NY, USA, 2013, pp. 47–50, doi: 10.1145/2532748.2611263.

[34] S. Hug, J. Sandry, R. Vordermann, E. Pontelli, and B. Wright, “DISSECT: Integrating Computational Thinking in the Traditional K-12 Curricula Through Collaborative Teaching (Abstract Only),” in Proceeding of the 44th ACM Technical Symposium on Computer Science Education, New York, NY, USA, 2013, pp. 742–742, doi: 10.1145/2445196.2445452.

[35] J. Lofland and L. Lofland, “Analyzing social settings,” Belmont, CA: Wadsworth, 1995.

[36] U. Flick, E. von Kardoff, and I. Steinke, A Companion to Qualitative Research. SAGE, 2004.

[37] F. Cornish, A. Gillespie, and T. Zittoun, “Collaborative Analysis of Qualitative Data,” in The SAGE Handbook of Qualitative Data Analysis, 1 Oliver’s Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2014, pp. 79–93.

[38] G. S. Aikenhead and O. J. Jegede, “Cross-cultural science education: A cognitive explanation of a cultural phenomenon,” Journal of Research in Science Teaching, vol. 36, no. 3, pp. 269–287, 1999, doi: 10.1002/(SICI)1098-2736(199903)36:3¡269::AID-TEA3¿3.0.CO;2-T.

[39] A. C. Barton, E. Tan, and A. Rivet, “Creating Hybrid Spaces for Engaging School Science Among Urban Middle School Girls,” American Educational Research Journal, vol. 45, no. 1, pp. 68–103, Mar. 2008, doi: 10.3102/0002831207308641.

[40] J. S. Brotman and F. M. Moore, “Girls and science: A review of four themes in the science education literature,” Journal of Research in Science Teaching, vol. 45, no. 9, pp. 971–1002, 2008, doi: 10.1002/tea.20241.

[41] C. D. Allen and M. Eisenhart, “Fighting for Desired Versions of a Future Self: How Young Women Negotiated STEM-Related Identities in the Discursive Landscape of Educational Opportunity,” Journal of the Learning Sciences, vol. 26, no. 3, pp. 407–436, Jul. 2017, doi: 10.1080/10508406.2017.1294985.

Teaching Computational Thinking to Multilingual Students through Inquiry-based Learning

Sharin Jacob
School of Education
University of California, Irvine
Irvine, US
sharinj@uci.edu

Ha Nguyen
School of Education
University of California, Irvine
Irvine, US
thicn@uci.edu

Leiny Garcia
School of Education
University of California, Irvine
Irvine, US
leinyg@uci.edu

Debra Richardson
Bren School of ICS
University of California, Irvine
Irvine, US
djr@ics.uci.edu

Mark Warschauer
School of Education
University of California, Irvine
Irvine, US
markw@uci.edu

***Abstract*— Central to the theory of learning are inquiry-based approaches to education. Whereas there is a plethora of research on inquiry learning in the domain of science [19, 20], few studies have analyzed how inquiry-based learning can be applied to computer science education, and how different approaches to inquiry may benefit diverse learners. This is one of the first studies to analyze teacher enactment of inquiry-based learning during the implementation of an upper elementary, computational thinking curriculum, and to explore how teacher approaches to inquiry appear to support or constrain multilingual students' development of computational thinking and computer science identities. Design-based research was used to iteratively develop, test, and refine the inquiry-based curriculum, which aligns with computer science and literacy standards, provides linguistic scaffolding, and integrates culturally responsive materials. We adopt a cross-case mixed-methods design to collect data from five teachers and 149 students including detailed field notes, teacher interviews, student computational artifacts, and student identity surveys. Through analyses of teacher moves, we find that teachers adopt different approaches to inquiry that can be indexed along a continuum ranging from open to closed. Patterns in student data revealed that those who received more structured inquiry lessons developed more sophisticated computational artifacts and showed greater identification with the field of computer science. Findings from this study are being used to add more structured inquiry approaches to the next iteration of our curriculum, including integrating USE/MODIFY/CREATE models into lessons and applying metacognitive strategies from reading research to students' programming activities.**

Keywords—inquiry-based learning, computer science, computational thinking, multilingual, English learners

I. Introduction

Considerable effort has been dedicated to integrating computer science into K-12 education for students who are traditionally underrepresented in STEM (e.g., women, students of color, students with disabilities). For example, the White House's 2016 Computer Science for All (CSforAll) initiative seeks to equip all K-12 students with the computing and computational thinking skills necessary to become creators, and not just consumers, of technology [1]. To help realize this goal, the National Science Foundation developed the CSforAll program which focuses on developing research-practice partnerships (RPPs) that foster the types of theory and practice needed to bring computer science and computational thinking to all students in K-12 schools. With a focus on CSforAll, educational policy makers and stakeholders have shifted their attention to developing computer science pedagogy and materials that meet the needs of diverse learners.

While efforts to combat underrepresentation in computer science education have been numerous and laudable [2, 3], little attention has been paid to broadening participation for multilingual students [4, 5], or those who speak a language other than English at home. This is especially important for the large and growing Latinx population--which grew from 9 million (6% of U.S. population) in 1970 to 59 million (18% of population) in 2017, and is projected to reach 132 million (30% of population) by 2050, but is seriously underrepresented in CS education and achievement. For example, in California, the site of this study, Latinx students constitute 54% of the K-12 population, but only 22% of advanced placement CS test takers [6]. A number of important obstacles hinder CS study for Latinx students, including reduced access to home computers or family members who are knowledgeable about CS [7], lack of Latinx role models in CS whether through direct experience or through media representations [8], fewer course offerings in CS in Latinx-neighborhood schools [6], and decontextualized and individualized methods of CS instruction that are not a good match for the cultural values of Latinx students and families.

Inquiry-based learning has shown particular promise for engaging culturally and linguistically diverse students in STEM education [9]. Given the efficacy of inquiry-based learning for raising science achievement for multilingual students [9], inquiry-based approaches may also be effective for engaging the nation's growing Latinx student population in computer science education. Despite the promise of inquiry learning approaches, it remains unclear as to whether more structured or open inquiry approaches are more effective for engaging these student in computer science. Proponents of open inquiry argue that the freedom to construct and conduct investigations develops students' higher order thinking skills, disciplinary

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

knowledge, and inductive methods of inquiry [10]. Those who prefer structured approaches claim that providing students systematic methods for conducting investigations supports the development of content knowledge, scientific skills, and a nuanced understanding of the discipline [11]. Structured approaches are further thought to prevent lost opportunities that arise from students getting stuck due to minimal guidance [12].

The purpose of this study is to analyze teacher enactment of inquiry-based learning during the implementation of an upper elementary, computational thinking curriculum, and to explore how teacher approaches to inquiry appear to support or constrain multilingual students' development of computational thinking. Whereas there is a plethora of research on inquiry learning in the domain of science [13,14], few studies have analyzed how inquiry-based learning can be applied to computer science education. The curriculum has been adapted from a grade 3-5 sequence developed by Computer Science in San Francisco, a path breaking initiative that seeks to normalize K-12 computer science instruction in schools across the San Francisco Unified School District. It has been adapted to integrate inquiry-based approaches to learning, align with computer science, English language development, and literacy standards, provide linguistic scaffolding, and integrate culturally responsive materials. We adopt a cross-case mixed-methods design to collect data from five teachers and 149 students including detailed field notes, teacher interviews, student identity surveys, and student computational artifacts. Through analyses teacher moves, we find that teachers adopt different approaches to inquiry that can be indexed along a continuum ranging from open to structured. Patterns in student data revealed that those who received more structured inquiry lessons developed more proficient computational artifacts and showed greater identification with the field of computer science. Findings from this study are being used to add more structured inquiry approaches to the next iteration of our curriculum including integrating USE/MODIFY/CREATE models into lessons and applying metacognitive strategies from reading research to students' programming activities.

We address the following research questions: (1) In what ways, if any, did teachers endeavor to teach computer science as inquiry to multilingual students in their classrooms? (2) How do differences in teachers' approaches to inquiry appear to support or constrain students' development of computational thinking skills and computer science identities?

II. THEORETICAL FRAMEWORK

A. *Inquiry-based Learning and Computational Thinking*

Inquiry-based learning involves engaging students in authentic scientific practices and methods for the purpose of constructing knowledge [15]. Through student engagement in exploration, experimentation, and hands-on activities, inquiry-based learning provides a powerful mechanism for providing authentic contexts for language use [16]. During open inquiry-based learning, students develop questions and participate actively in open ended interrogations to discover and construct new knowledge [17]. During structured inquiry, teachers model methods and procedures for conducting investigations [14]. Inquiry-based learning emphasizes problem solving and students apply multiple problem solving approaches, practices, and skills as they conduct their investigations [18]. Since the mid-1990s, teachers have been encouraged to better meet the needs of language learners by integrating inquiry-based approaches to make instruction more engaging, concrete, and meaningful [19].

Pedaste et al. [20] conducted a systematic literature review identifying key features of inquiry-based learning and synthesized a framework incorporating all elements of inquiry that persisted across models. This general framing of the phases of inquiry relates inquiry to the scientific method, requiring a measure of reconsideration in its application to the field of computer science. Notably, scientific inquiry focuses on identifying and evaluating hypotheses to understand a set of principles governing the physical world. This objective contrasts with inquiry in computer science, which focuses on constructing and testing logical processes to address an abstract computational problem. Instruction in computer science then seeks to develop a set of skills, practices, and dispositions collectively referred to as computational thinking, representing an ability to formulate thoughts and questions for interpretation by a computer to achieve desired results [21]. Constructing a theoretical framework for applying inquiry-based learning to the field of computer science is beyond the scope of this paper.

In its implementation, inquiry-based learning can be structured or unstructured based on the teaching and learning goals of a lesson or unit of instruction. Windschitl [14] conducted a multiple case study investigating how teachers perceived and enacted inquiry in their science classrooms and developed a continuum of inquiry demarcated by the degree of freedom students have in developing and conducting investigations. At the structured end of the continuum lies confirmatory experiences, in which students are provided a systematic method for authenticating scientific principles. Next to confirmatory experiences lies structured inquiry, in which the teacher presents a scientific concept, question, or hypothesis and students are prescribed a procedure for exploring it. The next level is guided inquiry, where the teacher provides a problem to be solved but leaves the method of investigation up to the students. The most independent form of inquiry is open inquiry, in which students identify their own concepts or questions and devise their own methods of investigation. We use this continuum to characterize participants' approaches to teaching computer science lessons to multilingual students.

B. *Review of the Literature*

Research on engaging students in Science, Technology, Engineering, and Mathematics (STEM) through inquiry-based learning has been well established. A recent meta-analysis conducted by Estrella at al. [22] examined the effectiveness of inquiry instruction in increasing STEM achievement for elementary language learners. An analysis of 26 articles indicated that inquiry-based instruction produced significantly greater results on measures of science achievement than traditional instruction. Furthermore, elementary students who participated in a blended program that integrated linguistic scaffolding with science inquiry-based unit plans showed statistically significant increases on California English Language Development Test (CELDT) and California Standards Test for English Language Arts scores compared to students in a traditional program [23].

A growing body of research on using inquiry to teach computational thinking demonstrates benefits for students [24, 25], however little research specifically focuses on the types of inquiry approaches and levels of support that develop computational thinking and identity development for diverse learners. Reiser [26] acknowledges the potential of inquiry to provide authentic learning contexts for students, but also articulates the challenges inherent to inquiry learning. For example, students need to acquire sufficient foundational discipline specific knowledge to conduct investigations, and often focus on finding the right answer to a problem as opposed to identifying the principles underlying answers. To ameliorate these issues, he proposes presenting more structured problem solving activities and problematizing subject matter to promote deeper understanding of content.

C. *Overview of the computational thinking curriculum*

Researchers worked collaboratively with teachers to adapt an existing grade three through five curriculum created by Computer Science in San Francisco. The curriculum was adapted to meet the needs of the district's culturally and linguistically diverse students. This was achieved by 1) integrating inquiry-based approaches, 2) aligning the curriculum with computer science and literacy standards, 3) providing linguistic scaffolding, and 4) including culturally responsive pedagogy and materials.

First, researchers and teachers aligned materials with the Common Core State Standards for English Language Arts (ELA), and the California Department of Education English Language Development (ELD) Standards. Linguistic scaffolds were developed to promote and leverage academic language proficiency for language learners. Researchers and teachers developed linguistic frames to scaffold both the academic language related to computer science concepts as well as the functions of social interaction. To integrate inquiry-based approaches, we utilized the "5 E" model of inquiry to guide unit development. Bybee [27] drew from constructivist approaches to learning to construct the "5E's" model, which includes five indicators of inquiry-based instruction: Engage, Explore, Explain, Elaborate, and Evaluate. [1] While we integrated the phases of inquiry into the curriculum, we encouraged teachers to use their own judgement when determining the level of structure necessary to meet students' needs. Finally, the partnership paid special attention to integrating literacy into the computational thinking curriculum. Culturally responsive stories depicting diverse characters who pioneered the computer science and engineering fields were selected to make the content relatable to students.

III. METHOD

A. *Study Context and Participants*

This study took place in five upper elementary (grades 3-5) classrooms across a large urban school district. The district in which the study is situated has among the highest percentages low-income students (91%), Latinx students (96%), and English learners (63% in elementary grades) in the nation. Due to attrition, five out of the seven original teachers were selected for this study. All the students in their classes (total N=149) participated in the project and thus were part of the study. Student demographics at the classroom level broadly mirror those at the district level.

B. *Data Sources & Analysis*

The participating teachers piloted the year long, five-unit computational thinking curriculum in their classrooms once a week for a lesson duration of fifty minutes. The researchers conducted weekly classroom observations and took detailed field notes on the types of instructional strategies used. The McGill Inquiry Teacher Short Interview (MITSI) protocol was used to interview the five participating teachers in their classrooms. A rubric for scoring Scratch projects developed by SRI International was utilized to assess students' 1) overall proficiency in programming, 2) user experience, and 3) the use of coding and computational thinking constructs [28]. The researchers conducted interrater reliability checks on the rubric data. After each scorer completed ten projects, interrater-reliability ranged from 75% to 80. Finally, this study adapted the "Is Science Me?" [29] survey to computer science to measure student attitudes towards and identification with the field of computer science.

The generation of codes and categories for classroom observations and teacher interviews is situated within a procedural, deductive, frame of analysis [30]. This process consisted of reading the data multiple times to categorize inquiry learning phases and subcategories within each phase. Codes and categories were then compared within and across each case to determine the types of inquiry being enacted in each classroom.

To assess students' Scratch projects, a sum score for each category (e.g., overall proficiency, design mechanics, user experience) was calculated and z-score transformed. A one-way ANCOVA with post-hoc Tukey HSD test was conducted to examine whether there was a statistically significant difference among the teachers on the computational thinking criteria for the end-of-unit projects, controlling for student background information (i.e., computer access and parental education). Assumptions of normal distribution and homoscedasticity were met. When the ANOVA tests indicated that the scores across

[1] Engage involves stimulating interest on a topic. Explore refers to conducting hands-on activities in which students grapple with a problem or phenomenon. Explain means to leverage the language and conceptual understanding used by students to develop explanations. Elaborate involves providing opportunities for students to apply what they have learned. Finally, evaluate means engaging students in reflecting on their own understanding.

classes were significantly different, this study performed pairwise t-tests with Bonferroni and Holm adjustments to examine which class was substantially different from the other classes.

Finally, the *Is Science Me?* survey mostly included three-point Likert scale items. This study calculated internal consistency using McDonald's omega instead of Cronbach's alpha, as Cronbach's alpha may be less accurate when data come from ordinal items with few response options [31]. A confirmatory factor analysis using polychoric correlations matrix was conducted based on the theorized constructs on the pretest and posttest datasets. Both datasets showed good model fit according to the guideline in [32]: CFI and TLI higher than or equal to .90, RMSEA smaller than .05, SRMR smaller than .08. Because the survey items were ordinal and did not approximate a normal distribution, this study performed the Wilcoxon matched-pairs signed-rank test to measure the changes from pre to posttest for each survey item for each teacher.

IV. Findings

Based on classroom observations and detailed field notes, it became apparent that teachers enacted the curriculum differently across the five classrooms. The first four teachers used inquiry in different points along the continuum mentioned in the theoretical framework of this paper, with Ellen using open inquiry, Juanita using guided inquiry, Jenny using a combination of guided and structured inquiry, and Helen using confirmatory experiences. The fifth teacher, Sue, did not use inquiry-based instruction and instead adopted a direct, explicit approach to teaching computer science content to her students. What follows are descriptions of teaching episodes for each classroom that are representative of how teachers conducted inquiry in their classrooms.

A. Open Approaches to Inquiry

Two of the teachers, Ellen and Juanita, exemplified open inquiry approaches in mentoring their students through various aspects of computer science research. On a typical day, both teachers would orient students to computational thinking concepts through activities structured around focal phenomena, and facilitate collaborative sense-making of key computational thinking concepts and practices. During investigation, Ellen often promoted independent learning in her classroom, acting as a facilitator of the research process by equipping students with the resources and strategies necessary for conducting open-ended investigations.

Ellen openly expresses her views of computer science learning as a research process in which students seek out the resources necessary to solve complex problems.

> Ellen: When you get stuck, we have resources. I am not the greatest resource because I am learning with you too. I can guide you to resources. Your peers are a resource…When you get stuck, we have resources...Am I your only resource?
> Students: No
> Ellen: You know, many of you have learned that I am not the greatest resource. I'm not wanting to be. Why, because I'm learning this with you too. Okay. So I can kind of guide you in how to be resourceful. I'm finding more and more places that I can get help when I need it and that's what you need to do as scholars.

Ellen describes herself as a being a *guide* for her students, using herself as a model to illustrate the types of habits (i.e., being resourceful, help-seeking) her students can engage in as scholars. To this end, she disrupts her traditional role as teacher to create a more horizontal, symmetrical space in which students and the teacher co-navigate computer science research. She provides the learning environment and resources necessary for students to ask and answer complex problems, and steps aside to facilitate scholarly activity.

Juanita similarly promotes independence during the investigation phases of inquiry, but unlike Ellen, models methods of problem formulation. She also disrupts the direct instruction model by encouraging students to negotiate their own learning among peers before coming to her for answers. For example, in the excerpt below Juanita modeled the first steps in a shape drawing activity designed to teach algorithms. Students were presented with written steps for drawing shapes and a picture with the desired visual outcome (i.e. a picture of a house). However, the steps did not match the shape, that is, there were errors embedded in the steps and students were tasked with debugging the algorithm so that the steps matched the desired outcome.

> Juanita: Who can read step two?
> Anita: Draw an orange equilateral triangle with one edge lined up with the of the square
> Juanita: Do you guys see that?
> Class: No
> Juanita: Okay, again let's look at this, who could tell me where my equilateral triangle is
> Roxanne: On top of the blue square
> Juanita: Remember, equilateral means it's what on all sides.
> Class: Equal.
> Juanita: Equal. Very cool. Okay, so check that it's lined up with the top of the blue square. Ok, so do you guys see it now?
> Class: Yes
> Juanita: Now talk to your table, your elbow partner. And I want you to go through...I want you to figure out with your partner the rest of the steps and let me know what you think the bug is. Once you've figured out what the bug is, I don't want to hear any ah ah ah's or ooh ooh ooh's. Figure out what it is before you raise your hand.

In this teaching episode, Juanita defined the scope of the problem for students and modeled the first few steps for solving it, then encouraged students to rely on their peer networks to finish debugging the algorithm. To this end, she established a peer learning community in which students discuss debugging techniques with their classmates before they ask the teacher. As students were provided with a problem, but not explicitly given a procedure for solving the problem, the above example supports the guided inquiry model. After students worked to debug the sample algorithm, students were assigned to individually create their own algorithm and drawing using only their peer networks for support, further supporting the guided inquiry hypothesis.

B. Structured Approaches to Inquiry

Two of the teachers, Jenny and Helen, tended to teach inquiry learning in a structured manner by 1) providing methods for formulating and solving problems, or 2) demonstrating and confirming key computational principles. Jenny utilized a combination of guided and structured inquiry to teach computer science to her students. She typically opened with a guided inquiry lesson and then moved to more structured approaches when students had difficulty accessing abstract concepts. In the example below, Jenny initially used the guided inquiry approach to develop students' understanding of sequence and repetition. Students were provided with multiple steps of a dance and tasked with working in teams to conceptually map the dance, using loops so as to not articulate each single step. While Jenny identified the scope of the problem for students, she did not provide with them methods for solving the problem.

> Jenny: In your team, I want you to identify the actions in this dance…write a computer code, if you were to tell someone how to do this dance, what would you do, are there repeated actions, how many times do they repeat. What would an algorithm, a code for this, look like?

In this example, students were given more freedom to develop and conduct their own investigations and the teacher focused primarily on facilitating the learning process and detecting student issues as they arose. As Jenny focused in on students' needs, she moved from guided to structured inquiry to create more efficient learning environments. For example, students had difficulty characterizing the dance on their first attempt, likely because they had not committed the sequence of moves to memory. In response, Jenny used a variety of techniques to respond to this need including replaying the dance, refocusing students' attention to counting and naming the moves, using dialogic questioning to facilitate students' recall of the dance, and physically enacting the dance before the class. Each of these instructional moves points toward a more structured inquiry approach, that is, Jenny modeled alternative methods for students to investigate the key computational concepts.

Helen provided structure for her students through confirmation experiences designed to teach computing concepts. Helen's typical investigation was highly structured and relied primarily on teacher modeling and scaffolding techniques to facilitate knowledge acquisition. To illustrate a simple example, Helen drew two sprites, or characters in the Scratch interface, on the whiteboard, prepping the class to discuss what parallelism means.

> Helen: What do I do if I want the sprites to do the same thing at the same time?

Next, Helen drew two columns, one for sprite 1 and one for sprite 2 and added blocks to each column. Then, she manipulated blocks in a variety of ways and asks students to make predictions.

> Helen: What's going to happen?

To test the concept, Helen hit a mock flag button to start a "test run" of parallel commands. When sprites 1 and 2 correctly executed their commands, students verified their understanding of how to use commands in Scratch to make two sprites take actions simultaneously.

> Helen: It worked!

Upon checking student understanding, Helen added additional layers of complexity to teach more advanced computational concepts. For example, she modeled more complicated multi-step commands for each sprite to execute simultaneously, except in this case the sprites are doing two different things at the same time (i.e., sprite 1 walks forward, sprite 2 jumps up and down). Furthermore, she purposefully included errors in her mock code to engage students in debugging during concept development.

In the above scenario, students were presented with a variety of scenarios in which parallelism could occur, and then these scenarios were verified by 'test runs.' Although she increased the complexity of her examples, students were not provided the opportunity to generate or conduct investigations on their own. Instead, they engaged in confirmatory experiences of key computational principles.

C. Direct Approaches to Teaching

Sue did not take an inquiry-based approach to teaching computer science to her students. Instead, she focused on rhythm and periodicity within her classroom, ensuring that students had access to stable routines and durable infrastructure to support knowledge acquisition. This allowed her to manage interaction and bring about predictability of sequential classroom activities and students' behaviors.

Sue predominantly used the mirroring technique to teach computer science concepts to her students. In the example below, she taught the concepts of sequence and order, initiating the mirroring activity, in which she would say "mirrors on", and the students would imitate her words and actions

> Sue: Okay. I liked what you said about the events, but when we're talking about sequence of events, what does that mean? Is it, are we talking about groups or am I talking about order?
>
> Class: Order
>
> Sue: Right? Mirrors on! Sequence (Sue waives hand motions, class repeats) is order (Sue waives hand motions, class repeats) or sequence is the order of events.

In this excerpt, Sue took a direct, explicit approach to teaching, enforcing targeted stimuli (i.e., teacher models specific motions) and response (students mimic teacher's motions) behaviors, coupled with repetition to teach key concepts. She also reinforced correct verbal and motor associations with a clip up classroom management technique, using positive reinforcement as an example for the class of what types of behaviors are preferred.

D. *Student Outcomes*

First, we combined students' scores on items using the selected SRI rubric scale. When examining teachers' overall combined average rubric scores for complexity, design mechanics, user experience, and use of computer science constructs, we saw that Helen and Jenny's students performed better overall (See Figure 1). Results of the ANCOVA showed that overall, Helen's and Jenny's class performed substantially better in several criteria (See Figure 2). There were significant differences among the classes in overall complexity, $F(4, 107) = 17.33$, $p < .01$; user experience, $F(4, 107) = 5.27$, $p < .001$; CS constructs, $F(4, 107) = 9.11$, $p < .001$; and counts of different types of Scratch blocks, $F(4, 107) = 4.58$, $p < .01$, after accounting for home computer access, mother's education, and father's education. Tukey HSD test revealed that there was a significant difference in the overall scores for Ellen and Sue ($p < .001$), and Jenny and Sue ($p < .01$). For user experience, there was a significant difference between Helen and Ellen ($p = .03$), Juanita and Sue ($p < .01$) and Helen and Sue ($p < .001$). For CS constructs, there was a significant difference between Helen and Ellen ($p < .001$), Helen and Juanita ($p < .001$), Ellen and Sue ($p < .001$), Sue and Juanita ($p = .01$), and Helen and Jenny ($p = .02$). For block use, there was a significant difference for Juanita and Helen ($p = .01$), and Juanita and Jenny ($p < .01$).

There appeared to be positive changes from pre to posttest in three classes (Helen, Jenny, and Sue) in terms of students' ability beliefs, perceptions of support for computer science interests from family and friends, and perceptions of the usefulness and importance of computer science (See Figure 3). The effect size ranged from medium to large, Cohen's $d = (.46, 1.07)$.

V. Discussion

The idea of teaching science as inquiry has been well supported by research [33, 34] and has been found particularly effective for engaging English learners in STEM [22]. Recently, researchers have called inquiry learning into question [35, 36], finding that explicit instructional approaches better support learning and transfer [37]. This is one of the first studies to investigate how different approaches to inquiry support or constrain multilingual students' development of computational thinking skills. Preliminary findings indicated that more structured forms of inquiry appear to better support multilingual students in engaging in and identifying with computer science.

A. *Overview of Findings*

A primary aim of this study was to explore the question: "In what ways, if any, did teachers endeavor to teach computer science as inquiry in their classrooms?" One of the ways to gain

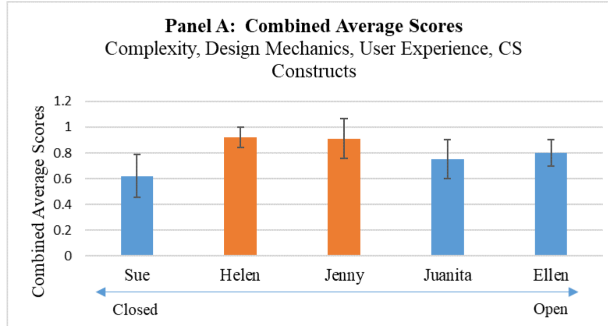


Fig. 1. Combined ratings of student Scratch projects by teacher

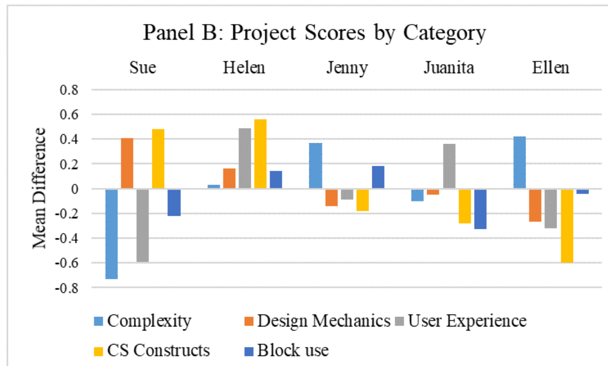


Fig. 2. Mean differences in Scratch project scores by category

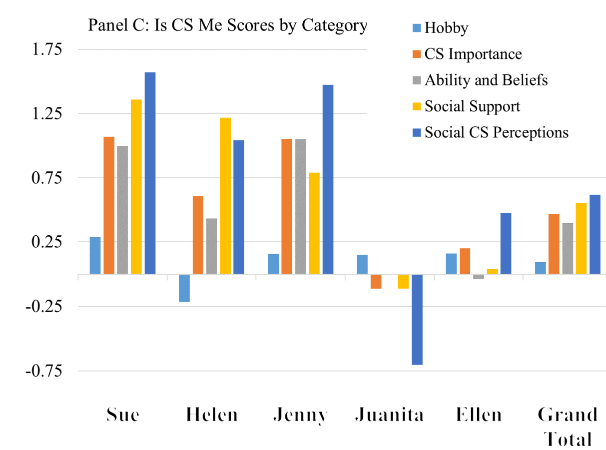


Fig. 3. Mean differences in student identity survey scores by category

insight into how teachers used inquiry approaches was to analyze how teachers enacted computer science lessons in their classrooms. By exploring the phases of inquiry that emerged from the lessons, we were able to piece together the ways in which teachers approached inquiry and index these approaches as being more open or closed along an established continuum. While the phases [20, 27] and types [14] of inquiry in science education have been well established, our study provides considerable insight into how the types of inquiry pertain to the discipline of computer science. These results extend our knowledge of the ways in which computer science can be taught as inquiry, and how different approaches can be used to meet the needs of diverse students.

An additional aim of this study was to explore how teachers' differing approaches to inquiry appeared to support or constrain multilingual students' development of computational thinking skills. Patterns in the data revealed three clusters of teachers, those whose teaching sequences revealed more open approaches, those whose sequences revealed more structured approaches, and those whose patterns displayed direct instructional approaches. For teachers who were indexed as being more structured along the inquiry-based learning continuum (Helen and Jenny), students tended to develop more sophisticated Scratch projects. We present several conjectures for this relationship. In these classrooms, teachers used modeling techniques to illustrate methodologies for solving problems, such as simulating algorithmic processes, physically enacting computational concepts, and incrementally increasing levels of complexity. The upshot of these moves is that they facilitate schema building, in which students draw from a conceptual foundation when addressing increasingly abstract problems, thereby building knowledge from prior understandings [38].

The current literature on inquiry learning portrays students as scientists who develop hypothesis and conduct investigation, linking these practices to the development of discipline specific skills such as computational thinking [13, 14]. In this model, confirmatory experiences are frowned upon as encompassing the rote presentation of scientific facts, with little contribution to students' development of scientific practices. Yet these teachers provided worked examples to characterize conceptual and investigative principles, using strategies such as repetition, refocusing students' attention, and open ended questioning techniques to address student confusion. Studies have indicated that providing worked examples reduces the tax on working memory and opens up the resources necessary for learning [39]. It is plausible that working through examples of algorithmic processes, as observed in Helen's class, provided the scaffolding necessary for successful problem solving.

In this study, we also see that more structured and direct approaches produced better outcomes for diverse learners' identification with the field of CS. Although inquiry-based instruction engages students in authentic scientific practices, delivering unstructured inquiry without sufficient schema building and preparation can lead to disappointment and lost opportunities [40]. All four teachers who implemented inquiry-based approaches reported students getting lost, getting stuck, and jumping in without seeing the big picture. If we want to broaden participation in computing, it is important to not only give students experiences, but to give them successful experiences. We were especially impressed the work from Estelle, herself a Latina who had substantial experience with the community she served and taught large number of multilingual students and students with disabilities. Further exploration into the methodological and incremental approach she used could uncover valuable strategies that meet the cognitive and affective needs of multilingual students.

B. Limitations and Future Research

There are several limitations to this study. First, as this was an exploratory study that is part of a larger project aimed at revising, testing, and scaling instructional materials and pedagogies that meet the needs of diverse learners, we do not make causal claims about our findings. Each of the classes we observed had different compositions and grade levels and these factors could provide confounds to our claims. Furthermore, the data instruments we used to measure students' computational thinking skills may not be sensitive to the types of learning that took place in the open inquiry classes. In open inquiry classrooms, different types of learning and growth may take place, such as problem formulation, goal setting, planning strategies, and persistence. Future studies should design measures for capturing the types of learning and growth taking place in these classrooms.

Despite these limitations, this paper poses several questions to the understudied area of teaching computational thinking to multilinguals students through inquiry-based learning. As this project represents the exploratory phase of a larger project, we are currently using these findings to integrate more structured approaches in the next iteration of our curriculum. This includes integrating the Use-Modify-Create model into our lessons and applying metacognitive strategies from reading research to students' development of computational thinking. To integrate more structure, the next phase of this project will modify the curriculum to integrate a CS instructional approach known as Use-Modify-Create [41] in which students will first *use* existing programs, then work together to *modify* them, and finally *create* their own. Furthermore, during the *use* stage, we will incorporate an additional layer of scaffolding with a learning strategy borrowed from reading research known as "TIPP&SEE," developed by the Computing for ANyONe (CANON) lab at the University of Chicago and faculty at Texas State University. TIPP&SEE is derived from the reading strategy THIEVES [42], and focuses students on using context clues to better grasp intended material. Students first read the *title* of the program and make predictions based on the title. Then they analyze the *instructions* to better understand the tasks they are asked to engage in. Next, students think about the *purpose* of the program to consider the learning goals of the activity. Finally, they *play* with the program to examine its characteristics and practice documenting their observations. Students are then tasked with looking inside the program to examine the *sprites* and the *events* controlling the sprites, and then they *explore* the code. During the explore phase, students are instructed to change features of the code, test the changes, and document the results, preparing them for the MODIFY stage of the USE/MODIFY/CREATE model. This new curriculum will be scaled to three school districts and tested using randomized control trial to formally examine the impact of structured approaches to inquiry on multilingual students' development of computational thinking skills.

ACKNOWLEDGMENT

This research was supported in part by a NSF Computer Science for All grant 1738825

REFERENCES

[1] M. Smith, “Computer Science for All,” Online Submission, pp. 1-13, 2016.

[2] J. Goode and J. Margolis, “Exploring computer science: A case study of school reform,” ACM Trans. on Comp. Edu. (TOCE), vol. 11, pp 1-16, 2011.

[3] R. Ladner and M Israel., “For all in computer science for all,” Communications of the ACM, vol. 59, pp. 26-28.

[4] S. Jacob, H. Nguyen, C. Tofel-Grehl, D. Richardson, and M. Warschauer, “Teaching computational thinking to English learners,” NYS TESOL journal, vol. 5, pp. 12-24, 2018.

[5] S. Vogel, C. Hoadley, L. Ascenzi-Moreno, and K. Menken, “The role of translanguaging in computational literacies: Documenting middle school bilinguals' practices in computer science integrated units. In Proc. of the 50th ACM Tech. Symp. on Comp. Sci. Ed, pp. 1164-1170, 2019.

[6] A. Martin, F. McAlear, and A. Scott A, “Path not found: Disparities in access to computer science courses in California high schools,” 2015.

[7] D. Royal and A. Swift, “U.S. minority students less exposed to computer science,” Gallup, October 2016.

[8] J. Wang, H. Hong, J. Ravitz,, and S. H. Moghadam, “Landscape of K–12 computer science education in the US: Perceptions, access, and barriers,” In Proc. of the 47th ACM Tech. Symp. on Comp. Sci. Edu., pp. 645–650, February 2016.

[9] G Estrella, J. Au, S. M. Jaeggi, and P. Collins, “Is inquiry science instruction effective for English language learners? A meta-analytic review,” AERA Open, vol. 4, 2018.

[10] R. A. Krystyniak and H. W. Heikkinen, “Analysis of verbal interactions during an extended, open-inquiry general chemistry laboratory investigation,” JRST, vol. 44, pp. 1160-1186, 2007.

[11] C. Quintana, X. Zhang, and J. Krajcik, “A framework for supporting metacognitive aspects of on-line inquiry through software-based scaffolding,” Educational Psychologist, vol. 40 pp. 235-244, 2005.

[12] N. Trautmann, J. MaKinster, and L. Avery, “What makes inquiry so hard? (and why is it worth it?),” Paper presented at the annual meeting of the Nat. Assoc. for Research in Sci. Teach., Vancouver, BC. April, 2004.

[13] B. A. Crawford, “Learning to teach science as inquiry in the rough and tumble of practice,” JRST, vol. 44, pp. 613-642, 2007.

[14] M. Windschitl, “Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?,” Science Education, vol. 87, pp. 112-143, 2003.

[15] A. Keselman, “Supporting inquiry learning by promoting normative understanding of multivariable causality, JRST, vol. 40, pp. 898-921, 2003.

[16] National Research Council, “National Science Education Standards,” Washington, DC: National Academy Press, 1996.

[17] National Research Council, “National Science Education Standards,” Washington, DC: National Academy Press, 2008.

[18] T. De Jong and W. R. Van Joolingen, “Scientific discovery learning with computer simulations of conceptual domains,” Review of Educational Research, vol. 68, pp. 179-201, 1998.

[19] National Research Council, “A framework for K–12 science education: Practices, crosscutting concepts, and core ideas,” Washington, DC: National Academies Press, 2012.

[20] M. Pedaste, M. Mäeots, L. A. Siiman, T. De Jong, S. A. Van Riesen, E. T. Kamp, , ... and E. Tsourlidaki, “Phases of inquiry-based learning: Definitions and the inquiry cycle,” Educational Research Review, vol. 14, pp. 47-61, 2015.

[21] J. M. Wing, “Computational thinking. Communications of the ACM,” vol. 49, pp. 33–35, 2006.

[22] G. Estrella, J. Au, S M. Jaeggi, and P. Collins, “Is inquiry science instruction effective for English language learners? A meta-analytic review, AERA open, vol. 4, 2018.

[23] S. G. Zwiep and W. J. Straits, “Inquiry science: The gateway to English language proficiency,” JRST, vol. 24 pp. 1315-1331, 2013.

[24] A. Wagh, K. Cook-Whitt, and U. Wilensky, “Bridging inquiry‐based science and constructionism: Exploring the alignment between students tinkering with code of computational models and goals of inquiry,” JRST, vol. 54, pp. 615-641, 2017.

[25] S. Basu, G. Biswas, P. Sengupta, A. Dickes, J. S. Kinnebrew, and D. Clark, D, “Identifying middle school students’ challenges in computational thinking-based science learning,” Research and Practice in Technology Enhanced Learning, vol. 11, 2016.

[26] B. J. Reiser, “Scaffolding complex learning: The mechanisms of structuring and problematizing student work,” The Journal of the Learning Sciences, vol 13, pp. 273-304, 2004.

[27] R. W. Bybee, Achieving Scientific Literacy: From Purposes to Practical action, Portsmouth, NH: Heinemann, 1997.

[28] S. Basu, K. W. McElhaney, S. Grover, C. J. Harris, and G. Biswas, “A principled approach to designing assessments that integrate science and computational thinking,” Intl. Soc. of the Learn. Sci., 2018.

[29] P. R. Aschbacher, M. Ing, and S. M. Tsai, “Is science me? Exploring middle school students’ STEM career aspirations,” Journal of Science Education and Technology, vol. 23, pp. 735-743, 2014.

[30] R. E. Boyatzis, R. E. (1998). Transforming Qualitative Information: Thematic Analysis and Code Development, Newbury, CA: Sage, 1998.

[31] A. M. Gadermann, M. Guhn, and B. D. Zumbo, “Estimating ordinal reliability for likert-type and ordinal item response data: A conceptual, empirical, and practical guide, Research & Evaluation, vol. 17, 2012.

[32] R. B. Kline, Convergence of Structural Equation Modeling and Multilevel Modeling, The SAGE Handbook of Innovation in Social Research Methods, Newbury, CA: Sage, 2011.

[33] D. Dean Jr and D. Kuhn, “Direct instruction vs. discovery: The long view. Science Education, vol. 91, pp. 384-397, 2007.

[34] C. E. Hmelo-Silver, R. G. Duncan, and C. A. Chinn, “Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark,” Educational Psychologist, vol. 42, pp. 99-107, 2007.

[35] D. Cairns and S. Areepattamannil, “Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries,” Research in Science Education, vol. 49, pp. 1-23, 2019.

[36] J. Jerrim, M. Oliver, and S. Sims, “The relationship between inquiry-based teaching and students’ achievement. New evidence from a longitudinal PISA study in England,” Learning and Instruction, vol. 61, pp. 35-44, 2019.

[37] D. Klahr and M. Nigam, “The equivalence of learning paths in early science instruction effects of direct instruction and discovery learning,” Psychological Science, vol. 15, pp. 661-667, 2004.

[38] J. P. Smith III, A. A. Disessa, and J. Roschelle, “Misconceptions reconceived: A constructivist analysis of knowledge in transition,” The Journal of the Learning Sciences, vol. 3, pp. 115-163, 1994.

[39] P. A. Kirschner, J. Sweller, and R. E. Clark, “Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching,” Educational Psychologist, vol. 41, pp. 75-86, 2006.

[40] J. D. Bransford, D. J. Stipek, N. J. Vye, L. M. Gomez, and D. Lam, D, The Role of Research in Educational Improvement, Boston, MA: Harvard Education Press, 2009.

[41] I. Lee, F. Martin, J. Denner, B. Coulter, W. Allan, J. Erickson, et al., “Computational thinking for youth in practice, ACM Inroads, vol. 2, pp. 32-37, 2011.

[42] S. L. Manz, “A strategy for previewing textbooks: teaching readers to become THIEVES,” The Reading Teacher, vol. 55, pp. 434-436, 2002.

Teachers’ Use of Video Reflections to Reinforce Computer Science Language and Concepts

Ha Nguyen
School of Education
University of California, Irvine
Irvine, CA
thicn@uci.edu

Leiny Garcia
School of Education
University of California, Irvine
Irvine, CA
leinyg@uci.edu

Sharin Jacob
School of Education
University of California, Irvine
Irvine, CA
sharinj@uci.edu

Debra Richardson
Donald Bren School of Information and Computer Science
University of California, Irvine
Irvine, CA
djr@ics.uci.edu

Mark Warschauer
School of Education
University of California, Irvine
Irvine, CA
markw@uci.edu

***Abstract*—This paper examines teachers’ use of Flipgrid, a student-facing video platform, as a reflection tool to promote computer science language in upper elementary classrooms. We take a case-study approach with three fourth grade teachers: one had a high number of students with special needs, one had substantially more gifted and talented students, and one taught a dual immersion English-Spanish class. Data sources include teacher interviews, design meetings between researchers and teachers, and classroom observations. We find that teachers with different pedagogical visions adopted the tools for reinforcement, student engagement, and formative assessment. We document teachers’ iterative improvement strategies and shifts in teacher noticing, particularly the objects (i.e., computer science vocabulary and concepts), level (i.e., whole-class versus individual students), and depth of how they noticed students learning through video reflections. This study contributes to the ongoing work that examines instructional approaches to promoting computing education in diverse K-12 classrooms, especially among teachers with no formal training in computer science education.**

Keywords—computer science education, educational technology, student reflection

I. Introduction

Researchers have called for the introduction of CS in earlier grades to recruit interests and address the underrepresentation of women and minority students [5], [28]. An understanding of teachers’ existing knowledge, experiences, and instructional contexts, as well as how these components influence teachers’ adoption of CS tools and curriculum, is critical to promoting systematic integration of CS into formal education settings [31]. However, there is limited research on the instructional and learning processes that take place in the classrooms, especially in elementary grades [13], [14], [16]. We contribute to this growing research area by documenting how teachers in different instructional contexts adopted a video reflection tool to notice students’ CS learning. The tool was introduced in a one-year CS curriculum implemented by teachers and university researchers in a large, urban school district.

We draw from the extant research around instructional strategies in CS education [14], [16] and teacher noticing of instruction for improvement [8], [22], [24], [26]. We employ a cross-case analysis to examine the potential affordances of the video reflection tool in three elementary classes taught by teachers with no formal training in CS. The teachers faced different classroom dynamics: one had a higher number of students with special needs, one had substantially more gifted and talented students, and one taught a dual immersion English-Spanish class. We explore the instructional strategies and beliefs that characterize the teacher adopters of the tool. We also examine ways in which teachers use the tool to make sense of students’ development of CS-specific language.

This study has two main contributions. First, we explore how teachers in varied contexts experimented with a video reflection tool to reinforce CS discourse. A practical implication is that tools’ alignment with teachers’ knowledge, beliefs, and practices can be positively perceived by teachers who are new to CS education. Second, we examine the utility of student reflections in fostering teacher noticing of computational language and understanding. This is one of the first studies to apply teacher noticing frameworks to CS education. We find that teachers mostly focused on students’ vocabulary instead of conceptual understanding, and teacher noticing was mostly descriptive and not yet focused. We discuss implications for designing professional development opportunities that employ student artifacts to guide teacher instructional improvements.

II. Related Work

A. Examining Instructional Strategies in CS through the Universal Design Learning Framework

The literature on teachers’ perceptions when implementing CS curricula has been scarce. Studies have focused on teachers’ perceived challenges and instructional moves that are effective in fostering students’ computational thinking [14], [16], [21]. Multiple implementation models of CS curricula may emerge depending on intrinsic factors, such as teachers' perceptions of their professional efficacy, and extrinsic factors, namely time constraints and classroom contexts [14], [21]. A case study analysis [13] using observations and interviews with teachers and administrators across instructional contexts (e.g., library, art, general education classrooms) found that teachers employed different instructional strategies based on task open-endedness and classroom organization when teaching CS. For example, some teachers tend to employ more whole-class and explicit instruction, while others take a more open-ended approach [14]. These pedagogical choices were correlated with the amount of administrative support, teacher values, and teachers' perceived expertise [14], [15].

Studies have also employed the Universal Design Learning (UDL) framework to explore teachers' perceptions and implementation of CS curricula [14], [16]. The UDL framework encourages teachers to consider not only direct versus open-ended pedagogical approaches, but also ways in which instruction may broaden students' means of representation, action and expression, and engagement [20]. Applying the UDL framework to examining teachers' practices explores ways in which curricular planning and delivery can purposefully reduce barriers and increase meaningful entries for all students, including special education students and English learners (Els). The dimensions of the UDL framework can be summarized as follows:

- **Representation**: Provide multiple ways (e.g., texts, multimedia visuals, audio, discussion) for students to interact with content, communicate in disciplinary language, and generate understanding.
- **Action and Expression**: Provide ways for students to demonstrate comprehension in multiple modes (e.g., physical action, writing, speaking) and monitor their own progress (e.g., goal-setting, managing learning resources).
- **Engagement**: Recruit and sustain students' interests and collaboration.

B. *Universal Learning Design in Student Reflections*

UDL principles to promote student action and expression is the underlying theory for prompting students' self-reflection on content knowledge. Discussion and argumentative activities to clarify, reflect, and build on one's own and others' ideas have been promoted in mathematical, science, and English Language Arts (ELA) classrooms [1], [9], [17], [29]. Students may use multiple types of discourse–both everyday and scientific vocabulary–to present their understanding of scientific concepts based on situational demands [11]. Strategies in English Language Arts posit that multiple exposures and reinforcements are required before students begin to correctly use and understand new terms [1].

In the field of CS, students engage in discipline-specific language as they develop and test logical processes to address abstract computational problems. Students articulate the exploratory, explanatory, and elaborative steps involved in problem solving to construct understanding of key computational concepts and associated vocabulary knowledge [11]. Attending to student voices in reflection develops students' discursive identities and promotes identification with the field [6]. Research has shown that developing STEM identities at the elementary level promotes later interest in CS careers [30].

Teachers can utilize several UDL strategies to scaffold the reflection activities. Compared to simply stating the vocabulary's definition, combining instruction of language and content knowledge more effectively builds students' knowledge base for productive reflection [9]. Scaffolding with explicit prompts can be effective for supporting student argumentation and general reflection in the discipline [9]. Encouraging students to use multiple methods of action and expression to explain how they design their codes can also increase access and involvement in computing education, particularly for learners with special needs [7], [16].

C. *Teacher Noticing of Student Discourse*

Few studies have examined the tools and learning moments that teachers use to notice students' computational thinking in K-12 classrooms [14]. We thus draw on related work on teacher noticing of instructional moments and student discourse in mathematics and science [8], [22], [24], [25]. Several aspects are salient in teacher noticing framework [27]:

- Object of noticing: Strengths and weaknesses in student thinking, classroom interactions, lesson content, ...
- Focus: Specific concept versus general theme.
- Perspective: Description, interpretation, evaluation.
- Level: Whole-class versus individual student.

To hone into teacher noticing, classroom artifacts such as student work and video segments of student interactions have been employed as locally grounded representations of teaching practice to help teachers reflect on instruction and student thinking more intentionally [1]. The current study frames teacher noticing of CS knowledge in terms of the contexts and artifacts that helped teachers assess task appropriateness and student understanding. An example of task appropriateness is teacher's assessment of whether the instruction on programming loops was effective. An illustration of student understanding is whether students can use the acquired vocabulary and everyday language to explain the concepts.

III. Research Questions

1) What instructional strategies and beliefs characterize the adopters of the reflection tool within a CS curriculum? To what extent do these strategies and beliefs influence how teachers adopted the tool?
2) How do teachers use reflection videos to make sense of students' development of CS-specific language?

IV. Method

A. *Study Setting & Participants*

This study follows teachers from three fourth and fifth grade (ages 9-11) classes in one of the largest, most linguistically and culturally diverse school districts in the U.S. (92.9% Hispanic or Latino, 80.4% on Free and Reduced lunch, 38.7% ELs). Each class had 25 students on average.

The teachers differed in classroom demographics and instructional routines. Ellen and Helen (pseudonyms) taught all subjects in fourth grade in the same school and co-planned the CS lessons. Meanwhile, Juanita (pseudonym) worked with groups of special education students in Math at a dual-immersion charter school. The one hour per week teaching CS was the only time Juanita had with a whole class. The teachers reported no prior experience teaching formal CS curricula.

The teachers also faced different constraints and affordances from their classes. Ellen had a class with mainly Gifted and Talented students. About 10% of students in Helen's class received various Individualized Education Programs (IEP). Juanita had a group of five special education students that she consistently worked with throughout the year. The students in this study had no prior computing courses, although students in Ellen and Helen's classes had participated in Hour of Code activities in the previous academic year.

B. Curriculum

Teachers were part of a district-wide initiative to integrate CS into elementary schools. The project team, consisting of teachers and researchers, developed a curriculum that built on UDL framework to target computational concepts and vocabulary appropriate for students aged 9-11 and meet the needs of the district's linguistically diverse student populations. The curriculum includes language frames intended to develop student's use of computational language and interweaves stories to promote identity towards the CS field. The linguistic scaffolds leverage both academic language and interaction functions (e.g., discussion, reflection).

The researchers and teachers met monthly to reflect on curriculum progress and devise instructional strategies to accommodate the needs of each classroom. During those in-person design meetings, supplementary pedagogical tools were introduced to further facilitate students' acquisition of CS disciplinary language. In particular, researchers did a demo of Flipgrid, a platform where students could videotape themselves presenting their codes and share with their peers. . The reflection activities align with the UDL frameworks to foster multiple student expressions and engagement. Ellen, Helen, and Juanita decided to pilot the tool.

The reflection activities occurred at the end of Unit 1 and 2 of the curriculum and took about 45 minutes each. Most student responses were brief, lasting 1.15 minutes on average.

For Unit 1, students pair-programmed in Scratch with only ten designated code blocks. At the end of the unit (lesson 5), students were asked to reflect in pair about their "10 Blocks Challenge" in response to the Flipgrid prompt: *"Walk us through your project. What blocks did you use? What was difficult? What did you find?"* Because the activity occurred quite early in the year, students had only been introduced to a few CS vocabulary (e.g., code) and concepts (e.g., algorithm).

At the end of Unit 2 (lesson 10), students reflected individually on a digital collage they created about themselves. The activity occurred about three months into the curriculum, when students had been introduced to more CS vocabulary and concepts, namely event, sequence, initialization, and parallelism. Example of the Flipgrid reflection prompt: *"BRIEFLY state some details about you that are in the program. Then, pick ONE SPRITE, open the code, and explain what you did. Be sure to use vocabulary words like "algorithm," "code," "program," "parallel program" or "initialization".*

All teachers reported reviewing their student Flipgrid videos right after the reflection lessons. The design meetings (December 2018 and March 2019) gathered additional teacher insights about students' language. During the meetings, all the teachers piloting the curriculum watched a selected set of students' Flipgrid video responses explaining their codes from all the teachers' classes. Teachers were then asked to reflect in the whole-group setting on student videos based on two questions: *(1) "What do you notice about student language and CS understanding?*, and *(2) "What insights for instruction do you gather from the student Flipgrid responses?"*.

C. Data Sources

Data sources include teacher interviews, two design meetings (detailed above), and classroom observations. These data sources are selected to produce a more comprehensive view of teachers' beliefs and practices through their own and researchers' perceptions across settings (e.g., individual interviews, teacher-researcher, teacher-student interactions). Interviews and classroom observations were used to answer research question 1 about the characteristics of teacher adopters. Teacher reflections during the design meetings were used to answer research question 2 about teacher noticing.

The research team visited classrooms almost every week and took structured notes of instructional strategies using the UDL framework [22]. A subset of two of the same lessons from each teacher (lesson 4 and 6; conducted between November 2018 and January 2019) was selected for analyses because they were part of the units students were reflecting on. Semi-structured interviews lasting about 30 minutes were conducted at the end of the school year to understand each teacher's experiences with the CS curriculum more generally. The interviews included questions such as *"How would you describe your CS instructional approaches?"*

D. Cross-case Analysis

We conduct a cross-case analysis to examine teachers' instructional practices as they unfolded in time [3]. Cross-case analysis is chosen as a means to explore complex social units of interconnected variables to understand a focal phenomenon [19]. The units of analysis are the three teachers teaching the same lessons and adapting the same pedagogical tool. We identify the salient themes in each teacher's approach to teaching CS before examining common themes across cases.

Observation notes, interviews, and transcripts from the design meetings were analyzed using an initial set of codes for pedagogical visions, instructional goals, and teacher noticing of student thinking. Prior frameworks, namely UDL [19] and teacher noticing [7, 26] inform these codes. The final coding

TABLE I

CODING SCHEME FOR TEACHER INSTRUCTIONAL STRATEGIES AND SENSE-MAKING OF STUDENTS' CS REFLECTION. THE ARROW INDICATES INCREASING LEVELS OF SOPHISTICATION IN TEACHER NOTICING

Domain	Code	Sub-code	Description for teacher actions
Instructional Strategies *Data sources: Teacher interviews, classroom observations*	Representation	Display information in alternative forms	Display information in alternative forms (e.g., visual, auditory, verbal)
		Provide language and symbols	Clarify vocabulary and symbols by scaffolding questions
		Reactivate background knowledge	Activate student background knowledge by drawing connections to other subjects or previous activities
		Model	Model activities through step-by-step instruction
	Expression	Display comprehension using multimedia	Provide students opportunities to demonstrate understanding in multiple modalities (e.g., write, speak, code, etc.)
		Recruit student interests	Recruit student interests in multiple ways
	Engagement	Foster collaboration and communication	Foster group work, pair programming, communication, etc.
		Provide mastery-oriented feedback	Provide feedback to orient students to mastery
		Scaffold resources	Vary demands and resources to support learning according to students' ability
Teacher Noticing *Data source: design meeting transcripts*	Object (What teachers notice)	Vocabulary	Notice students' use of computer science vocabulary (e.g., code, algorithm) or everyday language
		Concept	Notice students' use of computer science concepts (e.g., abstraction, initialization, parallelism)
		Practice	Notice students' engagement, communication, collaboration
	Level (At what level)	Whole class	Make general comments about whole class environment, behavior, learning, and pedagogy
		Individual	Attend to particular students' thinking
	Elaboration (How teachers notice) ↓	Basic	Form general impressions of students' learning, or provide description and evaluation of their performance.
		Mixed	Highlight noteworthy episodes, or provide primarily evaluations with some interpretations of student learning patterns.
		Focused	Propose alternative pedagogical solutions citing specific learning interactions as evidence.

scheme pertains to instructional strategies and noticing patterns that appear in the data (Table 1). Data from each teacher were coded separately, and then compared for similarities and differences to generate themes.

E. Validity

Instrumentation and researchers' biases may result in interpretations of teachers' instructional strategies and noticing in ways that significantly differ from their intentions. We triangulated observation notes with audio recording and teacher interviews and conducted member checking as a validity procedure. The interview and design meetings prompts include open-ended questions to avoid biasing teachers' responses.

F. Hypothesis

We hypothesized that classroom contexts and pedagogical visions about the curriculum, instruction, and student ability would inform teachers' adoption of Flipgrid and implementation of the reflection activities. For example, teachers with more structured instructional approaches may use the tool for reinforcement and employ more directive prompts [13].

V. FINDINGS

A. Characteristics of Teacher Adopters

1) Beliefs – Teacher as Learner: Teachers' belief in teaching CS emerged in all interviews. Teachers posited themselves as learners who were getting used to the curriculum alongside their students. They indicated an willingness to experiment with ideas and teaching methods to see what worked best. For instance, Ellen gave examples of going back and forth with the tools (e.g., notebook, language frames, Flipgrid). She reflected that she became more confident with teaching the curriculum as she practiced beforehand what the students did. She admitted having no experience in computer programming and feeling confused in the beginning, and emphasized the importance of positioning herself as ”learning with the students”. The teachers further reflected that adopting a new tool is always challenging, but it is a “learning curve and students would get something out of it in the end” (Juanita, interview).

2) Tool Purposes – Reinforcement, Engagement, & Formative Assessment: The three teachers possessed different views about students' ability to thrive in the CS curriculum in terms of computing knowledge, language and academic needs, and persistence. These views seemed to intertwine with their goals for adopting Flipgrid. First, teachers viewed the reflection tool as an opportunity to engage all students. For example, Helen frequently described her class in terms of varying student skills and needs in her interview. She framed her students in different groups—those who may be more comfortable exploring and those who may need additional encouragement and support. The teachers reportedly adopted Flipgrid to invite all students to share about their programming progress.

Second, teachers adopted the tool as a reinforcement mechanism. The teachers expressed the belief that students learned more effectively if teachers could slow down on certain parts of the lessons and gave students time to reflect and practice. This theme particularly stands out in Helen's and Juanita's classes, which have a high number of ELs and special education students. Both teachers referred to going at the pace that accommodates students with particular needs.

Third, teachers used the tool as a formative assessment to understand potential changes in student learning. Mapping student reflections to their programming projects provided teachers an opportunity to quickly evaluate the learning progress of the whole class, and adjust their instruction accordingly. Juanita alluded to differentiating instruction:

> You have a span - Special Ed students who need more time to process and students who run and are ready to go. What I'm finding is that I can't get to them all, and now that I know what they can do, I can push these kids to go higher and deeper.

Traditionally Juanita was used to working in small groups with special education students. Her reflection following the first use of Flipgrid reflected her hope to use the tool to assess students' CS understanding and language use simultaneously at the whole class level. She further noted in her interview that reflective tools such as Flipgrid could be a means to derive personalized instruction to accommodate different needs. Helen shared this vision, claiming that the reflection could show her "a side of students I have not seen before".

3) Instructional Strategies – Reinforcement & Multiple Representations: Analyses of classroom observation notes helped clarify how teachers' pedagogical strategies overlapped and diverged to adapt to specific classroom needs. All teachers employed explicit instruction, including reviewing prior knowledge and modeling tasks, before moving toward student-driven practices. The instructional routine was largely similar across the three classrooms across lessons. The teachers started the lessons by explaining the CS concepts, vocabulary, and tasks of the day. A common strategy to review content knowledge is to bridge students' background knowledge in other subjects with the new CS content. For example, teachers connected the concept of an "algorithm" to step-by-step algorithms in Math, or computer "events" to "events" in stories. Next, teachers provided step-by-step instruction before letting students explore coding individually or in pair for more than half of the lessons.

However, teachers employed different focus on language and representation. The teachers who identified special education and ELs as a focal point of instruction during interviews tended to clarify new vocabulary and symbols and repeat these vocabulary words and concepts more frequently. For Helen, it was connecting the visual representations with the CS concepts in printouts for students to refer to throughout the lessons. For Juanita, it was a routine of introducing the vocabulary with visual illustrations and definitions in the beginning of the lesson. The visual demonstrations of the vocabulary were put up in the Technology corner, accumulating into a display of new vocabulary and concepts over time. Juanita also pointed to these images to spot-check with students about the newly acquired vocabulary throughout the lessons.

Additionally, teachers differentiated task expectations to accommodate students' varied abilities. One example is the extent to which teachers encouraged students to use the language frames from the curriculum to explain CS concepts. All three teachers printed out the language frames and reminded

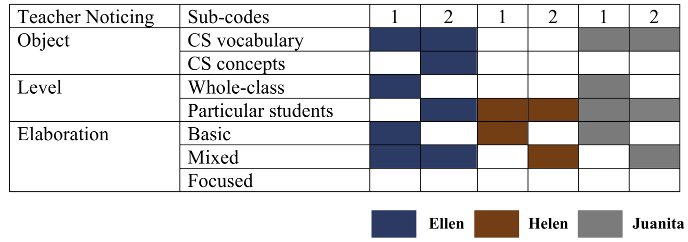


Fig. 1. Teacher Noticing. Colored boxes indicate occurrences of codes. 1 & 2 denote teacher noticing at the first and second design meeting.

students to use them during whole-class, group, and pair discussions. However, their expectations for students' usage of the frames differed, with teachers in classes with special education and ELs providing more explicit scaffolds and reinforcements of how students could practice the language. Helen and Juanita particularly designated the specific levels of language that they would like students to use, and gave example student responses based on this designated baseline.

In sum, although employing quite similar representation and representation strategies, teachers adjusted these strategies to classroom needs. The two teachers who focused on learners with special needs and ELs particularly emphasized using the reflection tool to reinforce CS concepts and vocabulary, as well as assess students.

B. Teacher Noticing & Instructional Revision

The variation in pedagogical goals and approaches may also influence how teachers employed Flipgrid to improve CS instruction. We document teachers' reactions to students' video reflections at the two design meetings, particularly the object, level, and depth of their noticing. We highlight how their noticing of students' CS vocabulary and concepts shifted over time and informed insights for instructional improvements. Fig. 1 provides an overview of teachers' varied noticing.

1) First iteration: Focus on Vocabulary. Teachers mostly focused on students' vocabulary use, rather than CS concept (i.e., algorithm, abstraction) in the first design meeting. Juanita, for example, was baffled when pointing out that she did not see any of the vocabulary they were teaching in student reflections. Teachers commented that students were using a range of everyday language to describe their projects, but were not yet using the target vocabulary.

Whole-class versus Individuals. In addition, pedagogical visions influenced the level (whole-class versus individual students) that teachers identified with student data. The level of noticing in the interviews revealed important insights into how teachers anchored their goals and problems of practice. Consider teachers' reactions to student videos:

> Ellen: You could see some of them using the vocabulary but they got carried away with the acting.
>
> Juanita: You know, even though we get around, we don't get around to every single one. I am looking at Natalie. I had to go see her stuff because she looked

> a little lost. Very quiet. Very compliant. It doesn't mean that she doesn't need help on it.

Whereas Ellen made global comments about her students' presentation and vocabulary as a class, Helen and Juanita anchored their answers in specific students who they considered as needing the most attention and showing the most critical changes. For example, Juanita wanted to see how her more "quiet, compliant" students interacted with the codes. These insights overlapped with the teachers' anchoring in individual cases when reflecting on lesson planning and tool adoption.

Descriptive, not yet Focused Elaboration. The depth of teachers' noticing pertains to the extent to which teachers provide interpretive comments of students' learning patterns, and propose alternative strategies. After commenting on students' vocabulary, two of the teachers immediately brainstormed ways to increase the use of the target vocabulary. Juanita pointed out that students' limited usage of CS vocabulary in the first set of videos may result from the open-ended nature of the task and not the lesson or teaching style. Upon this realization, Ellen and Helen co-planned and proposed instructional changes. For assessment, they incorporated the vocabulary into their assignment, reminding students to use words like "algorithm", "parallel", or "initialization". For instruction, following the first design meeting, teachers explicitly taught the vocabulary and reinforced it regularly. Helen, for example, created her own vocabulary printouts, with visual illustrations and definitions, and handed these out to her students so they could follow throughout the lessons.

2) Second Iteration: Shift towards CS Concepts & Student Everyday Sensemaking. There appears to be a shift in teacher noticing of CS vocabulary and concepts. In the first design meeting, teachers focused more on seeing whether students employed the target vocabulary. In the second meeting, teachers still attended to students' vocabulary use, but with an increasing focus on precision. Consider the following reactions in the second design meeting after teachers watched a Flipgrid response, where a student was describing his project while explaining the programming concept "parallelism". Part of the student's video stated:

> What I learned from my classmates' about me is that I could have multiple backgrounds, multiple sprites, and multiple parallelism in each step. So for example, let's say I have a parallelism for when I press M and it will move to x 25 y -15 and the background will change as well when I click M.

In response, Juanita noticed that "He called them backgrounds and not stages, sometimes kids say 'it won't move' and they are referring to the sprites, not the stages", and Ellen commented on the specificity of his description and the use of the target concept, "parallelism". In this instance, Juanita and Ellen were attending to the specific vocabulary ("stage", "background", "parallel") in student talk. However, their comments also suggested evaluation of how correctly the student was using the vocabulary and the extent to which vocabulary usage was related to conceptual understanding.

In addition, there appeared to be a shift in vocabulary goals. When seeing that the number of CS vocabulary did not increase substantially from the first to the second unit, Juanita reasoned that it was "natural for kids this age to use their everyday language", and that despite the limited vocabulary, she saw the values in students' talking about code in relation to their personal experiences. The teacher had moved from noticing specific vocabulary to student everyday language and how they used this language to talk about their codes.

Anchored Noticing Levels. The teachers continued to anchor their responses on their instructional focus on student engagement. Helen, for example, directed her attention to a special education student she had been following closely. The student demonstrated emerging use of CS vocabulary and concepts (e.g., sprite, set size) when explaining his Scratch project. Part of his response states "This is the fish. You click on sprite. Right there. And fish 5 escape by 25% size for one second". After watching the video, Helen did not emphasize the content of the talk as much as the fact that the student was engaging.

> There's a personality thing. I have a student who struggles a lot with panic attacks. He has many labelled needs. We're at a pace when we're going a lot more than he could handle. And he has meltdowns. And in this Flipgrid just about himself he's like the happiest kid. And he is just talking and talking.

Deeper Elaboration toward Instructional Practices. Although primarily descriptive (such as Helen's response above), the elaboration in some teachers' comments has moved from general (e.g., "Students did great") to specific instances of student display of CS vocabulary and concepts. The depth of elaboration has developed from basic—forming general impressions without grounding observations in evidence, to mixed—providing interpretative statements of student learning. For example, Helen and Juanita stated that they wanted to embed the reflection activities early in the next iteration of the curriculum, based on how deeply engaged students were with the reflections. The teachers indicated that the reflections would provide an early assessment of students' CS understanding, as well as an opportunity to invite students to practice disciplinary language both individually and collaboratively. Although their suggestions imply pedagogical strategies, their proposals did not directly draw from specific evidence of student learning, and thus are not yet at the focused level.

VI. Discussion

A. Pedagogical Visions & Knowledge Influence What and How Teacher Notice

The design meetings and interviews provided teachers the opportunity to make sense of students' demonstration of CS vocabulary and conceptual understanding through reflections. In general, teachers were able to notice students' use of vocabulary and CS concepts, although they tended to attend to students' vocabulary in greater details than conceptual understanding. Within noticing of vocabulary, there was a shift in focus from the target CS vocabulary to everyday language.

A possible explanation is because teachers did not receive formal training in CS education, they more comfortably drew on a familiar domain (i.e., vocabulary and strategies for language development). As teachers gained more experiences with the CS curriculum, they began to notice the curriculum's conceptual focus and the multiple types of discourse–both everyday sensemaking and CS vocabulary—-that students employ to present their understanding. Attention to students' use of both everyday and disciplinary language to express students' sensemaking has been called for in science, math, and increasingly in CS [11], [13], [22], [26]. More structure for professional development should be implemented to support teachers in learning to notice the details of student computational thinking—-to learn to identify how they are reasoning and connecting concepts, rather than just vocabulary.

Analyses also revealed the nuances in teachers' levels of noticing. Even though Ellen and Helen taught at the same school with the same materials, Helen, who consistently related her classroom experiences and pedagogical strategies to specific student populations, appeared to anchor noticing in individual student cases. Having a stronger impression of individual and student pairs engaging in CS discussion, Helen wanted to foster these activities in her next iteration of the curriculum. This is an encouraging sign that student reflection provided a basis for teachers to gather evidence of their learning and derive strategies [3].

B. Align Tools with Teachers Beliefs to Promote Use

We seek to understand the characteristics of teachers who voluntary adopted reflective pedagogical tools to assess students' CS vocabulary and understanding of concepts. An overarching finding was the teachers' internalization as learners alongside their students. This aligned with prior frameworks on teachers' technology learning and adoption trajectory [23]. This framework posits that teachers move from being "learners" who acquire the knowledge and skills to perform tasks to "adopters" that experiment with the tasks in their classrooms. After gaining an understanding of task management, teachers become "co-learners" with more focus on the relationship between the curriculum and technology. While teachers in this study have consistently positioned themselves as learners of the curriculum, in testing out tools such as Flipgrid in their classrooms and developing instructional strategies for improvement, they shifted to "adopters" and "reaffirmers", increasingly gaining agency over the tool and curriculum.

Tool adoption was also associated with specific pedagogical goals. The tool appears to match with the three teachers' tendency to employ reinforcement and multiple representations. The reflection on pedagogical goals and strategies from Juanita, Helen, and Ellen reveals their perceptions of learning and teaching in terms of students' own experiences and knowledge base, and their willingness to adopt technology-mediated experiences to help students learn CS in their own terms. Prior research states that technology whose affordances align with a teacher's pedagogical styles is more likely to be positively received and employed [19].

C. Implications & Future Work

Findings from this study have implications for developing reflection tools in CS curriculum and supporting teachers' use of those tools. First, we found that teachers with different classroom contexts chose to adapt the reflection activity for an array of purposes. The tool fosters values (i.e., multiple forms of student engagement and formative assessment) that teachers identified with. A practical implication for broader uptake of CS curricular initiatives is to frame them in terms of shared values with teachers–such as promoting student reflective voice. Our experience shows that aligned pedagogical visions can promote positive reception from teachers who are not yet familiar with CS discipline and instructional tools.

Second, pedagogical stances and content knowledge influenced teachers' interpretation of student reflections. In particular, teachers tended to attend more to student vocabulary than conceptual understanding. A direction for future work is to create opportunities for teachers to develop more focused noticing of students' CS practices, beyond counts of vocabulary. Emerging models for teacher learning in CS education include instructional coaching [15], credential programs [10], and sustained professional learning communities [12]. A recent evaluation of CS coaching models indicates that co-planning and co-teaching are critical to providing support to teachers [15]. We are exploring the systematic integration of student reflection and programming artifact in design cycles with teachers to better understand how to guide teachers towards instructional decisions based on their insights. Co-planning models such as the case of Ellen and Helen may also encourage teachers to converse about student learning and propose instructional changes. Our future work will also examine the potential differences in teachers' noticing when they are reflecting in group (this study) or individually.

Third, teachers used insights from student responses to propose instructional modifications, particularly to employ more scaffolds, diversify grouping strategies, and embed the tool as a formative assessment early in the school year. Future work can leverage teachers' insights to adapt tool use to classroom contexts and track the impact of instructional adjustments on student learning and teacher noticing. Following larger samples of teachers with different experience may yield valuable information about a broader range of pedagogical stances, strategies, and noticing in computing education.

D. Limitations

Findings from this study should be interpreted in light of several limitations. First, the small sample size limits the findings' generalizability. Second, because the teachers were experiencing other aspects of the CS curriculum between the first iteration of the tool and the second design meetings/teacher interviews, other factors may have influenced how teachers came to analyze instruction and develop pedagogical strategies. Third, the individual interviews and design meetings prompted teachers to reflect in retrospect, and thus may not have fully captured their in-the-moment noticing of students' learning as they were watching the video reflections.

VII. Conclusion

This cross-case analysis reveals the characteristics of teacher adopters of a reflective pedagogical tool to reinforce CS vocabulary and concepts in elementary grades. Findings from this study reveal the affordances of using student video reflection on their programming projects as a form of authentic assessment, reinforcement, engagement, and facilitator of teacher noticing for instructional improvements. These insights are crucial in light of expanding computing education initiatives in K-12 education [13], [15], [16], accompanied by the need for professional development to prepare teachers who may not have been formally exposed to computing education.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 1738825. Any findings expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We thank the reviewers, teachers, and students.

References

[1] D. August, M. Carlo, C. Dressler and C. Snow, "The critical role of vocabulary development for English language learners," *Learning Disabilities Research Practice*, vol. 20, no.1, pp. 50-57, Jan. 2005. https://doi.org/10.1111/j.1540-5826.2005.00120.x

[2] D. L. Ball and D. K. Cohen, "Developing Practice, Developing Practitioners: Toward a Practice-Based Theory of Professional Education," in *Teaching as the learning profession: Handbook of policy and practice* , G. Skykes and L. Darling-Hammond, Ed. San Francisco: Jossey-Bass Inc., 1999, pp. 3–32. https://doi.org/10.1037/0022-3514.90.4.644

[3] T. Barnhart, and E. A, van Es, "Studying teacher noticing: Examining the relationship among pre-service science teachers' ability to attend, analyze and respond to student thinking," *Teaching and Teacher Education*, vol. 45, pp. 83–93, Jan. 2015. https://doi.org/10.1016/J.TATE.2014.09.005

[4] J. Creswell, and C. Poth, *Five qualitative approaches to inquiry. In Qualitative inquiry and research design: Choosing among five approaches*. Thoasand Oaks, CA: Sage Publications, 2016.

[5] J. Blickenstaff, "Women and science careers: leaky pipeline or gender filter?," *Gender and education*, vol. 17, no. 4, pp. 369-386, Oct. 2005.

[6] B. A. Brown, J. M. Reveles and G. J. Kelly, "Scientific literacy and discursive identity: A theoretical framework for understanding science learning," *Science Education*, vol. 89, no. 5, pp. 779–802, Sep. 2005. https://doi.org/10.1002/sce.20069

[7] Q. Burke, W. I. O'Byrne, and Y. B. Kafai, "Computational Participation: Understand coding as an extension of literacy instruction," *Journal of Adolescent & Adult Literacy*, vol. 59, no. 4, pp. 371–375, Jan. 2016. https://doi.org/10.1002/jaal.496

[8] F. Erickson, "On Noticing Teacher Noticing," in *Mathematics teacher noticing: Seeing through teachers' eyes*, M. Sherin, V. Jacobs and R. Philipp, Ed. New York, NY: Routledge, 2011, pp. 47–64. https://doi.org/10.4324/9780203832714-13

[9] National Academies of Sciences, Engineering, and Medicine. "English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives," in *The National Academies Press*, Dec. 2018. https://doi.org/10.17226/25182

[10] J. Gal-Ezer, and C. Stephenson, "Computer science teacher preparation is critical," *ACM Inroads*, vol. 1, no. 1, pp. 61-66, Mar. 2010. https://doi.org/10.1145/1721933.1721953

[11] K. Gomez, "Negotiating discourses: Sixth-grade students' use of multiple science discourses during a science fair presentation," *Linguistics and Education*, vol. 18, no. 1, pp. 41–64, Mar. 2007. https://doi.org/10.1016/J.LINGED.2007.03.002

[12] J. Goode, J. Margolis and G. Chapman, "Curriculum is not enough," in *Proceedings of the 45th ACM Technical Symposium on Computer Science Education - SIGCSE '14*, 2014, pp. 493–498. https://doi.org/10.1145/2538862.2538948

[13] S. Grover and R. Pea, "Using a discourse-intensive pedagogy and android's app inventor for introducing computational concepts to middle school students," in *Proceeding of the 44th ACM Technical Symposium on Computer Science Education - SIGCSE '13*, 2013, pp. 723-728. https://doi.org/10.1145/2445196.2445404

[14] M. Israel, J. N. Pearson, T. Tapia, Q. M. Wherfel and G. Reese, "Supporting all learners in school-wide computational thinking: A cross-case qualitative analysis," *Computers Education*, vol. 82, pp. 263–279, Mar. 2015. https://doi.org/10.1016/J.COMPEDU.2014.11.022

[15] M. Israel, M. Ray, W. Maa, G. Jeong, C. Lee, T. Lash, ... and V. Do, "School-Embedded and District-Wide Coaching in K-8 Computer Science: Implications for Including Students with Disabilities," *Journal of Technology and Teacher Education*, vol. 26, no. 3, pp. 471–501, Jul. 2018. https://www.learntechlib.org/p/181938/

[16] M. Israel, Q. M. Wherfel, J. Pearson, S. Shehab and T. Tapia, "Empowering K-12 Students With Disabilities to Learn Computational Thinking and Computer Programming," *Teaching Exceptional Children*, vol. 48, no. 1, pp. 45–53, Sep. 2015. https://doi.org/10.1177/0040059915594790

[17] O. Lee and S. H. Fradd, "Science for All, Including Students From Non-English-Language Backgrounds," *Educational Researcher*, vol. 27, no. 4, pp. 12–21, May 1998. https://doi.org/10.3102/0013189X027004012

[18] S. B. Merriam, *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass Publishers, 1998. https://eric.ed.gov/?id=ED415771

[19] D. S. Niederhauser and D. L. Lindstrom, "Instructional technology integration models and frameworks: Diffusion, competencies, attitudes, and dispositions," in *Handbook of Information Technology in Primary and Secondary Education*, J. Voogt et al., Ed. Springer, 2018, pp. 1-21.

[20] D. H. Rose and A. Meyer, A practical reader in universal design for learning. Cambridge, MA: Harvard Education Press, 2006.

[21] S. Sentance and A. Csizmadia, "Computing in the curriculum: Challenges and strategies from a teacher's perspective," *Education and Information Technologies*, vol. 22, no. 2, pp. 469–495, Mar. 2017. https://doi.org/10.1007/s10639-016-9482-0

[22] M. Sherin, V. Jacobs and R. Philipp, Ed. New York, NY: Routledge, 2011.

[23] L. Sherry, S. Billig, F. Tavalin and D. Gibson, "New insights on technology adoption in communities of learners," in *Society for Information Technology Teacher Education International Conference*, Association for the Advancement of Computing in Education (AACE), 2000, pp. 2044-2049.

[24] V. Talanquer, D. Tomanek, D. and I. Novodvorsky, "Assessing students' understanding of inquiry: What do prospective science teachers notice?" *Journal of Research in Science Teaching*, vol. 50, no. 2, pp. 189–208, Feb. 2013. https://doi.org/10.1002/tea.21074

[25] V. Talanquer, M. Bolger, and D. Tomanek, "Exploring prospective teachers' assessment practices: Noticing and interpreting student understanding in the assessment of written work," *Journal of Research in Science Teaching*, vol. 52, no. 5, pp. 585–609, May 2015. https://doi.org/10.1002/tea.21209

[26] E. A. van Es and M.G. Sherin, "Mathematics teachers' "learning to notice" in the context of a video club," *Teaching and Teacher Education*, vol. 24, no. 2, pp. 244–276, Feb. 2008. https://doi.org/10.1016/J.TATE.2006.11.005

[27] E. A. van Es, "A framework for learning to notice student thinking," in *Mathematics teacher noticing* (pp. 164-181). M. Sherin, V. Jacobs and R. Philipp, Ed. New York, NY: Routledge, 2011, pp. 164-181.

[28] R. Varma, "Making computer science minority-friendly," *Communications of the ACM*, vol. 49, no. 2, pp.129-134, Feb. 2006.

[29] M. Walshaw and G. Anthony, "The Teacher's Role in Classroom Discourse: A Review of Recent Research Into Mathematics Classrooms," *Review of Educational Research*, vol. 78, no. 3, pp. 516–551, Sep. 2008. https://doi.org/10.3102/0034654308320292

[30] J. Wang, H. Hong, J. Ravitz, and S. Hejazi Moghadam, "Landscape of K-12 Computer Science Education in the U.S," in *Proceedings of the 47th ACM Technical Symposium on Computing Science Education - SIGCSE '16*, 2016, pp. 645–650. https://doi.org/10.1145/2839509.2844628

[31] A. Yadav, C. Mayfield, N. Zhou, S. Hambrusch and J. T. Korb, "Computational thinking in elementary and secondary teacher education," *ACM Transactions on Computing Education (TOCE)*, vol. 14, no. 1, pp. 5, Mar. 2014.

The Role of Familial Influences in African American Women's Persistence in Computing

Yolanda Rankin
School of Information
Florida State University
Tallahassee, FL, USA
yrankin@fsu.edu

Maedeh Agharazidermani
School of Information
Florida State University
Tallahassee, FL, USA
magharazidermani@fsu.edu

Jakita Thomas
College of Engineering
Auburn University
Auburn, GA, USA
jnt0020@auburn.edu

***Abstract*—Because African American women represent a vastly underrepresented population in the field of computing (i.e., 1% of bachelor's degrees awarded to African American women in 2018), multiple approaches have been utilized to increase the representation of African American women in the computing pipeline. However, strategies to recruit and retain African American women in computing emphasize mentorship in educational settings, ignoring the significance of familial influences in African American women's decision to pursue a degree in computing or how this impacts their ability to successfully navigate the computing pipeline. Furthermore, familial influences represent one form of social capital that can be leveraged to gain access to opportunities in computing. In this exploratory study, we investigate the role of family members and the family values that influence African American women's decision to pursue computing as a preferred field of study and a viable career option. Leveraging Black Feminist Thought as a critical framework, we interview 34 African American women in various stages of the computing pipeline to explore their lived experiences. Qualitative analysis reveals that families play a pivotal role in African American women's persistence in computing in six crucial ways: 1) early exposure and access to computing; 2) support for African American women's self-efficacy; 3) education as a family value; 4) career guidance and advice; 5) emotional support; and 6) family members as role models. We provide recommendations to leverage African American women's strong ties with family members.**

Keywords—African American Women, family, computing

I. INTRODUCTION

With the increasing job growth in the technological sector, recent statistics show a shortage of employees with the necessary education or job training to fill positions in the field of computing (e.g., Computer Science, Information Technology, Computer Engineering, etc.) [1], [2]. Having a more diverse group of skilled personnel regardless of race and gender increase likelihood of success in the global market[3]. The 2019 Taulbee Survey [4] reveals that only 1% of the 28,884 bachelor's degrees in computing were awarded to African American women, a vastly underrepresented population in the field of computing. Recruiting more African American women to pursue computing as a career choice not only helps to address the shortage of competent employees, but also contributes towards a more inclusive culture in the field of computing.

Current efforts to recruit and retain African American women in computing emphasize mentoring in educational settings. Examples of mentorship models include faculty members of the same race and/or same gender who serve as role models in computing departments, students of color campus organizations that provide safe havens from the oftentimes toxic, White male-dominated computing culture perpetuated on so many predominantly White institutions (PWIs) or cohorts of African American students who serve as an immediate network of emotional, cultural, and academic support at both PWIs and Historically Black Colleges & Universities (HBCUs) [2], [5]–[8]. However, none of these approaches explore the sociological factor of familial influences that impact African American women's pursuit of and persistence in computing education.

Persistence, one's determination to complete required course work/curriculum to attain a degree [9], becomes a crucial predictor in women's choice of majors and careers [10]. Prior research shows African American women in computing often struggle with persistence, resulting in decreased retention in computing [11]–[13]. Although multiple factors such as hostile computing departments and workplaces, gendered racism, lack of exposure, and access to computing education contribute to the underrepresentation of African-American women, persistence is crucial to their retention in the computing pipeline[5], [13]–[15]. Although the aforementioned mentorship models have served as strategies for increasing the recruitment and retention of African American women in computing, less is known about how relationships with family members and family values can provide another level of professional and emotional support that contributes to African American women's persistence in computing. Given this dilemma, additional research is needed to develop an in-depth understanding of the lived experiences or personal journeys of African American women in computing, especially how they leverage their social capital to persist in computing.

One's ability to leverage social capital largely influences the level of success one can achieve [16]. In this paper, we examine African American women's familial relationships—an example of bonding social capital—as a first step towards understanding how African American women in computing leverage their social capital to gain greater access to career opportunities in computing, including educational preparation and professional development. Bonding social capital indicates strong social ties with African American parents, siblings, spouse, and/or extended family members (aunts, uncles, grandparents, etc.), is based on trust, and negates the lack of visibility and the feelings of discouragement and isolation experienced by some African American women in the field of computing [13], [17], [18].

Black Feminist Thought (BFT), a critical framework based upon the unique, intersectional experiences of women of African descent, positions African American women as experts of their lived experiences [19]. BFT encompasses all women of African descent (e.g., West Indian women, Afro Brazilian women, etc.) as being Black women intellectuals with a collective standpoint [19]. Consequently, in this paper, we leverage BFT as a methodology for invoking the personal experiences of 34 African American women in various stages of the computing pipeline (e.g., first-year graduate students, Ph.D. candidates, early career professionals, seasoned career professionals, assistant professor). Content analysis of the 34

978-1-5386-5541-2/18/\$31.00 \©copyright 2020 IEEE

interviews reveal that African American families do indeed play a crucial role in African American women's persistence in computing, especially when they encounter obstacles that would deter them from reaching their educational and/or career goals. Results from the data analysis reveal six effective strategies that African American family members employ to help their daughters, sisters and granddaughters prevail against the odds, thus leveraging the bonding social capital inherent in African American women's social networks.

The paper is structured as follows: First, we provide a cursory overview of BFT and the significance of social capital as a gateway to opportunities in the field of computing. Next, we provide a detailed outline of the methodology for conducting 34 semi-structured interviews, including the details for how we recruited African American women to participate in the interviews. Data analysis reveals patterns of emergent themes that surfaced in the content analysis, demonstrating a counter-narrative that shows that African American families do appreciate the wealth of opportunities available in the field of computing. Finally, we conclude with a short list of key takeaways for leveraging the bonding social capital inherent in the African American women's social networks, takeaways that can significantly contribute to their persistence in computing.

II. Review of Related Work

A. Black Feminist Epistemologies (BFEs)

Within the field of education research, a range of epistemological frameworks, theories, methodologies, and methods have emerged to understand STEM+Computing learning, but much of that work has not centered Black girls [20]. Black Feminist Epistemologies (BFEs) are which concerned with writing Black women into existence, through their lived experiences with both oppression and resilience in all aspects of society, including education systems [19]. Because Black women live at the intersection of, at a minimum, race and gender, Black women face intersectional subordination, not only in their everyday lives, but also in STEM+C contexts [21], BFEs help interpret Black girls' and women's lived experiences in computing contexts because these contexts illuminate the White supremacy, White logics, and patriarchy upon which these spaces were built historically and remain contemporarily [13]. For this work, we'll explore two such epistemologies: Intersectionality and Black Feminist Thought.

1) Intersectionality

Collins and Bilge [20] describe Intersectionality as "a way of understanding and analyzing the complexity in the world, in people, and in human experiences." Informed by Critical Race Theory [22], Intersectionality posits that social inequality in societies rarely emerges from one social division, but rather at the intersection of people's identities and the ways those identities simultaneously interact with systems of oppression [22]. Intersectionality can be leveraged as an analytic tool when the research aim is to problematize extant de-contextualized narratives related to discrimination that people experience. As a result, issues that are specific to Black women often remain unaddressed or "subordinated within racial- or gender-focused movements. Intersectionality examines how power relations are intertwined and mutually constructing"[2]. Although the term Intersectionality was coined by Kimberle Crenshaw [21],[22] and her work focused on the discrimination of Black women in the legal system, intersectional work towards social justice for women of color dates back to the 19th century [25]. Collins and Bilge point out that the organization of power in our society can be examined through four distinctive lenses, including interpersonal, disciplinary, cultural, and structural [20]. Overall, intersectional analyses provide ways to illuminate the structure of social inequality as an interlocking system of oppression for Black and other women of color. (ibid), suggesting single-axes analyses (i.e., race or gender) as insufficient.

2) Black Feminist Thought (BFT)

Black Feminist Thought (BFT) argues that women of African descent from all walks of life (the ordinary, the educated, the illiterate, the young, the old, etc.) must define their own self-worth, espouse their relationships to other Black women and speak their truth [13]. It also argues that the experience of being a Black woman cannot be understood independently in terms of being Black and of being female, since Black women experience race and gender simultaneously (ibid). *BFT* encompasses all women of African descent (African American women, West Indian women, Afro Brazilian women, Black Puerto Rican women, Haitian women, etc.) as being Black women intellectuals with a collective, distinctive, and unique standpoint that comes from living as Black women (ibid).

B. Non-Technological Influences on Black Girls and Women In computing

The parent-child dyad is significant because it is one of the most influential, relevant, and meaningful relationships in an individual's life [26]. Vygotsky introduced the idea of social interaction with parents helping kids gain knowledge and cultural practices [27]. Previous research has illustrated how families play a significant role in keeping Black girls and women's interest in STEM+C pathways [13], [28]. Additionally, previous research has illustrated the importance of faith, family, and mentorship from mentors both inside as well as outside of the field of computing in helping Black women to persist personally, academically, and professionally [13], [29]. However, more research is needed to understand these influences and their impact on Black girls and women in computing. This is particularly true if colleges, universities, and other organizations who say they are committed to diversity and inclusion in computing really want to better support Black girls and women to not just persist, but to thrive and succeed within their organizations.

C. Bonding Social Capital

Social capital becomes useful for gaining access to education/training and exploring job opportunities, thus contributing to economic growth and career development [30]–[32]. Lack of social connections can limit one's ability to attain resources to overcome obstacles or resolve problems [30], [33]. Within the field of computing, social capital represents just one of the factors that has serious implications for upward career mobility. Thus, one can expect social capital to play a pivotal role in Black women's ability to persist in computing.

Social interactions (e.g., talking on the phone, sending text messages, eating lunch with friends) occur on multiple levels and can be characterized based on frequency, quality and mode of communication. Social capital refers to how these social interactions support the sharing of information with others, engender a sense of trust (or lack thereof), and afford opportunities to help others whenever possible (reciprocity) [16],[18],[32]. Additionally, social capital relies on the value of connections between an individual and others (people, institutions, professional organizations, etc.). As such, evaluation of one's social network reveals both strong ties (bonding social capital attributed to close connections with family and friends) and weak ties (bridging social capital that connects people across lines of race, age, class, and ethnicity).

Because strong ties are typically established with close family and friends, these social connections offer emotional support and are more likely to be within a homogenous group (i.e., same race, similar age range, same class) [16],[30], [32]. In contrast, weak ties are more likely to be established with distant friends, acquaintances, or strangers [30]. Weak ties provide exposure to new people, new information, new ideas and new opportunities [17],[18],[32],[34],[35]. Cultivating both bonding and bridging ties demonstrates high social capital whereas the lack of bonding or bridging ties can contribute to low social capital [18], [34]. Though both strong and weak ties are equally important, we focus on strong ties with family members or bonding social capital.

The culture of computing has proven to be a hostile environment for women, and even more so for women of color [2], [12],[13],[36]–[38]. As such, women of color seek *counterspaces* or safe social spaces from the White male-dominated culture associated with computing, one that devalues African American women and renders them invisible[6],[12]. For example, one African American woman enrolled in a computing course revealed that she experienced fear whenever the teacher instructed students to pick a partner because her male peers were reluctant to work with her and sometimes outright rejected her [12]. African American women often described themselves as "being the only one," thus experiencing feelings of isolation [13]. These examples indicate low social capital or weak bridging ties. However, strong bonding social capital can alleviate symptoms of weak bridging ties, reaffirming African American women's sense of self-worth and determination to succeed in the field of computing. As evidence of bonding social capital, Black women credited strong relationships with their fathers as influential in increasing their self-efficacy and self-esteem, inoculating them from microaggressions they experienced from computing faculty and peers [13]. These testimonies have only begun to scratch the surface as it pertains to understanding the characteristics of the social networks of Black women in computing and the social factors that inhibit their ability navigate the computing pipeline. As such, we seek African American women in various stages of the computing pipeline, imploring them to share personal information about social networks, specifically their familial experiences in the context of navigating the "leaky" computing pipeline [6].

III. Method

A. Participants & Setting

We employed the snowball sampling method [25] to gain access to African American women in computing who were willing to share their lived experiences. Initially, four African Americna women agreed to participate in an interview. After completing the interview, each participant recommended we contact one or two African American women they knew to participate in the interviews. This helped us to recruit a total of 34 African American women in various stages of the computing pipeline. Participants' status is as follows: a) 6% (2 out of 34) assistant professors; b) 23% (8 out of 34) graduate students; and c) 71% (24 out of 34) career professionals. One co-author conducted each interview. All 34 interviewers were conducted over a period of 10 weeks.

B. Procedure

Once a participant agreed to do the interview and signed the IRB consent form, the interview was scheduled at a time convenient for the participant. Each semi-structured interview was conducted via Google Hangout for a duration of approximately 45 minutes to 1 hour. The interviewer asked a series of questions about self-identity, educational background, social support, experiences at work or during the study as African American women, the process took them reaching the current status, their motivations, and future career aspirations. Participation in this study was strictly voluntary and participants could cease participating in the interview at any time. Upon completion of the interview, each participant was asked to recommend 1-2 African American women in computing that she knew and only provide their contact information after she received their permission to be contacted by the researcher to schedule an interview. Participants received compensation for completing the interview.

C. Data collection and analysis

Each semi-structured interview was audio-recorded and transcribed for data analysis purposes. Two researchers identify themselves as African American women in computing and leverage their positions within society to conduct the qualitative analysis [39]. In the first phase of data analysis, all 34 transcripts were imported into NVivo-12. Two researchers coded a small subset of the interviews to identify an initial set of 50 unique emergent themes (i.e., *a family member suggests student change major to computer science, dad encourages participant to major in computing, etc.)* related to familial influences. Similar emergent themes were collapsed into categories and all duplicates removed to reflect 10 categories of emergent themes. These initial 10 categories served as the basis of the codebook. Then, the researchers met repeatedly to compare and discuss the identification of categories of emergent themes before resolving differences to achieve an interrater-reliability of 85%. In the third phase, the two researchers individually coded the remaining interviews. Finally, two researchers met to discuss differences and collapse similar emergent themes into six distinctive categories: *1) exposure and access to computing; 2) support for self-efficacy; 3) education as a family value; 4) resource for career guidance & advice; 5) emotional support; and 6) family members as role models.*

IV. Findings

It is critical that individuals have access to a system of support when seeking help [40]. Support for the case of women in computing comes in many different forms, including encouragement to pursue educational opportunities, assistance with employment opportunities, financial support and parental support [41]. In this study, 59% of participants (20 women) talk about their familial influences that positively influenced their ability to persist in computing. These influences include: *1) exposure and access to computing, 2) support for self-efficacy, 3) education as a* *family value, 4) resource for Career Guidance & Advice, 5) emotional support, 6) family members as role models.*

A. Exposure and access to computing

Lack of exposure to a major—through course taking and preparation before college—is one of the reasons women are underrepresented in STEM courses [42]. Therefore, it is important to facilitate ways that female students learn about computing before college. P31 says:

> "*I got interested in computing in – really like in high school. When I was younger, my parents were always putting me in engineering camps and stuff, and my dad worked in IT stuff."*

P31 highlights the important role of African American parents in exposing their children to computing education and providing access to pre-college opportunities such as after-school classes, extracurricular activities, and summer camps.

Further exposure can be facilitated by encouraging African American girls to "look under the hood" to learn how technological devices work or to repair them [41]. Brickhouse and Potter discuss how they found a relation between being successful in computing and being exposed to masculine culture of computing by a father of African American girl that they studied [43]. P 30 says:

> *"I – it started when I was like six, seven. My dad gave me my first laptop. (laughs) It had no internet, so I had to find other things to make it interesting... I started learning how to replace the screens, and then it was said and done from then on."*

Her father's decision for giving her a laptop led her to explore the hardware and learn how to repair the laptop screen. These hands-on experiences made her pursuing a degree and ultimately a career in computing. Although early exposure can make students to learn more about the computing and join the formal education, we learned "never is too late" to join computing. P27 was an architect which joined computing after she was exposed to computing with her brother's work. She says:

> *"My brother is actually in computer science…I was uninformed about what computer science was. So he was doing a lot of side projects on nights and weekends, and he was like, hey, I don't know how to build web applications, could you help me out, you know, you could use some of the design skills that you've picked up from just your years in architecture and doing a lot of graphic presentation, and I was like, sure, you know, I'll sit down and figure it out."*

B. Support for self-efficacy

Self-efficacy is defined as an individual's belief that s/he can successfully execute a task or behavior for producing a specific outcome [44]. Although self-efficacy is addressed as an intrinsic motivation for success and persistence in study and work [9], [44] close ties with family members and friends can increase one's self-efficacy. In the study of career development of African American women, Pearson and Bieschke found verbal persuasion, receiving encouragement and support from family increased African American women's self-efficacy [45]. Participant 29 confirms this behavior:

> *"I have my family, whose response is just like, you can do it, you can do it. I'm just like, yeah, you all say that but you all are…I can't really do; it's not as simple as it sounds. Like, I hear you all, but no, it's not that simple. (laughs) But I have a good – I do have a good support system."*

Though the participant was doubtful about her ability to persevere, her family expressed confidence in her ability to do the work and bolstering her self-efficacy. Consequently, she graduated with a graduate degree in CS and was hired as a computing professional in one of the government agencies.

In another example, P14 talked about how her family encouraged her to overcome the challenges she faced as a graduate student at a PWI.

"I also think, you know, having family support, so your family, just being able to encourage you even when, you know, you feel like you're not doing good, and their support was really helpful...Having a good – a family that is there for you and very supportive."

Graduate school is not an easy endeavor for most students, regardless of race or gender. Going through this process is what caused these African American women to question their ability to succeed. However, both women apply family affirmations as a strategy for enhancement of their self-efficacy and to overcome the challenges associated with graduate school.

C. Education as a family value

Family expectations can influence on African American women education. Parents' focus on the importance of education from the early ages, drives students to perform better and persist in the college [46]. African American families who are interested to send their children to college and need their children to be persistent need to establish some expectations of obtaining postsecondary education from the early ages [46]. We also see the same pattern in case of our participants. Like P2 says:

> *"When I was younger, my dad always encouraged us to concentrate on our education, everything else is a distraction, that kind of thing, and me and all my siblings have kind of attributed our life to that, essentially...my dad kind of imprinted that on us when – from the time we were kids until we were adults."*

In a study of career development of African American women, the authors found: the most salient value that family emphasized was *education* within the familial unit [45] which in our investigation also stand out. P33 states:

> *"My sister has her master's, and like my mom just pushes education a lot…education is really important to our family."*

Additionally, P26 says:

"Well, education is, like, really important in my family, so it was kind of an unsaid thing that everyone kind of goes to grad school."

These testimonies exemplify how parents and siblings espouse a higher education, thus encouraging African American women to progress further down the computing pipeline. For some African American families, there is the expectation that their daughters or sisters will attain an advanced degree in their respected fields.

D. Resource for Career Guidance & Advice

Family members play a significant role in helping students to choose the right major for their undergraduate degree [47]. African American adolescents choose careers that are more inclined with their parents' desires and are more engaged with collective career decision making [48]. In this study, some participants involve their parents in the process of choosing a major. For example, P30 says:

"I was talking to my dad and he was like, well, you always liked taking apart computers. Why don't you try that, and I was like, okay, you know, and as soon as I started I realized how much I loved it, and how I could pursue my kind of creative problem-solving skills to change and alter technology and create programs and stuff"

In the case of P17, she says:

"My dad... comes to me and he tells me – it's like my senior year in high school and he's like, yeah, you know, this is the number one paying job in the US right now. So he gives me this newspaper article and it's this – it's a white woman who is a system programmer, and she – they did this article on her and how she was in like the top job in the country at the time. And they said that she majored in computer science (laughs)".

This particular woman seeks guidance from her father, whom she trusts to provide good advice. Her father suggests computer science as a major because he is intimately acquainted with his daughter's interests. Consequently, she selects computer science as her major, and the rest is her story.

In some cases, individuals may initially choose one major before realizing that they do not like that major. In this instance, familial relationships serve as a reliable resource to guide African American women through the process of finding the best fit between self-interests and choice of major. P1 shares her mother's influence in changing her major:

"When I was younger. I always wanted to be a doctor. And then I took a biology class and I was like, yeah, this is not really for me. And so my mom suggested I try out computer science because she could tell just based off of like my analytical skills and just like how I liked being on the computer and stuff that I would like doing that more. And so when I went to Spelman, I tried it out and I really liked the classes then so I just stuck with it. So (laughs) I ended up doing it."

Family can be a source for important information about work [45], especially when African American women are working as professionals in the tech industry. For example, P7 admits that she seeks her mother's advice about work issues:

"...my mom didn't have a person in a similar situation to get advice from or to get feedback from and she moved on in her professional career, so it's a major benefit to me to have somebody that has been in my shoes before and navigated around in a male-dominated society and been able to excel. So it's nice to have somebody that's in a similar place that I can bounce ideas off of and just communicate with on a regular basis."

For this participant, her mother represents as a successful African American woman in the tech industry who has firsthand experience dealing with and overcoming the challenges that African-American women face in male-dominated occupations. She is comfortable going to her mother for career advice which helps her to excel as a computing professional.

In terms of recruitment efforts, African American women may not enter the computing pipeline using traditional pathways (e.g., bachelor's degree in Information Technology), but are contemplating a much-desired career change. Sibling relationships can motivate African American women to consider computing as a viable career option. P27 talks about how her brother encouraged her to make a career switch:

"My brother is also in computer science… and he was like, hey, I don't know how to build web applications, could you help me out, , you could use some of the design skills that you've picked up from just your years in architecture and doing a lot of graphic presentation, and I was like, sure…, I'll figure it out. So, what I realized very quickly was that I – you know, my skills are mostly for print and the web is a totally different game. So, I had to start looking around to figure out how do I learn how to translate those skills from print to web."

Though P27 did not possess a bachelor's degree in computing, she transferred her architectural skills to the context of web design before eventually completing a computing boot camp and securing a position in industry.

E. Emotional support

Emotional support is an important factor which positively impact on students' success in college[46]. Family members serve as the primary source of emotional support in the lives of African American college students, specifically mothers who provide encouragement and reassurance [46], [49]. P3 shares that her parents offered her emotional support when she started college:

"They were huge in terms of emotional support because I mean I felt like I was ready but it was still some emotional things that were going on. (laughs) It was a big culture shock and everything else."

P12 talked about her spouse's emotional support.

"My husband … you know, the people that were in my outside academic space were also very important emotionally. And so you need to have that … space where you can go and kind of, you know…let you push real hard and help you get over the bumps and the bruises and stuff and so I think without that, a lot of people will struggle."

For this particular interviewee, her husband was instrument in her ability to attain her doctoral degree. This suggests that, for married African American women in computing, spouses can play an important role in their ability to persist in the computing pipeline. This is in agreement with Mc Gee et al.'s finding about the important role of significant others for motivating African American PhD students to complete their engineering doctoral degrees [50].

F. Family members as role models

1) Role models external to the field of computing

Families can be count as a source of inspiration and instill values that are critical for success in people's life. Therefore, mothers and other family members can be seen as role models and the source of inspiration in Black women's life. Basow and Howe [36] define role model as someone who influence student's life in their career choice. Role models may play more important role in women's life who are from the minority groups comparing to their male counterparts because this influence their self-efficacy indirectly[51].

P4 talks about how her mother was an inspiration for her in terms of being a hard worker. she states:

"From my mother, I've always learned to be a hard worker. My mother is also Afro-Latina. She grew up there in a tiny village like seven hours away from like the nearest town or city. And her story of how she got to America, how she got her bachelor's degree, how she became one of the most successful employee of... for the state of Texas, like her story makes me cry every time I tell it. And she's just my biggest inspiration in the world."

The narrative P4's mother of being strong and successful through difficulties in life pictured her as a source of inspiration and helped her to be persistent in her life.

"But from her, I've learned how to work hard and what preparation means, and taking the opportunities that come to me. I'm so grateful to both of my parents for the lessons that they taught me. I've had so many opportunities because of them. But you can have all the opportunities in the world and still miss, still not be successful if you don't work hard. And so the lessons that my mother instilled in me and the inspiration and the example that she set has always encouraged me to work hard and build upon everything that she's created. So when I think about any success, I have to thank my mom."

2) Family members who are computing professionals

One of the participants sees herself as an inspiration for her younger sister, as she joined CS recently.

"I have a little sister who really, really looks up to me. She's starting computer science at XXX this year, so this is her first year of undergrad. She's starting computer science there, and I know like she really mitigates me. I know that there are so many people who depend on me and I just don't want to let anybody down, and I know that like I'm not just doing this for me. Like I'm doing this for me. I'm doing this for my family."

V. Discussion – Recommendations for the Field

These African American women's lived experiences provide a counter-narrative to the misperceptions that African American families are totally oblivious to the career opportunities available in the field of computing. It is in contrast with the idea that African American families do not value computing as a viable career option, nor do they encourage their children to acquire 21st-century computing skills. This exploratory study demonstrates that the African American community has become more astute about the economic benefits attributed to computing professionals and seek educational opportunities that give their children early exposure and access to computing resources (i.e., attending summer camps where children learn how to code) [52], [53],[54]. Similar to Ellison et al.'s criticism of scholarly research that depicts African Americans as being apathetic about technology in this growing global economy, we caution those whose goal is to broaden participation in computing to seek authenticity in their research methodology [55]. Rather than relying solely on numerical data, researchers need to empower the voices of marginalized populations to capture the nuances of socio-cultural norms that are often misinterpreted by the dominant culture [20],[22]. These interviews reveal a different perspective of African American families, one that shows that their hopes and dreams for their children are the same as most parents – for their daughters or sisters to be successful and happy human beings. This is counter-narrative to prior work which portrays African American culture as being non-supportive of computing[56]. As such, the African American women in this study have strong bonding capital with parents and siblings who value computing. Consequently, they successfully navigate the computing ecosystem, turning to family members during challenging times or to get a second opinion about a professional dilemma.

While prior efforts [57] have been utilized to recruit and retain African American women in computing, such efforts, more or less, have emphasized the development of students' computational skills. We are not critical of these efforts as they have proven to be beneficial. However, a more holistic approach is required if the field of computing is to be more inclusive. Our recommendation is to apply a community-based approach to recruiting efforts for grades K-12 since this approach would engage African American parents and children. For example, a tech-based company (or research lab) could partner with teachers and parents of a local high school, collecting survey responses about the kinds of games the parents played when they were younger and the kinds of games their children currently play. Then, the tech-based company could sponsor a game night at a local high school, invite parents and students, and hold a competition for the best parent-child gaming team after playing a series of "old school" and current games. Later during the school year, the organization could moderate a panel about opportunities in gaming and so forth. The point is that such an approach demonstrates an appreciation for the active role that African American parents play in their children's education, including helping them to figure out which college to attend, which major to choose, and what career opportunities are available to them. In addition, it also creates an opportunity for African Americans to build and strengthen their bridging ties, those social connections that cut across race, gender, class, and age. It is the combination of strong and bridging bonding capital that will make a noticeable difference in increasing the recruitment and retention of African American women in the field of computing.

Of course, given the small sample size of African American women who participated in these interviews, we dare not infer that what is true for this specific population of African American women holds true for all African American women. Just a BFT espouses a collective standpoint, it also supports divergent experiences [19]. This brings us to the second recommendation for the field—to conduct more authentic research of African American women (and other women of color) in computing, research that chronicles their successes and failures, the sociological factors that impact their ability to remain in the field, or in some cases, contribute to them deciding to leave the field. Without studying why some African American have left the field, we miss the opportunity to fix what is broken. This is why this particular paper only represents a first step towards understanding the significance of familial influences in the lives of African American women in computing. As an evolving discipline, the field of computing still has a long way to go to achieve diversity, inclusion and equity.

VI. Conclusion

Results from this study reveal that family members play a pivotal role in the persistence of African American women in computing. Parents become mentors who offer career advice to help their daughters succeed in male-dominated workplaces. They function as role-models and a source of inspiration for getting through tough times. Siblings who are computing professionals encourage their sisters to contemplate a career change, pushing them to take the risk of starting over the field of computing. African American family members stress the value of education from early ages and expect their children to go to college and even graduate school, providing both emotional and social support. The combination of these familial influences serves as positive mechanisms for countering factors that negatively impact African American women's ability to persist in computing.

References

[1] S. Beyer, K. Rynes, J. Perrault, K. Hay, and S. Haller, "Gender differences in computer science students," *ACM SIGCSE Bull.*, vol. 35, no. 1, pp. 49–53, 2003.

[2] L. J. Charleston, P. L. George, J. F. L. Jackson, J. Berhanu, and M. H. Amechi, "Navigating underrepresented STEM spaces: Experiences of Black women in U.S. computing science higher education programs who actualize success.," *J. Divers. High. Educ.*, vol. 7, no. 3, p. 166, 2014.

[3] J. D. Burge and T. L. Suarez, "Preliminary analysis of factors affecting women and African Americans in the computing sciences," in *2005 Richard Tapia Celebration of Diversity in Computing Conference*, 2005, pp. 53–56.

[4] S. Zweben and B. Bizot, "2017 CRA Taulbee Survey," *Comput. Res. News*, vol. 30, no. 5, pp. 1–47, 2018.

[5] S. Cheryan, J. O. Siy, M. Vichayapai, B. J. Drury, and S. Kim, "Do female and male role models who embody STEM stereotypes hinder women's anticipated success in STEM?," *Soc. Psychol. Personal. Sci.*, vol. 2, no. 6, pp. 656–664, Nov. 2011.

[6] P. Garcia and K. Scott, "Traversing a political pipeline: An intersectional and social constructionist approach toward technology education for girls of color," *Interact. UCLA J. Educ. Inf. Stud.*, vol. 12, no. 2, 2016.

[7] J. F. Jackson, L. J. Charleston, J. E. Gilbert, and C. Seals, "Changing Attitudes About Computing Science at Historically Black Colleges and Universities: Benefits of an Intervention Program Designed for Undergraduates," *J. Afr. Am. Stud.*, vol. 17, no. 2, pp. 162–173, 2013.

[8] "iAAMCS Releases Guidelines for Successfully Mentoring Black/African-American Computing Sciences Doctoral Students," *Computing Research Association Bulletin*, 18-Sep-2018. [Online].

[9] M. B. Kinzie, M. A. Delcourt, and S. M. Powers, "Computer technologies: Attitudes and self-efficacy across undergraduate disciplines," *Res. High. Educ.*, vol. 35, no. 6, pp. 745–768, 1994.

[10] G. Hackett, "Role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis.," *J. Couns. Psychol.*, vol. 32, no. 1, p. 47, 1985.

[11] L. T. Ko, R. R. Kachchaf, M. Ong, and A. K. Hodari, "Narratives of the double bind: Intersectionality in life stories of women of color in physics, astrophysics and astronomy," presented at the 2012 Physics Education Research Conference, Philadelphia, PA, USA, 2013, pp. 222–225.

[12] M. Ong, J. M. Smith, and L. T. Ko, "Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success," *J. Res. Sci. Teach.*, vol. 55, no. 2, pp. 206–245, 2018.

[13] J. O. Thomas, N. Joseph, A. Williams, and C. Crum, "Speaking Truth to Power: Exploring the Intersectional Experiences of Black Women in Computing," *IEEE 2018*, pp. 8–16, 2018.

[14] J. M. Blaney, "Looking beyond representation: How women develop their leadership perceptions during the introductory computing course," in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education - SIGCSE '18*, Baltimore, Maryland, USA, 2018, pp. 453–458, doi: 10.1145/3159450.3159458.

[15] A. Solomon, D. Moon, A. Roberts, and J. E. Gilbert, "Not Just Black and Not Just a Woman: Black Women Belonging in Computing," in *2018 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*, 2018, pp. 1–5, doi: 10.1109/RESPECT.2018.8491700.

[16] M. Woolcock, "Social capital and economic development: Toward a theoretical synthesis and policy framework," *Theory Soc.*, vol. 27, no. 2, pp. 151–208, 1998.

[17] R. D. Putnam, *Bowling alone: The collapse and revival of American community*. Simon and schuster, 2000.

[18] B. Wellman and S. Wortley, "Different strokes from different folks: Community ties and social support," *Am. J. Sociol.*, vol. 96, no. 3, pp. 558–588, 1990.

[19] P. H. Collins, "Gender, black feminism, and black political economy," *Ann. Am. Acad. Pol. Soc. Sci.*, vol. 568, no. 1, pp. 41–53, 2000.

[20] J. O. Thomas, Y. Rankin, and Q. Saunders, "Exploring Collaborative Talk Among African-American Middle-School Girls in the Context of Game Design for Social Change," *J. Comput. Sci. Coll.*, p. 80, 2019.

[21] E. O. McGee and L. Bentley, "The troubled success of Black women in STEM," *Cogn. Instr.*, vol. 35, no. 4, pp. 265–289, 2017.

[22] A. P. Harris, K. Crenshaw, N. Gotanda, G. Peller, and K. Thomas, "Critical race theory," *Int. Encycl. Soc. Behav. Sci.*, 2012.

[23] K. Crenshaw, "Mapping the Margins: Intersectionality, Identity Politics, and Violence against Women of Color," *Stanford Law Rev.*, no. 6, pp. 1241–1300,1990.

[24] K. Crenshaw, N. Gotanda, G. Peller, and K. Thomas, *Critical Race Theory: The key writings that formed the movement*. New York: The New Press, 1996.

[25] P. H. Collins and S. Bilge, *Intersectionality (Key Concepts)*. UK: Polity.: Cambridge, 2016.

[26] H. K. Horstman, A. Hays, and R. Maliski, "Parent–Child Interaction," in *Oxford Research Encyclopedia of Communication*, 2016.

[27] L. S. Vygotsky, *Mind and society: The development of higher mental processes.* Cambridge, MA: Harvard University Press, 1978.

[28] V. J. Rideout, K. A. Scott, and D. K. A. Clark, "The digital lives of African American tweens, teens, and parents: Innovating and learning with technology," Bill and Melinda Gates foundation, 2016.

[29] S. L. Gregory, "African American Female Engineering Students' Persistence in Stereotype-threatening Environments: A Critical Race Theory Perspective," 2015.

[30] T. R. Dillahunt, "Fostering social capital in economically distressed communities," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2014, pp. 531–540.

[31] F. Fukuyama, "Social capital and the global economy," *Foreign Aff*, vol. 74, p. 89, 1995.

[32] M. S. Granovetter, "The strength of weak ties," *Univ. J. Sociol.*, pp. 347–367, 1973.

[33] S. L. Erete, "Community, group and individual: A framework for designing community technologies," *J. Community Inform.*, vol. 10, no. 1, pp. 1–13, 2013.

[34] A. L. Kavanaugh, D. D. Reese, J. M. Carroll, and M. B. Rosson, "Weak ties in networked communities," *Inf. Soc.*, vol. 21, no. 2, pp. 119–131, 2005.

[35] P. Resnick, "Beyond bowling together: Sociotechnical capital," in *HCI in the New Millennium*, vol. 77, 2002, pp. 247–272.

[36] L. J. Charleston, "A qualitative investigation of African Americans' decision to pursue computing science degrees: Implications for cultivating career choice and aspiration.," *J. Divers. High. Educ.*, vol. 5, no. 4, p. 222, 2012.

[37] S. Cheryan, S. A. Ziegler, A. K. Montoya, and L. Jiang, "Why are some STEM fields more gender balanced than others?," *Psychol. Bull.*, vol. 143, no. 1, pp. 1–35, Jan. 2017, doi: 10.1037/bul0000052.

[38] A. K. Hodari, M. Ong, L. T. Ko, and R. R. Kachchaf, "New enactments of mentoring and activism: US women of color in computing education and careers," in *Proceedings of the tenth annual conference on International computing education research*, 2014, pp. 83–90.

[39] P. H. Collins, *Black feminist thought: Knowledge, consciousness, and the politics of empowerment*. Routledge, 2002.

[40] C. J. Wilson, F. P. Deane, J. V. Ciarrochi, and D. Rickwood, "Measuring help seeking intentions: Properties of the General Help seeking Questionnaire," 2005.

[41] L. J. Charleston, "A qualitative investigation of African Americans' decision to pursue computing science degrees: Implications for cultivating career choice and aspiration.," *J. Divers. High. Educ.*, vol. 5, no. 4, p. 222, 2012, doi: 10.1037/a0028918.

[42] C. A. Shapiro and L. J. Sax, "Major selection and persistence for women in STEM," *New Dir. Institutional Res.*, vol. 2011, no. 152, pp. 5–18, 2011.

[43] N. W. Brickhouse and J. T. Potter, "Young women's scientific identity formation in an urban context," *J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach.*, vol. 38, no. 8, pp. 965–980, 2001.

[44] A. Bandura, "Self-efficacy: toward a unifying theory of behavioral change.," *Psychol. Rev.*, vol. 84, no. 2, p. 191, 1977.

[45] S. M. Pearson and K. J. Bieschke, "Succeeding against the odds: An examination of familial influences on the career development of professional African American women.," *J. Couns. Psychol.*, vol. 48, no. 3, p. 301, 2001.

[46] M. K. Herndon and J. L. Moore III, "African-American factors for student success: Implications for families and counselors," *Fam. J.*, vol. 10, no. 3, pp. 322–327, Jul. 2002, doi: 10.1177/10680702010003009.

[47] Y. Ma, "Family Socioeconomic Status, Parental Involvement, and College Major Choices—Gender, Race/Ethnic, and Nativity Patterns," *Sociol. Perspect.*, vol. 52, no. 2, pp. 211–234, Jun. 2009.

[48] J. M. Dillard and N. J. Campbell, "Influences of Puerto Rican, Black, and Anglo parents' career behavior on their adolescent children's career development.," *Vocat. Guid. Q.*, 1981.

[49] J. H. Valery, P. O'Connor, and S. Jennings, "The nature and amount of support college-age adolescents request and receive from parents," *Adolescence*, vol. 32, no. 126, pp. 323–37, 1997.

[50] E. O. McGee *et al.*, "Black engineering students' motivation for PhD attainment: Passion plus purpose," *J. Multicult. Educ.*, vol. 10, no. 2, pp. 167–193, 2016.

[51] J. L. Quimby and A. M. De Santis, "The Influence of Role Models on Women's Career Choices," *Career Dev. Q.*, vol. 54, no. 4, pp. 297–306, Jun. 2006.

[52] C. M. Gardner and J. L. Kolodner, "Turning on minds with computers in the kitchen: Supporting group reflection in the midst of engaging in hands-on activities," in *Proceedings of the 8th iternational conference on Computer supported collaborative learning*, 2007, pp. 212–221.

[53] S. Erete, C. K. Martin, and N. Pinkard, "Digital youth divas: A program model for increasing knowledge, confidence, and perceptions of fit in STEM amongst Black and Brown middle school girls," in *Moving students of color from consumers to producers of technology*, IGI Global, 2017, pp. 152–173.

[54] J. O. Thomas, Y. Rankin, R. Minor, and L. Sun, "Exploring the difficulties African-American middle school girls face enacting computational algorithmic thinking over three years while designing games for social change," *Comput. Support. Coop. Work CSCW*, vol. 26, no. 4–6, pp. 389–421, 2017.

[55] T. Ellison, "The matter of parents' stories: Urban African American mothers' counter-stories about the common core state standards and quality teaching," *Urban Educion.*, vol. 54, no. 10, pp. 1431–1461, 2017.

[56] B. DiSalvo *et al.*, "African American men constructing computing identity," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011, pp. 2967–2970.

[57] K. Hulick, *Kimberly Bryant: Founder of Black Girls Code*. Cavendish Square Publishing, LLC, 2017.

What Makes a "Computer Science Person"? Minoritized Students' Sense of Identity in AP CSP Classrooms

Jean J. Ryoo
UCLA
Los Angeles, CA, USA
jeanryoo@ucla.edu

Kendrake Tsui
UCLA
Los Angeles, CA, USA
tsui.kendrake@gmail.com

***Abstract*—The CS for All Movement is making great strides toward increasing access to quality computer science (CS) education, particularly for minoritized youth from communities historically underrepresented in computing fields. However, it can be both mentally and emotionally challenging to enter fields of expertise where people do not look like you, and where your culture and experiences are seen as foreign or "different." If we want to see students engaging with computing in their varying academic/career pathways, they must feel a sense of belonging and "rightful presence" in computing classrooms [1]. In an effort to prioritize students' voices and ideas about what matters most for their sense of belonging in CS, this study administered end-of-year surveys to 860 students across Advanced Placement Computer Science Principles classrooms in a large west coast urban school district serving majority low-income students of color. This study describes students' levels of engagement with CS, whether or not they identify as "computer science people," and the factors impacting their sense of belonging with the field. These findings will be important to consider when shaping both curricula and professional development opportunities geared at broadening participation in computing, by informing ways to support students' sense of belonging and engagement with computing.**

Keywords—Equity, K-12 education, Advanced Placement Computer Science Principles, Identity, Student Engagement

I. Introduction

The Computer Science for All Movement seeks to ensure that all students have access to high-quality, rigorous, and engaging computer science (CS) education. A focus on equity guides this effort, as parents, educators, researchers, administrators, and policymakers challenge the ways youth have had differential access to computing education based on race/ethnicity, gender, and socioeconomic status [2]. There is also a desire to diversify our highly segregated CS workforce: in 2018, only 26% of the U.S.'s computing workforce was female, and of those women only 6% were Asian American, 3% African American, and 2% Latina [3]. Projecting forward in the U.S., there will be more computing jobs available than there will be Americans qualified to fill those positions [4]. And as the U.S. demographically moves toward becoming a majority-minority country, it would be problematic if the CS workforce creating the technological innovations impacting all our lives continues to represent only White and certain Asian males. As others have argued, diversity in the CS workforce is needed to not only ensure that innovations have equal positive impact across our diverse communities, but also so that a greater variety of solutions are shared to solve the future problems we cannot currently foresee [for example, 5, 6].

Of course, this CS for All Movement is fueled by more than a desire to prepare minoritized youth, who have been historically underrepresented in computing, for participating in the CS workforce. CS is valuable for all students to learn because of its potential to shape the futures of all fields. For many, there is a hope that youth can be instilled with an appreciation for computing and its problem-solving practices because it can inform the thinking and work students do across all areas of interest. Equity at the heart of the CS for All movement does not mean simply creating future computer scientists, but supporting all youth to be our communities' future innovators and problem-solvers in any personal pathway.

Yet if we want to see students either pursuing CS or engaging computing in their own academic/career pathways, great shifts must happen in students' sense of belonging and identity with computing beyond simply having access to learning CS. It can be mentally and emotionally challenging to enter a world where people do not look like you or where you do not feel like you "fit in." This is especially true in STEM and CS classrooms where, historically, minoritized youth's expertise and knowledge have been positioned as "different" and unwelcome while Eurocentric views of the world have been upheld as "correct" [7]. In such contexts, youth are often denied "rightful presence," or "legitimate and legitimized membership in a classroom community because of who one is (not who one should be), where practices of that community support re-structuring power dynamics towards more just ends through making both injustice and social change visible" [1, p. 5-8].

In an effort to learn directly from youth about what it takes to feel a sense of "rightful presence" toward engaging and identifying with computing, this paper will explore how high school students—enrolled in Advanced Placement Computer Science Principles (AP CSP) across a large west coast district—articulate what it means to be "computer science people." Through the perspectives and words of high school students coming from communities historically underrepresented in CS, this paper shares what impacts their interest with computing, and how they do or do not identify with the field.

We believe it is particularly important to hear from AP CSP contexts, because the number of historically underrepresented students enrolling in AP CSP (i.e., students of color, young

This work was funded by the National Science Foundation (1743336) and Bill & Melinda Gates Foundation (81652).

women, etc.) have been steadily increasing since the launch of the course in 2016-17. More specifically, in the state of California in 2018, for example, the percentage of girls enrolled in AP CSP was higher than in either introductory CS courses or AP CSA [8]. And while Latinx students are still under-represented in AP CSP compared to their enrollment in public schools, they are participating in AP CSP at higher percentages than AP CSA [8]. There are no differences in passing rates between male and female students on the AP CSP exam, however more than 75% of White and Asian students pass the exam, compared to only 40% Latinx and 39% Black students [8]. While increasing enrollment of students of color is promising for AP CSP contexts, we still have much to learn from the students' perspectives about their own sense of engagement and identity with computing when deciding to take and persist through the course. As such, this paper seeks to answer the following research questions:

1) To what degree do minoritized youth feel engaged with computing in AP CSP classrooms, and how does this compare to their sense of belonging in the field of CS?

a) Do minoritized youth coming from communities historically underrepresented in CS feel that they are, or can be "computer science people"?

b) What characteristics/features of "computer science people" do minoritized youth believe they can or cannot identify with?

Our exploration of student engagement and belonging is informed by research revealing how high school students often have misconceptions about what CS involves, and therefore choose not to pursue computing [9], but that after taking introductory CS courses such as Exploring Computer Science, they would recommend CS to friends because of its value to their futures and ability to achieve personal college/career goals [10]. Also, students' motivation to pursue computing is particularly influenced by the encouragement they receive, especially for women and people of color [11]. Such research serves as a diving board into our exploration of how youth in this study described their own relationship to the field of CS.

II. Methods

A. Student Surveys and School District Context

Student surveys were administered online to 861 AP CSP students after completion of the AP CSP exam during the 2018-19 school year in a large urban school district on US's west coast. This district is 73.5% Latinx, 10.5% White, 8.2% Black, 4.2% Asian, and ~80% of students receive free/reduced lunch.

Surveys built upon validated questions created by the Outlier's project surveying high school CS students [12], Haynie and Packman's surveys for AP CSP students [13], and the BRAID initiative's surveys for college CS students [14]. CS teachers and students from the district tested and provided feedback on the questions prior to administration. The survey covered background information (grade level, prior CS experience, etc.), self-rated knowledge level of AP CSP curricular topics, degree of CS interest, CS identification and belonging, beliefs about whether CS ability is innate or learned, CS alignment with educational and career goals, ideas for using CS in the world, and demographic information. We sought to understand students' end-of-year perceptions of CS, while also trying to surface their voices about what matters most for their engagement, identity, and agency with computing. Likert-scale questions were rated on a 0-10 scale, where 0 corresponded with "strongly disagree," 5 corresponded with "neither agree nor disagree," and 10 corresponded with "strongly agree."

We analyzed all likert-scale questions using SPSS. Answers were separated by respondent's race/ethnicity and gender. Racial/ethnic groups were all-inclusive, meaning if students were mixed-race, we counted those students in all the groups that they identified as. For example, an Asian-Latinx student's answers counted in both the Asian and Latinx group analyses. We believe this was important to ensure that students were represented as they chose to be identified, rather than making assumptions about their primary race/ethnicity. In likert-scale analyses, responses of groups whose total numbers were less than 30 people were not included to prevent potentially skewing statistical analyses (specifically: non-binary/non-conforming, Indian/South Asian, Middle Eastern, and American Indian students). Students who did not mark a race/ethnicity or gender identity were also excluded from likert-scale analyses.

Within each ethnic/racial group, we conducted independent two-sample t-tests to determine the statistical significance between male vs. female responses. We also explored the degree to which males vs. females varied around mean responses (by calculating the coefficient of variation), to ensure that p-values were not impacted by variance around the mean; there was little to no difference in the variation from the mean for males vs. females in the different groups for each question. Finally, we conducted an analysis of variance (ANOVA) to compare differences in responses between racial/ethnic groups.

For open-ended questions, we used MaxQDA to analyze students' explanations for why or why not they considered themselves "computer science people." This was conducted through two rounds of coding. The first round of coding surfaced specific codes that fell into larger themes. For example, codes such as "likes computer science," "likes programming," and "likes technology" fell under the larger theme of "likes CS/technology." This first round of coding helped identify potential "outliers" among students' responses that did not fall under clear categories. In the second round of coding, we looked more closely within categories to identify shared meaning across answers, as well as which responses carried nuance that required further investigation. In particular, close attention was paid to responses in which students used words such as "but" or "however" that signified ways youth wanted to express their engagement with CS despite not identifying as CS people.

III. Findings

A. Engagement with Computing – Overall Positive Ratings

By the end of the 2019-20 school year, **students from all racial/ethnic and gender groups had positive views of CS** according to mean likert scores across statements such as "I like computer science" or "I think computer science is interesting." ANOVA analyses of responses related to engagement/interest with computing showed **no statistically significant differences**

based on race/ethnicity. However, there were statistically significant differences between females/males within racial/ethnic groups regarding degree of engagement.

For example, while all student groups agreed with the statement "I like computer science," Asian males agreed most (8.16 out of 10), with a statistically significant difference from Asian females (6.97; p-value = 0.001). Latino males also rated this statistically significantly higher than Latina females (7.82 vs. 6.36, p-value < 0.001). There was no statistically significant difference in rating between males and females in other racial/ethnic groups (Blacks: 7.14 vs. 7.38; Whites: 7.69 vs. 6.79, males vs. females respectively). It is important to understand that while there were differences along gender lines, average ratings were "agree" to "strongly agree" for all groups to the statement "I like computer science." See Table I below.

TABLE I. STUDENTS AGREE THAT THEY LIKE COMPUTER SCIENCE

Race / Ethnicity	"I like computer science."		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 199) Female (n = 176)	7.82 6.64	< 0.001
Asian	Male (n = 63) Female (n = 39)	8.16 6.97	0.001
White	Male (n = 71) Female (n = 34)	7.69 6.79	0.066
Black	Male (n = 28) Female (n = 21)	7.14 7.38	0.719

For the statement, "I think computer science is interesting," again, all students, on average, agreed. However, Asian males rated this statistically significantly higher than Asian females (8.43 vs. 7.15, p-value = 0.001), Latino males rated this statistically significantly higher than Latina females (8.15 vs. 6.14, p-value < 0.000), and White males rated this statistically significantly higher than White females (8.11 vs 6.15, p-value = 0.007). Latino and White males rated this question similarly to one another, challenging the notion that Latinx students are not as interested in CS as White students. There was no statistically significant difference between Black male and female students (males: 7.18 vs. females: 8.05), although Black females agreed more to this statement than Black males. See Table II below.

TABLE II. STUDENTS FIND COMPUTER SCIENCE INTERESTING

Race / Ethnicity	"I think computer science is interesting."		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 199) Female (n = 175)	8.15 6.86	< 0.001
Asian	Male (n = 63) Female (n = 39)	8.43 7.15	0.001
White	Male (n = 71) Female (n = 34)	8.11 6.85	0.007
Black	Male (n = 28) Female (n = 21)	7.18 8.05	0.220

For another engagement statement, "I am interested in learning more computer science either on my own or in school," similar trends persisted: Asian, Latino, and White males all rated this statistically significantly higher than their female counterparts (males vs. females respectively: Asian: 7.70 vs 6.10, p-value = 0.001; Latinx: 7.16 vs 5.22; p-value < 0.000; White: 6.68 vs. 5.29, p-value = 0.030). Importantly, Latina and White females rated this more neutral than agree. Latino males agreed more with this statement than White males, although there was no statistical significance in difference. There was no statistical significance in difference between Black male and female responses (5.79 vs. 6.48), but females did rate this higher than males. See Table III below.

TABLE III. STUDENT DESIRE TO LEARN MORE COMPUTER SCIENCE

Race / Ethnicity	"I am interested in learning more computer science either on my own or in school."		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 199) Female (n = 174)	7.16 5.22	< 0.001
Asian	Male (n = 63) Female (n = 39)	7.75 6.10	0.001
White	Male (n = 71) Female (n = 34)	6.54 5.62	0.123
Black	Male (n = 28) Female (n = 21)	6.37 6.76	0.650

B. *Belonging in the Field of CS –Males vs. Females*

Students also rated agreement/disagreement to a series of statements related to sense of belonging in the field. Students were asked to consider whether they felt that people with their same racial/ethnic background or gender did CS, whether they felt they could become computer scientists, and whether they thought they would be accepted in the field if they chose to pursue it. There were statistically significant differences in opinion between males and females across all racial/ethnic groups, but ANOVA analyses revealed statistically significant differences for only one statement (between Latinx and Whites).

All student groups agreed that people of their race/ethnicity did CS. However, Asian females rated this statistically significantly lower than Asian males (females 6.76 vs. males 7.70, p-value = 0.045). This statement resulted in the only statistically significant difference between racial/ethnic groups using ANOVA analyses, with Latinx students agreeing with this statement slightly less than White students (p-value = 0.006). See Table IV below.

TABLE IV. PERCEPTIONS OF RACE/ETHNICITY IN COMPUTER SCIENCE

Race / Ethnicity	People with my same racial/ethnic background do computer science.		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 190) Female (n = 166)	6.52 6.24	0.383
Asian	Male (n = 61) Female (n = 37)	7.70 6.76	0.045
White	Male (n = 71) Female (n = 32)	7.66 7.16	0.398
Black	Male (n = 26) Female (n = 20)	6.31 6.50	0.834

Answers were more varied to the statement that people of one's own gender do CS (Table V below). Both male and female Latinx students agreed with this statement, and had no statistically significant difference in response (males 7.16 vs. females 6.67). However, for White, Black, and Asian students, male vs. female agreement varied significantly. White males agreed that men do CS (8.15) whereas White females rated near neutral (5.94, p-value < 0.001). Similarly, Black males agreed that men do CS (8.46), but Black females agreed much less that women do CS (6.90, p-value = 0.033). Asian males agreed that men do CS (8.29), but Asian females barely agreed that women do CS (5.84, p-value < 0.001).

TABLE V. PERCEPTIONS OF GENDER IN COMPUTER SCIENCE

Race / Ethnicity	People with my same sex or gender do computer science.		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 190) Female (n = 164)	7.16 6.67	0.117
Asian	Male (n = 62) Female (n = 37)	8.29 5.84	< 0.001
White	Male (n = 72) Female (n = 32)	8.15 5.94	< 0.001
Black	Male (n = 26) Female (n = 20)	8.46 6.90	0.033

Interestingly, all students believed they could pursue CS if they wanted to, reflecting a sense of confidence in ability with CS (Table VI below). However, there were statistically significant differences between male vs. female agreement (with males agreeing more) among Latinx, White, and Asian students. Black males agreed almost the same amount as Black females.

TABLE VI. CONFIDENCE WITH COMPUTER SCIENCE

Race / Ethnicity	I have what it takes to become a computer scientist one day if I want to		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 191) Female (n = 163)	7.39 6.58	0.004
Asian	Male (n = 63) Female (n = 37)	8.37 6.30	0.001
White	Male (n = 72) Female (n = 32)	8.22 6.38	0.943
Black	Male (n = 26) Female (n = 20)	7.46 7.40	< 0.001

Regarding sense of belonging in the field of CS if one were to pursue it, Asian and White females felt neutral to this statement (5.00 and 5.19 respectively). Latina females and Black males barely agreed with the statement (5.93 and 5.92 respectively). Asian, White, and Latino males agreed with this statement with statistically significant differences within racial/ethnic groups between genders: Asian males (7.36, p-value < 0.001); White males (7.92; p-value < 0.001); and Latino males (7.03; p-value < 0.001). Interestingly, Black females believed they would be accepted more readily in the field of CS if they pursue it when compared to Black males (7.26 vs. 6.92), but with no statistical significance (See Table VII below). After comparing all questions with one another, this question had the most positive correlation with students' responses to 1) students' beliefs that they could be a computer scientist if they want to, 2) commitment to working through challenging problems even without teacher/peer support, and 3) belief that anyone is capable of improving one's CS abilities. This emphasizes how identity in CS may be correlated with students' commitment to persisting with CS and beliefs that all people are capable of excelling in CS, regardless of external pressures or stereotypes.

TABLE VII. SENSE OF BELONGING IN THE FIELD

Race / Ethnicity	If I wanted to pursue a career in computer science, I would be readily accepted by people in the field.		
	Gender Identity	*Mean Likert Score*	*P-Value*
Latinx	Male (n = 190) Female (n = 163)	7.03 5.93	< 0.001
Asian	Male (n = 63) Female (n = 36)	7.35 5.00	< 0.001
White	Male (n = 72) Female (n = 31)	7.92 5.19	< 0.001
Black	Male (n = 26) Female (n = 19)	5.92 7.26	0.676

C. *Identifying or Not Identifying as a "CS Person"*

In addition to the above likert-scale questions, students were asked open-ended questions seeking to surface their views on identity and CS. More specifically, one question asked if students identified as "a computer science person" and to explain why or why not. "Computer science person" was left undefined so that youth had the space to express the characteristics/features that made up CS people, and how they aligned or did not align with such characteristics/features.

Initial analyses of whether or not students did or did not identify as CS people reveal that a little more than half (n = 439) identified as "CS people," whereas a little less than half (n = 422) did not. A table showing the breakdown of students who said yes or no by race/ethnicity and gender is shown below.

TABLE VIII. STUDENT IDENTIFICATION AS "CS PEOPLE"

Race / Ethnicity	Do you consider yourself a computer science person?		
	Gender Identity	*Yes (%)*	*No (%)*
Latinx	Male (n = 199) Female (n = 176)	132 (66%) 63 (36%)	67 (34%) 113 (79%)
Asian	Male (n = 142) Female (n = 70)	86 (61%) 29 (41%)	56 (39%) 41 (59%)
White	Male (n = 72) Female (n = 34)	41 (57%) 12 (35%)	31 (43%) 22 (65%)
Black	Male (n = 28) Female (n = 21)	10 (36%) 11 (52%)	18 (64%) 10 (48%)

Over half of all Latino, Asian, and White males considered themselves CS people, but less than half of Black males identified as such. The majority of Latina, Asian, and White females did *not* identify as CS people, whereas nearly half of the Black females *did* (52%).

But why did students identify as CS people? As one might expect, the majority (305 of 439 students; 70%) explained that they **loved the subject, enjoyed programming, found CS to be fun, and/or really liked technology and computers**. They stated things such as, "I consider myself a 'computer science' person because I like working with computers and would love to learn more about how they work" and "I have a passion for coding" and "Because I like Comp Sci and I also really like to code, I also really love critical thinking."

Additionally, 70 students described that they felt they were CS people because they had the **knowledge and experience** backing this identity. For some students, this involved having the ability to not only code, but also teach others to program: "I consider myself a computer science person because I can code and I know how to use a computer and I can teach others on how to use one or code." Others wrote how they were able to learn and this made them CS people: "I consider myself a computer science person because I can do things now that I couldn't do before." Or yet others described how the knowledge they had was beyond what most people understood: "I know more about computer science than the average person." Interestingly, when breaking down this group by race/ethnicity and gender, there were almost equal numbers of Latino males and Latina females citing knowledge/experience as the reason why they identified as CS people (23 males; 20 females). Among Asians, 7 males described having knowledge/experience, but no Asian females cited this as a reason. Only 1 White male and 2 White females fell into this category. No Black males or females cited their knowledge/experience as reasons for identifying as CS people. [Note: While these numbers are small, we believe it important for these students' voices to be heard].

However, 5 Black students (4 male, 1 female) did cite that their **skills and abilities** with computing were reasons why they identified as CS people. 8 Asian males and 3 Asian females also cited their skills/ability as reasons for identifying as CS people. Among Latinx students, 20 Latino males cited skills/ability, but only about half that number (9 Latina females) identified as CS people because of their skills/ability. 5 White males and 3 White females described their skills/abilities. Overall, 67 students described their skills and ability with computing as reasons to be considered CS people, stating things such as: "I consider myself a computer science person because I can find solutions to problems and I can create algorithms for a program" or "[I] can understand new commands fairly quick" or "I have the strategic skills in which to be able to figure out hard and unique codes."

Twenty-seven students who identified as CS people explained that they had **plans to pursue computing in either college or their future careers**. Of those students, 10 were Latino males, 5 Latina females, 5 Asian males, 2 Asian females, 1 Black male, 1 Black female, 2 White males, 2 White females.

Interestingly, another category that emerged for why students identified as CS people was because they felt that they **could help others with computing or contribute to the larger world with their skills**. While only 12 students fell under this category, their statements around this idea were notable, including: "I actually get to contribute to the digital world by providing programs of my own" or "my classmates were asking me for help and most of the time I was able to help them" or "in my household, I am usually the one everyone goes to when they are seeking help with a program."

D. Reasons for Not Identifying as "CS people"

Interestingly, reasons why students did not identify as "CS people" despite enrolling in an AP CS course were not as simple as merely disliking the subject. Almost a third **(124 of the 422) of "non-CS people" cited a dislike of CS or technology** (this included 16 Black, 14 Asian, 72 Latinx, and 13 White students), writing things such as: "Throughout the whole year, computer science did not excite me very much and my passion for it never grew" or "I understand everything because it is simple but I do not like doing computer science." Additionally, **21% (n = 90) explicitly described feeling more excited about different subject areas** (without necessarily saying they disliked CS), and **almost 10% (n = 35) of non-CS people actually noted that they really enjoyed or are interested in CS.**

Beyond these categories, 63 students (15%) cited that they found **CS too stressful or frustrating and struggled** too much to be considered CS people. Students wrote things such as, "It is something that I struggle with and have a difficult time learning and understanding," or "I feel like I would get frustrated easily when a program doesn't work," or "I feel like I would stress too much when I don't get the right code." More females than males cited this as a reason why they didn't identify as CS people (37 females vs. 21 males). Latina females (n = 27) described frustration/difficulty with CS more than Latino males (n = 13). No White, Black, or Asian males cited this as a reason for not identifying as CS people, but 2 White females, 2 Black females, and 4 Asian females did.

The next largest category of non-CS people were students who felt they **still had more to learn** before calling themselves CS people (n = 54). This category of responses suggested that there was a possibility of becoming a CS person in the future, and that identity was not set in stone. A typical response in this category included: "I don't fully consider myself a 'computer science' person because I have a lot more to learn about computer science. I may have learned about the basics, but I feel that I would have to study more about computer science and understand the deeper meaning it has on society as a whole, in order to consider myself a 'computer science' person." Interestingly, males outnumbered females in this category (33 males vs. 21 females), with Latino males (n = 21) being nearly twice in number compared to Latina females (n = 12). Among other racial/ethnic categories: 1 White male, 4 Asian males, 2 Black males, 1 White female, 3 Asian females, and 0 Black females cited this reason for not identifying as CS people. The difference between males and females, and Latino males vs. Latina females, suggests that males felt more confidence and room for growth to eventually become CS people with increased experience, knowledge, or skills.

The next largest category included students who were not CS people because they **did not plan on pursuing careers or studies in computing** (n = 37). Of these students, females outnumbered the males (28 females described pursuing non-CS futures, compared to only 9 males). No Asian males shared this as a reason for not being CS people, but 5 Asian females described wanting to pursue non-computing fields/majors. Similarly, Latina females (n = 19) stated this as a reason for not being CS people more than Latino males (n = 7). 1 White male and 1 White female, as well as 1 Black male and 2 Black females cited this as reasons for not being CS people.

Of course, some students also believed that they couldn't be CS people because **they didn't think they were "good at" computer science** (n = 28). These students wrote things such as "cause I can't code" or "I am not skilled in that particular subject." Interestingly, no Black students chose this as a reason for not being CS people, and nearly equal numbers of Latinx males and females chose this as a reason for not being CS people (7 females vs. 5 males). Again, while only 6 Asians fell into this category, it is notable that 5 Asian females believed they were not good enough at CS, compared to only 1 Asian male. No White males cited lack of ability, but 2 White females did.

Relatedly, 9 people described that since **they weren't "the best" at CS**, they couldn't consider themselves CS people. For this small group of students, there was a sense of comparing oneself to others, where one had to be at the top of the class to be considered a CS person. Respondents in this group included 2 Asian females, 2 Latina females, 1 Black female, 1 White female, 1 Asian male, and 1 Latino male.

While stereotypes may have informed the ways that youth identified themselves as being or not being CS people, **only 4 students explicitly referenced stereotypes about what CS people are.** More specifically these students wrote that they are not "the type of person to do this," "don't fit the stereotype of one. I'm a girl in a mostly male class and I feel very out of place here," "Not really a tech guy," and "not much of a computer science guy." Almost no students explicitly referenced the stereotype of CS identity requiring one to be "smart" or "nerdy."

E. *"I'm not a CS person **but**…" – CS Identity as Possibility*

While the above themes offer a window into students' beliefs about what characteristics, skills, and features make up CS people, another trend appeared among students' explanations for why they were not CS people that is also illuminating. Ninety-one students (22%) used words such as "but," "however," or "although" in ways that **suggested there was either room for growth to become CS people**, or that denying such an identity did not necessarily mean they disliked CS. These "but statements" were written in conjunction with many of the categories described above, including: liking CS but wanting to pursue other interests, liking CS but feeling like they had more to learn, and recognizing that CS was relevant to their future and the world. "But statement" examples reflect how teenagers saw possibilities for CS identification: "I don't consider myself a computer science person YET…there are several things I have to and want to learn before I can consider myself an exemplary computer science person," and "Although computer science is an interesting topic for me, I find myself lacking in this field…If I continue to study and engage in this field, I will definitely learn a lot more and someday consider myself a computer science person." Interestingly, more females than males fell into the "but statement" category (54 females vs. 35 males). Asian females used "but statements" twice as much as Asian males (14 vs. 7), and Black females outnumbered Black males (6 vs. 2). Latinx females and males were close to equal (24 vs. 19) as were White males and females (5 vs. 4).

IV. Discussion

A. *Complexifying Perceptions About CS Engagement for Students of Color and Females*

The findings in this paper help complexify stereotypical beliefs that students of color and young women are disinterested in CS. Of course, the overall positive engagement with CS across all student groups in this study might be expected because students presumably chose to enroll in AP CSP, which is not required for graduation. However, it is compelling to see that **there were no statistically significant differences in engagement between racial/ethnic groups**, with general agreement across all students to statements such as "I like computer science" and "I think computer science is interesting." The fact that all racial/ethnic groups enjoy CS, yet are not equally represented in the field of CS, both challenge racist beliefs about who wants to engage with CS, while highlighting the fact that something is happening to motivated CS students after high school, resulting in differential representation in CS.

Still, while Latina, Asian, and White females all stated that they like CS and find it interesting, they did not do so to the same degree as their male peers. Furthermore, Latina and White females felt closer to neutral about whether or not they would pursue further CS coursework, despite their interest and engagement with the subject. Importantly, these differences did not exist between Black male and female students whose agreement with statements about engagement and future CS learning were nearly equal to one another and yielded no statistically significant differences in responses.

This raises new questions: Why would students who enjoy a subject feel unsure about taking more courses in that subject? Why are young Latina, Asian, and White women (with Asian and White females more highly represented in CS careers than Black females) rating lower engagement than their male peers, yet Black males and females are rating engagement so similarly?

We believe that the similarities in answers between Black males and females, that were all quite positive about CS engagement in general, is something worth recognizing as a potential counterpoint to the belief that young women like CS less than young men. Regarding differences between genders in the other racial/ethnic groups, we believe that these findings are not simply reinforcing stereotypical notions that young women are disinterested in CS. On the contrary, female responses to questions about belonging help reveal that there is something else influencing how they rate their sense of interest and future engagement with computing. This is explored further below.

B. *Relationship between CS Engagement and Belonging*

When examining engagement scores in relation to students' sense of confidence in being able to excel in CS or feel welcome in the field, correlation values reveal that **lower engagement with CS for Latina, Asian, and White females is related to the fact that these same groups of young women did not feel as strongly that their race/ethnicity + gender do CS, or that they would be accepted in the field if they chose to pursue CS** (rating near neutral among all groups). Latina, Asian, and White females were also less likely to consider themselves CS people than their male peers. Meanwhile, their male peers who rated a higher agreement to feeling like their race/ethnicity + gender do CS and that they would be welcomed into the field if they pursued it, had higher levels of engagement with CS.

It seems to make sense that students, who feel they are unwelcome in a field, would report lower engagement with that field, simply because there must be recognition of the hurdles one must overcome in order to pursue and be accepted by that specific field. And with this same logic, if one does not anticipate rejection by a field of study, then one might feel greater desire to engage with that field. Of course, additional research is needed to address assumptions about causality: it is unclear whether or not lower engagement is what made these groups feel less welcome in the field of CS, or if feeling like one couldn't fully belong resulted in lower engagement with CS.

However, looking at differences between Black male and female experiences may offer a window into this very issue. While there was no statistically significant difference between Black male and female responses to statements about CS belonging, we wonder why Black males, on average, agreed less than Black females about being welcomed in the field of CS (rating the statement just above neutral, similar to Latina, Asian, and White females). Also, why were Black males less likely to consider themselves CS people than Black females?

For this, we believe it is important to explore research literature regarding the experiences of Black males in school. More specifically, Black males face institutional racism that disproportionately impacts their educational, psychological, and emotional well-being compared to other racial/ethnic + gender groups [15, 16]. Black males are disciplined more in school than all other groups [17] and face more negative teacher attitudes, expectations, and behavior [18, 19] despite valuing academic success and school [20]. And while all students generally begin their school experiences identifying with academics, Black males' academic identification drops significantly lower than other racial/ethnic + gender groups from 8th to 12th grade [21], and lower than Black females or White males/females in college [22]. This research suggests that Black females may have a more positive academic identity by high school compared to their male peers, as Black males experience higher rates of school dropout [23] while also being tracked into a school-to-prison pipeline at higher rates [for example, 24, 25]. Thus, while we may want to celebrate that both Black females and males show engagement with computing at similar rates (in contrast to the gender-based differences in other racial/ethnic groups), there is a complexity here regarding engagement in relation to feelings of belonging in CS that must be explored. Further research is needed regarding the racism that Black males experience at the intersection of race/ethnicity and gender in CS and school.

C. *Emphasizing the Potential for Change and Growth*

While not all students considered themselves CS people, the category of students who saw potential to be CS people one day was a particularly important group to explore more closely (22% of non-CS people). More females than males were represented in this category. These students did not actually dislike CS, but saw their identity as either reflecting more than their appreciation of CS, or they saw a positive potential to become computer science people in the future. These students' perspectives offer an important reminder about how identity is not a fixed feature, and how teenagers, in particular, see the potential in themselves to change and grow with experience and time. But how can curricula and instruction provide the positive supports necessary for youth to feel like they can be CS people when they are on the verge of becoming one? A closer look at students' perspectives regarding qualities that make a CS person can inform our answers to this question.

D. *Qualities of Computer Science People*

Of course, it is not surprising that students who considered themselves computer science people cited their love of computing and technology. However, it is notable that only 29% of students who did not identify as CS people described disliking the topic or technology, and that 10% of non-CS people actually described liking CS. Also, it is important to recognize that many of the non-CS people described liking another subject more, *not disliking* CS. This suggests that, again, there is room for growth or change in perception of CS as students continue to learn and experience the world around them. The students who had other interests or actually like CS may have wiggle room to change their minds about computing and or find themselves identifying as CS people one day, with appropriate supports to feel that they have the ability and the right to excel with the subject.

But even more importantly, we should take into consideration those students who explained that they did not identify as CS people because the subject was too stressful, challenging, or frustrating. These students—that included mostly females—most likely experienced struggles that felt insurmountable. These students may also have felt pressure to get good grades in either the course or on their AP exams, and that added stress may have colored their feelings about computing at a particularly influential time when they are first exploring CS in high school.

Another fairly large group of students emphasized that they could not be CS people because they had more to learn. These students sit in interesting contrast to the students who identified as CS people because of their skills/abilities (e.g., ability to code) because many of these non-CS students who said they had more to learn may have known as much about CS as their peers who considered themselves CS people. While there are always varying abilities in every course, the perspective of having more to learn as a barrier to being a CS person vs. not seeing that as a barrier is interesting to take into consideration for the ways that we encourage youth in subjects that are new to them, like CS.

Finally, for students who said that they are not CS people because they are not pursuing careers in CS, we must question why they do not see how their future careers are impacted by and relate to computing. All fields are impacted by CS—from the arts to agriculture to medicine to sports—and for youth to feel that their career trajectories do not relate to CS suggests that we still have a ways to go in showing youth why computing is relevant to their lives, no matter their career pathways.

V. CONCLUSION

This paper emphasizes the importance of learning directly from youth—and especially minoritized youth coming from communities historically underrepresented in computing—about their sense of engagement, feelings of belonging, and identification with CS. Their ideas about what makes up a CS person can powerfully inform what the CS for All movement needs to focus on to better support all youth in feeling like they can pursue CS if they want to, or that they can engage CS in whatever career pathways they follow. More specifically, we believe that curriculum developers and professional development providers must consider the following to ensure that minoritized youth feel they can have a rightful presence and meaningful learning experience in computing:

1) CS classrooms should openly discuss issues of discrimination in the field of computing, and ways that youth can disrupt learning and career contexts that do not welcome their intersecting identities of race/ethnicity, gender, etc. We must ensure that youth, who do not feel like they would be welcomed into CS fields, find ways to counter discrimination *and build new communities. We must find ways to discuss difficult issues without discouraging students, while providing supports/resources/encouragement for youth who like CS but don't feel they are welcome in the field.*

2) CS classrooms should openly address the feeling of stress and frustration that youth face when solving challenging computing problems. We must encourage youth to persist and accept that they don't have to know the answers immediately all of the time. How can computer science be demystified so that youth can see that even expert computer scientists struggle too?

3) We must encourage youth to see connections between CS learning and their personal passions and visions for the future. For youth who do not feel like there are connections between what they learn in AP CSP and their academic or career pathways, we must make learning more relevant so they can feel empowered to be computer science people.

4) We must build better supports for youth who are on the boundaries of computing—students who enjoy CS but do not think they can yet be considered CS people.

Building on these ideas, we believe that curricular and pedagogical shifts can be made to ensure that youth feel they have a rightful presence in CS classrooms and fields, and that their contributions can help shape a better future for all. And while this study has limitations—more specifically, we cannot draw definitive claims about Black students' experiences because the total number of Black survey-takers was small, and came from a select number of segregated schools in the district—we believe important insight can still be learned from all the youth perspectives shared in the survey responses. Yet further research is needed to dig deeper into the nuances of CS identity and engagement. We believe qualitative data sources from interviews with students can help fill the gaps in our knowledge about what students want and need in order to feel they have the right to pursue CS and belong in the field. We are pursuing such ethnographic efforts today, but invite others to join us in this exploration. We need to hear more from students' voices directly about what could have the greatest positive impact on their CS learning experiences to ensure that all youth have access to rigorous and meaningful CS education.

ACKNOWLEDGMENTS

This work was funded by the National Science Foundation (1743336) and Bill & Melinda Gates Foundation (81652). Any opinions, findings, conclusions and/or recommendations expressed in this material are those of the authors and not necessarily those of the funders. We would like to thank the teachers and students who participated in this study, as well as Jane Margolis, Priscilla Liu, Julie Flapan, Roxana Hadad, Nina Kasuya, Andrea Arias, our Center X colleagues, and our school district partners who are unnamed to protect district identity.

REFERENCES

[1] A. Calabrese Barton, & E. Tan. STEM-Rich Maker Learning: Designing for Equity with Youth of Color. NY, NY: Teachers College Press, 2019.

[2] J. Margolis, R. Estrella, J. Goode, J. Jellison-Holme, and K. Nao, Stuck in the Shallow End: Education, Race, and Computing. Cambridge, MA: MIT Press, 2008/2017.

[3] National Center for Women and Information Technology, By the Numbers, Retrieved from www.ncwit.org/bythenumbers, 2019.

[4] Bureau of Labor Statistics. Employment Projections. Retrieved from https://www.bls.gov/emp/tables.htm, 2019.

[5] L. Winning. It's Time to Prioritize Diversity Across Tech. *Forbes*. Retrieved from https://www.forbes.com/sites/lisawinning/2018/03/13/its-time-to-prioritize-diversity-across-tech/#2106ffd216f8, 2018.

[6] L. Stowe, 14 Reasons Why Diversity in Tech Still Matters in 2018. Retrieved from https://devskiller.com/diversity-in-tech/, 2018.

[7] D.L. Medin, & M. Bang. Who's Asking? Native Science, Western Science, and Science Education, Cambridge, MA: MIT Press, 2014.

[8] A. Scott, S. Koshy, M. Rao, L. Hinton, J. Flapan, A. Martin, & F. McAlear, Computer Science in California's Schools: An Analysis of Access, Enrollment, and Equity, Oakland, CA: Kapor Center and CSforCA, 2019.

[9] L. Carter. Why students with an apparent aptitude for computer science don't choose to major in computer science, ACM SIGCSE Bulletin, vol 38, no 1, 2006, pp. 27-31.

[10] Outlier Research & Evaluation. Saying Yes to Computer Science: Why Students Tell their Peers to Take Introductory Computer Science. Chicago, IL: Outlier Research & Evaluation at UChicago STEM Education, 2017.

[11] M. Guzdial, B.J. Ericson, T. McKlin, and S. Engelman. A statewide survey on computing education pathways and influences: factors in broadening participation in computing. [9th Annual Internat Conf. on Internat Computing Ed Research, pp. 143-150, 2012].

[12] Outlier Research & Evaluation. Barriers and Supports to Implementing Computer Science. U of Chicago. http://outlier.uchicago.edu/basics/.

[13] K.C. Haynie and S. Packman. AP CS Principles Phase II: Broadening Participation in Computer Science Final Evaluation Report. Prepared for The College Board and the Nat Sci Fdtn. 2017. Skillman, NJ.

[14] Building, Recruiting, and Inclusion for Diversity (BRAID) Research. UCLA. https://braidresearch.gseis.ucla.edu/.

[15] T. Howard, Black Male(d): Peril and Promise in the Education of African American Males, New York, NY: Teachers College Press, 2014.

[16] T.C. Howard and Associates. The Counter Narrative: Reframing Success of High Achieving Black and Latino Males in Los Angeles County. Los Angeles: University of California, Los Angeles, UCLA Black Male Institute, 2017.

[17] H.C. Stevenson, R. Cameron, T. Herrero-Taylor, and G.Y. Davis, Development of the Teenager Experience of Racial Socialization Scale: Correlates of Race-Related Socialization Frequency from the Perspective of Black Youth, Journal of Black Psychology, vol 28, 2002, pp. 84–106.

[18] S. Ross and J. Jackson, Teacher's Expectations for Black Males' and Black Females' Academic Achievement, Personality and Social Sciences Bulletin, vol 17, 1991, pp. 78–82.

[19] G. Marcus, S. Gross, and C. Seefeldt, Black and White Students' Perceptions of Teacher Treatment, Journal of Educational Research, vol 84, no 6, 1991, pp. 363–367.

[20] K. Cokley, What Do We Know About the Motivation of African American Students? Challenging the Anti-intellectual Myth, Harvard Education Review, vol 73, 2003, pp. 524–558.

[21] J.W. Osborne. Race and academic disidentification. Journal of Educational Psychology, vol 89, 1997, pp. 728-735.

[22] K. Cokley, Ethnicity, Gender and Academic Self-Concept: A Preliminary Examination of Aacademic Disidentification and Implications for Psychologists. Cultural Diversity and Ethnic Minority Psychology, vol 8, no 4, 2002, pp. 378–388.

[23] U.S. Department of Education, National Center for Education Statistics., The Condition of Education 2019, NCES 2019-144, Status Dropout Rates, 2019.

[24] C.Y. Kim, D.J. Losen, and D.T. Hewitt, The School-to-Prison Pipeline: Structuring Legal Reform. New York: NYU Press, 2010.

[25] C.A. Christle, K. Jolivette, and C.M. Nelson, Breaking the School to Prison Pipeline: Identifying School Risk and Protective Factors for Youth Delinquency. Exceptionality, vol 13, no 2, 2005, pp. 69-88.

Who Takes Intro Computing? Examining the Degree Plans of Introductory Computing Students in Light of Booming Enrollments

Linda J. Sax
Department of Education
UCLA
Los Angeles, CA, USA
lsax@ucla.edu

Jennifer M. Blaney
Department of School Psychology and Educational Leadership
Idaho State University
Pocatello, ID, USA
jenniferblaney@isu.edu

Christina Zavala
Department of Education
UCLA
Los Angeles, CA, USA
zavalac@ucla.edu

Kaitlin N. S. Newhouse
Department of Education
UCLA
Los Angeles, CA, USA
k.newhouse@ucla.edu

***Abstract*—This article examines the major and minor degree intentions of undergraduates enrolled in introductory computing courses. Focusing on three primary groups (computing majors, non-computing majors, and undecided majors) we examine specific major choices, double major combinations, and minors. Further, we examine the degree intentions of women and underrepresented racially minoritized students compared to their male and majority counterparts. Findings reveal wide variation in the degree plans of intro students and that degree intentions vary by gender and race/ethnicity in several ways.**

Keywords—Computer science education, CS1, broadening participation, booming enrollments, degree intentions

I. Introduction

The enrollment boom in undergraduate computing has received significant attention in recent years, with reports from prominent organizations—including the Computing Research Association (CRA) [1] and the National Academies of Sciences, Engineering and Medicine (NAS) [2]—addressing the urgency of understanding and responding to growing demand for computing courses. In fact, computing departments in the United States have experienced record growth in the last decade; the 2017-2018 academic year alone witnessed a 13.3% increase in undergraduate computer science majors from the prior year [3]. Recent research reveals that this enrollment boom has had a particularly significant impact on the size and composition of introductory (or intro) computing courses [1].

In light of the surging interest and enrollments in computing, reasonable concerns remain about the representation of women and underrepresented racially minoritized[1] (URM) students pursuing computing courses and majors. This is in part because previous surges in computing enrollments have typically resulted in decreases in the representation of women (even when their overall numbers have risen) [5]. Yet, in this current enrollment surge, the percentage of both women and URM students has increased modestly [3, 5]. However, introductory computing courses have been diversifying much more quickly than the computing major. For example, from 2010 to 2015, the median percentages of Black, Latinx, and Native students who were non-computing majors in intro computing courses increased 43% relative to only a 9% increase in the median percentage of Black, Latinx, and Native students enrolled as computing majors [1]. Despite their increased participation in computing courses, both women and URM students remain underrepresented in computing degree attainment. In 2016, women earned 57.2% of all bachelor's degrees, but only 18.7% of bachelor's degrees in computing, while students from Black, Latinx, and Native groups collectively earned 23.1% of all bachelor's degrees in 2016 but were just 19.7% of computing bachelor's degree recipients [5].

Given changes in the composition of intro course enrollments, particularly among non-computing majors whose representation in intro courses has increased 177% between 2005-2010 [1], growing attention has been given to the nature and function of these courses. For example, scholars have recently focused on the interdisciplinary nature of computing itself and some suggest that making interdisciplinary applications more explicit may serve to attract more women and URM students to computing [6, 7, 8]. More broadly, being mindful of the needs of women and URM students in intro courses is particularly important given the possibility that efforts to manage surging enrollments (e.g., capping enrollments in popular courses or raising minimum requirements) run the risk of undermining the goal of diversifying computing [1].

While recent reports have provided insight into the changing composition of intro computing students, little is

[1] We use the term "underrepresented racially minoritized students" as opposed to the more common "under-represented minority students" to acknowledge minoritization as a socially constructed process in keeping with Benitez's usage [4]. Underrepresented racially minoritized students include those from Black, Latinx, and/or Native groups.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

known about the specific degree plans of students who contribute to booming enrollments or how these plans might vary by gender and race/ethnicity. As departments grapple with the well-documented trend of attrition after intro computing courses among women and URM students, a more nuanced understanding of students' academic orientations may inform initiatives and efforts to successfully recruit and retain women and URM students [9, 10].

This study uses data from a fifteen-campus study of diversity efforts in computing to address this gap in the literature, focusing on the degree plans of the three primary groups of students in intro computing courses: computing majors, non-computing majors, and undecided majors. Accordingly, the following questions frame this inquiry:

1. What proportion of introductory computing students are computing majors, non-computing majors, and undecided majors? How does this vary by gender and race/ethnicity?
2. Of the computing majors enrolled in an introductory computing course, what are their specific degree plans, and how does this vary by gender and race/ethnicity?
3. Among introductory students not majoring in computing, what are their degree plans, and how does this vary by gender and race/ethnicity?
4. Among students who enter introductory computing undecided on a major, what majors are they considering, and how does this vary by gender and race/ethnicity?

II. METHOD

A. *Data Collection and Measures*

This study relies on survey data received from n = 3,656 intro computing students across fifteen doctoral-granting research universities. The survey—developed in collaboration with Center for Evaluating the Research Pipeline at the Computing Research Association—was administered to nearly 12,000 students during the 2015-2016 academic year and had a response rate of 31%. Notably, participating institutions are all members of the BRAID initiative to broaden participation in computing. Despite the unique characteristics of the institutional sample, trends in the representation of women and URM student respondents at BRAID institutions parallel national trends in computing [11].

Students indicated their gender as female, male, or non-binary. Analyses by gender do not include non-binary students due to small sample sizes. Our analyses by race/ethnicity are based on student reports of their race/ethnicity which were aggregated into underrepresented racially minoritized (URM) and majority groups in computing, in keeping with recent definitions [12, 13]. Specifically, URM students include the following: African American/Black; American Indian or Alaska Native; Arab/Middle Eastern/Persian; Latinx; Native Hawaiian or Pacific Islander. Majority students include those who indicated only a white and/or Asian race/ethnicity. Women and URM students account for 33% and 27% of respondents, respectively.

Students were also asked to indicate up to two majors and two minors on the survey. For the purpose of this study, students were grouped into three mutually exclusive categories: computing majors[2], non-computing majors, and undecided majors. All non-computing majors and minors were aggregated into the following categories: Engineering (not including computer/software engineering); Humanities; Biological Sciences; Business; Education; Physical Sciences; Math and Statistics; Health; Social Sciences; or Other. Students who indicated that their major was undecided were asked to indicate their most probable major; those responses were aggregated into the categories listed above.

B. *Analytical Procedures*

This study relies on frequency distributions and z-tests to examine differences in degree constellations by gender and URM status. When possible, we also consider gender and URM status together as intersecting identities (i.e., we compare URM women, majority women, URM men, and majority men).

III. FINDINGS

A. *Who Takes Intro Computing (RQ1)*

Over half (52.8%) of the intro course students in our sample were computing majors, another 41.5% represent non-computing majors, and 5.7% were undecided on their major. Notably, among the 41.5% of non-computing majors in the intro course, one-third had a computing minor.

Compared to women, men much more frequently reported a computing major (61.0% vs. 37.7%; $z = -12.64$, $p < .000$), while women more frequently reported a non-computing ($z = -10.83$, $p < .000$) or undecided ($z = 4.09$, $p < .000$) major. At the same time, 61.8% of URM students were computing majors, compared to 50.0% of their counterparts from majority racial/ethnic groups ($z = 5.98$, $p < .000$); majority students also more frequently reported having either a non-computing ($z = -4.78$, $p < .000$) or undecided ($z = -2.81$, $p = .005$) major, compared to their counterparts from minoritized groups.

Disaggregating further to account for intersecting identities (see Table I), the greatest representation of computing majors was among URM men (69%), followed by majority men (58%), URM women (48%), and majority women (34%).

B. *A Closer Look at Computing Majors (RQ2)*

As illustrated in Table II, we found that nearly three-quarters of the computing majors in intro computing had a single major with no minor. At the same time, 17.7% of computing majors reported having a single major with at least one minor, 6.7% reported having a double major with no minor,

[2] Adapting Zweben and Bizot's definition [14] to accommodate the major/minor offerings at BRAID institutions, we define computing broadly to include the following: Computer Science; Computer Information Systems/Informatics; Bioinformatics; Computing and Business; Information Technology; Data Science; Game Design; Computer/Software Engineering; and Other Computing.

and 2.3% reported having a double major and at least one minor. These findings differed by gender, with women more frequently reporting a double major, compared to men. While there were no significant differences by URM status, additional analyses revealed that majority women were more frequently double majors compared to their male counterparts from both minoritized ($z = 3.37$, $p = .001$) and majority ($z = 2.92$, $p = .004$) groups; no other differences emerged.

TABLE I. COMPUTING, NON-COMPUTING, AND UNDECIDED MAJORS BY GENDER AND URM STATUS

	Percent Among			
	Majority Men (a) n=1,573	***Majority Women (b) n=794***	***Minoritized Men (c) n=573***	***Minoritized Women (d) n=293***
Computing	58.0_{bcd}	33.8_{acd}	69.3_{ab}	48.1_{abc}
Non-Computing	36.7_{bcd}	57.4_{acd}	28.3_{ab}	45.7_{abc}
Undecided	5.2_{bc}	8.8_{ac}	2.4_{abd}	6.1_{c}

Note. Subscripts indicate significant differences from corresponding groups after accounting for the Bonferroni correction. For example, 69% of minoritized men were computing majors, which is significantly different from the rate at which majority men and majority women major in computing.

Next, we examined the specific majors represented among intro students majoring in computing. As shown in Table III, the majority (63.5%) of computing majors reported a major in computer science, with computer engineering as the next most popular major (18.4%). Compared to men, women more frequently reported a major in bioinformatics or "other computing". Men more frequently reported a major in computer engineering. There were no significant differences between URM and majority students. Beyond the results shown in Table III, we also ran analyses comparing minoritized women, majority women, minoritized men, and majority men, revealing that women from majority racial/ethnic groups more frequently pursued bioinformatics compared to men from majority groups ($z = 3.14$, $p = .002$) and less frequently pursued computer engineering compared to both minoritized men ($z = -2.76$, $p = .006$) and majority men ($z = -3.20$, $p = .001$). No other differences emerged between intersecting groups.

Next, Table IV summarizes the double major combinations among those with a computing major, revealing that the most popular double major combinations were computing + business (18.2%) followed by computing + math/statistics (17.5%). Due to small sample sizes, we did not run significance testing on double majors by gender, race, or intersecting identity groups.

Finally, Table V summarizes the different minors reported among computing majors. We found that, in addition to being the most common double major among this group, math/statistics was also one of the most common minors (19.3%). While no significant differences emerged by gender or race alone, we found that majority women were more frequently biology minors relative to their male counterparts from majority groups (1.9% vs. .3%; $z = 2.70$, $p = .007$).

C. Non-Computing Majors (RQ3)

Focusing on the 41.5% of intro students in our sample who were non-computing majors, we see that about half reported having a single major and no minor, 36.6% reported having a single major and at least one minor, 8.5% had a double major, and the remaining 5.0% had a double major and at least one minor (see Table VI). While no differences emerged by URM status, men more frequently had a single major compared to women. No differences emerged between intersecting groups.

TABLE II. MAJORS/MINORS AMONG INTRO STUDENTS MAJORING IN COMPUTING, BY GENDER AND RACE

	Percent Among						
	All students	***By Gender***			***By Race***		
	All (n=1917)	***Women (n=415)***	***Men (n=1319)***	***Z***	***Minoritized (n=536)***	***Majority (n=1186)***	***Z***
Single major	73.2	68.0	75.3	-2.94*	75.6	72.3	1.43
Single major + one or more minors	17.7	19.0	17.1	0.89	17.0	18.0	-0.50
Double major	6.7	9.9	5.5	3.16*	5.2	7.3	-1.62
Double major + one or more minors	2.3	3.1	2.1	1.18	2.2	2.4	-0.25

Note. *p<0.0125. The significance level has been adjusted using the Bonferroni correction.

TABLE III. DISTRIBUTION OF MAJORS AMONG INTRO STUDENTS WITH A COMPUTING MAJOR, BY GENDER AND RACE

	Percent Among						
	All Students	***By Gender***			***By Race***		
	All (n=1931)	***Women (n=416)***	***Men (n=1330)***	***Z***	***Minoritized (n=541)***	***Majority (n=1193)***	***Z***
Computer Science	63.5	62.7	64.3	-0.59	66.2	63.1	1.25
Computer Engineering	18.4	13.7	19.8	-2.81*	19.0	18.4	0.30
Information Technology	8.0	7.7	8.3	-0.39	5.5	9.1	-2.56
Computer Information or Systems Informatics	4.9	6.5	4.4	1.73	4.6	4.8	-0.18
Bioinformatics	1.6	3.6	1.0	3.67*	1.5	1.6	-0.16
Other Computing	1.8	3.6	1.1	3.45*	1.3	1.9	-0.89
Information Science Studies	1.5	1.9	1.0	1.46	1.7	1.0	1.23
Computing and Business	1.3	1.7	1.2	0.78	1.3	1.3	0.00

Note. *p<0.0063. The significance level has been adjusted using the Bonferroni correction. Percentages add to more than 100 because some students indicated more than one major.

TABLE IV. COMBINATIONS OF COMPUTING DOUBLE MAJORS ENROLLED IN INTRO COURSES, BY GENDER AND RACE

	Percent Among				
	All students	*By Gender*		*By Race*	
	All (n=143)	*Women (n=45)*	*Men (n=85)*	*Minoritized (n=34)*	*Majority (n=97)*
Computing + Business	18.2	20.0	18.8	8.8	22.7
Computing + Math/Statistics	17.5	22.2	16.5	17.6	18.6
Computing + Another Computing Major	16.1	13.3	18.8	23.5	14.4
Computing + Engineering	15.4	8.9	18.8	8.8	17.5
Computing + Arts and Humanities	13.3	20.0	5.9	11.8	10.3
Computing + Biological Sciences	8.4	2.2	12.9	14.7	7.2
Computing + Other	7.7	13.3	4.7	14.7	5.2
Computing + Physical Sciences	3.5	0.0	3.5	0.0	4.1

Note. This table includes no significance testing due to small sample sizes among groups.

TABLE V. DISTRIBUTION OF MINORS AMONG COMPUTING MAJORS ENROLLED IN INTRODUCTORY COURSES, BY GENDER AND RACE

	Percent Among						
	All Students	*By Gender*			*By Race*		
	All (n=384)	*Women (n=92)*	*Men (n=254)*	*Z*	*Minoritized (n=108)*	*Majority (n=248)*	*Z*
Computing (minor)	19.3	12.5	20.5	-1.70	23.3	16.1	1.62
Math/Statistics	19.3	16.3	21.3	-1.37	22.3	19.0	0.72
Arts and Humanities	18.2	26.1	16.5	2.01	17.5	20.2	-0.59
Business	17.4	18.5	17.3	0.26	13.6	19.4	-1.32
Other	12.8	10.9	13.8	-0.70	14.6	12.0	0.68
Social Sciences	7.3	8.7	6.7	0.63	7.8	7.0	0.27
Engineering	3.6	3.3	3.9	-0.26	2.9	4.1	-0.55
Biological Sciences	2.9	7.6	1.6	2.80	1.9	3.3	-0.73
Physical Sciences	2.6	1.1	2.8	-0.92	1.9	2.5	-0.66
Education	0.3	0.0	0.4	-0.61	0.0	0.4	-0.66
Health	0.3	0.0	0.4	-0.61	0.0	0.4	-0.66

Note. We tested for significant differences by gender/URM status, using the Bonferroni adjusted significance level, $p<0.0045$. No significant differences emerged. Percentages add to more than 100 as some students had more than one minor.

TABLE VI. MAJORS AND MINORS AMONG NON-COMPUTING MAJORS IN INTRODUCTORY COURSES, BY GENDER AND RACE

	Percent Among						
	All Students	*By Gender*			*By Race*		
	All (n=1510)	*Women (n=596)*	*Men (n=751)*	*Z*	*Minoritized (n=299)*	*Majority (n=1036)*	*Z*
Single major	49.8	46.0	55.3	-3.39*	56.9	49.6	2.22
Single major + one or more minors	36.6	37.8	33.4	1.68	33.4	36.1	-0.86
Double major	8.5	10.7	7.1	2.33	6.0	9.4	-1.84
Double major + one or more minors	5.0	5.5	4.3	1.02	3.7	4.9	-0.87

Note. $^*p<0.0125$. The significance level has been adjusted using the Bonferroni correction.

Next, Table VII displays the specific major fields reported among this group. Engineering majors represented nearly a third of non-computing majors in the intro course, followed by math/statistics, social sciences, and biological sciences. Some gender differences emerged, revealing that, compared to women, men twice as frequently reported an engineering major, while women more frequently majored in the social or biological sciences. Notably, while 20% of female non-computing majors in intro courses were engineering majors, this figure was 30% among URM women ($z = -3.10$, $p = .002$).

D. Undecided Majors (RQ4)

More than half of all undecided majors in intro computing courses reported that if they had to choose a major today, it would most likely be computing. However, gender differences reveal that men were significantly more likely than women to anticipate choosing computing as a major (72.6% vs. 48.9%; $z = -3.29$, $p = .001$). No other significant differences emerged for women and URM students. Due to small sample sizes, we did not run analyses by intersecting groups.

IV. DISCUSSION

This paper provides an overview of the majors and minors pursued by intro computing students, focusing on differences by gender and URM status. At a time of booming enrollments and increasing interest in broadening participation in computing, it is useful to understand the disciplinary pursuits of students taking computing courses. In addition to offering insight into how instructors can tailor their course to provide relevant content and responsive pedagogy, understanding students' degree plans may also help in identifying students who may be open to being recruited to a computing major. These considerations are especially important in the context of intro computing courses that attract students from a variety of majors and are often pivotal in determining whether students will pursue computing as a major or career [15].

TABLE VII. DISTRIBUTION OF MAJOR FIELDS AMONG INTRODUCTORY STUDENTS NOT MAJORING IN COMPUTING, BY GENDER AND RACE

	Percent Among						
	All Students	*By Gender*			*By Race*		
	All (n=1510)	*Women (n=597)*	*Men (n=753)*	*Z*	*Minoritized (n=300)*	*Majority (n=1038)*	*Z*
Engineering	31.9	20.3	41.7	-8.36*	36.7	31.1	1.83
Math/Statistics	17.8	19.3	16.1	1.54	15.7	17.8	-0.85
Social Science	13.0	19.8	8.2	6.23*	10.0	14.2	-1.89
Biological Sciences	11.9	16.4	9.4	3.86*	11.3	12.9	-0.70
Business	11.0	9.9	11.6	-1.00	7.7	11.7	-1.97
Arts and Humanities	7.0	7.5	6.4	0.79	5.3	7.4	-1.26
Physical Sciences	5.5	5.5	6.1	-0.47	5.3	5.9	-0.39
Other	5.2	6.7	3.9	2.31	8.3	4.1	2.93*
Education	1.3	2.0	0.8	1.91	1.7	1.3	0.52
Health	1.1	2.0	0.5	2.55	0.7	1.3	-0.85

Note. *p<0.005. The significance level has been adjusted using the Bonferroni correction.

It is noteworthy that nearly half of students enrolled in intro computing courses are not themselves computing majors. While a small portion of non-computing majors are undecided (and may ultimately choose to major in computing), over 40% are majoring in other fields of study, the majority of which do not have a computing minor. Still, by enrolling in the intro course, students in all of these groups have an expressed interest in computing. Therefore, one way to broaden participation in computing may be to encourage students majoring in other fields to adopt a double major in computing. Doing so may have other implications for equity later in careers, as pursuing computing as part of a double major is associated with increased salaries after college [16, 17].

Instructors ought to be aware of the disciplinary diversity in their intro computing courses and consider pedagogical approaches that would appeal to their students. The possibilities for making interdisciplinary connections are vast, as evident by computing departments from a variety of institutions that have restructured their intro courses to highlight how computing skills can be applicable to art and design, biology, music composition, robotics, and digital media production [18, 19, 20, 21, 22, 23]. Bringing in content, examples, and projects that have multi-disciplinary ties can enhance learning and interest from non-computing majors as well as computing majors who may have a broader range of interests. In fact, there is evidence that students who take CS1 courses with interdisciplinary applications may earn higher course grades, be more likely to persist in the major, and have higher confidence in their computing skills relative to students in a more traditional CS1 course [24, 25, 26]. Indeed, the ACM Retention Committee recommends interdisciplinarity as a best practice for CS1 instructors and the National Center for Women in Information Technology has created EngageCSEdu, a clearinghouse of course materials and supporting research to assist instructors in infusing their courses with interdisciplinary content [27, 28, 29].

A second set of key findings relates to gender. Among the women enrolled in intro computing, only 38% were majoring in a computing field, relative to 61% among men. Further, among computing majors, women were significantly more likely to be double majors compared to men (9.9% vs. 5.5%), which is notable given that college men and women generally tend to double major at the same rates [30]. Also, among the women who were still undecided about their major (and could theoretically pursue computing), fewer than half indicated interest in selecting a computing major, compared to nearly three-quarters of undecided men. Women from all of these groups—those already pursuing a computing major, those pursuing a different major, and those who have not yet decided—represent an opportunity for instructors to cultivate the computing interests that led them to the intro course.

Turning our attention to URM students in intro courses, our findings suggest that, contrary to prior literature [e.g., 1], URM students in the intro course were actually more frequently majoring in computing than their counterparts from majority racial/ethnic groups. At a time when there is a nationwide push to diversify the computing field, the presence of a sizeable number of URM students in intro computing courses who plan to earn a computing degree is noteworthy—though URM students are still the minority of students in these courses, accounting for only about a quarter of all intro course students. While this presents a significant opportunity, it is important to remember that aspirations are not synonymous with degree attainment; across STEM fields, retention rates for URM students are significantly lower than for their white and Asian peers [31]. In light of this, future research should continue to examine the intro course experiences that predict retention in computer science for all students and URM students in particular. For now, this study expands upon existing literature on broadening participation in computing by providing a more detailed picture of the types of degrees students are pursuing as they enter the intro computing course.

V. LIMITATIONS AND FUTURE DIRECTIONS

While this paper contributes to our understanding of the disciplinary pursuits of intro computing students, it is important to consider several limitations. Given our survey response rate of 31%, some results may have been affected by non-response bias. Specifically, computing majors may have a greater propensity to respond to a survey about computing experiences. Thus, our findings may underestimate the participation of non-computing majors in intro computing.

Additionally, data for this study were drawn from fifteen institutions, all of which represent doctoral-granting research universities. Thus, we do not know the extent to which our findings are applicable to students at different institution types (e.g., liberal arts colleges, community colleges, etc.). Similarly, some of the findings may be related to the degree offerings at the specific participating institutions, which may look different than those offered at other institutions. Further, the institutions included in this research represent a self-selected sample where the computing department chair volunteered to be part of the BRAID project (though as noted earlier, diversity trends in computing at BRAID institutions closely mirror national trends). Still, student experiences at the BRAID schools may not be generalizable to other institutional contexts. Future research should examine this topic among students who attend varying institution types and in more controlled settings.

While this paper compared students on the basis of gender and URM status, we did not have a sufficient sample to disaggregate racial/ethnic groups. Sample size limitations also prevented us from fully exploring intersecting identities of gender and race. In particular, the findings for all women or all URM students may not hold true for URM women who are marginalized in computing due to both their gender and racial/ethnic identities. We mitigated this limitation as much as possible by running additional analyses comparing intersecting groups, though small sample sizes limit our ability to detect significant differences. While these data only allowed for a cursory examination of such differences, the results do point to variation in major/minor plans between URM women and other intersecting groups. Future research should utilize larger and more diverse samples to examine this topic with consideration of intersecting identities.

Finally, our findings descriptively point to both gender and racial/ethnic differences in the specific degree constellations that students pursue when they enter intro computing courses. Future research should examine these patterns longitudinally, considering implications for career outcomes and social stratification over time.

VI. CONCLUSION

Students enrolled in introductory computing courses hail from a wide range of disciplines, with some of these students still exploring their interests. This study helps to illuminate the range of majors and minors represented among students enrolled in these gateway courses and highlights important gender and racial/ethnic differences in these patterns. This information should enable instructors to better meet the needs of their students, recognizing the kinds of fields they are likely to pursue, and thus designing courses that have clear application to fields such as business, biological sciences, and social sciences. Clear interdisciplinary applications may be one way to recruit more students to computing degrees and to better engage students who can apply these skills to their non-computing major.

ACKNOWLEDGMENT

The data used in this study were provided by the UCLA BRAID Research Project, whose collection of these data was supported AnitaB.org and NSF (#1525737). Additionally, we are grateful to the students who took our survey, the members of the BRAID Research team who managed data collection, and reviewers who provided feedback to improve this research.

REFERENCES

[1] Computing Research Association, Generation CS: Computer science undergraduate enrollments surge since 2006, 2015, Available from: http://cra.org/data/Generation-CS/.

[2] National Academies of Sciences, Engineering, and Medicine, *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments*, Washington, D.C.: The National Academies Press, Available from: https://doi.org/10.17226/24926

[3] S. H. Zweben and E. B. Bizot, “2017 Taulbee Survey: Another Year of Record Undergrad Enrollment; Doctoral Degree Production Steady While Master’s Production Rises Again”. *Computing Research News*, vol. 30, no. 5, pp. 2-48, 2018.

[4] M. Benitez Jr., “Resituating culture centers within a social justice framework: Is there room for examining Whiteness?”, *Culture Centers in Higher Education: Perspectives on Identity, Theory, and Practice*, Lori Patton Davis (Ed.). Stylus Publishing, Sterling, VA, pp. 119-134, 2010.

[5] National Center for Education Statistics, “Digest of education statistics: Bachelor’s degrees conferred by postsecondary institutions, by race/ethnicity and field of study: 2014-2015 and 2015-2016 (Table 322.3) and Bachelor’s degrees conferred by degree-granting institutions, by field of study (Table 322.50)”, 2017. Available from: https://nces.ed.gov/programs/digest/2017menu_tables.asp [Accessed November 29, 2017].

[6] L. N. Cassel, ” Interdisciplinary computing is the answer: Now, what was the question?” *ACM Inroads*, vol. 2, no. 1, pp. 4-6, February 2011.

[7] K. J. Lehman, L. J. Sax, and H. Z. Zimmerman, “Women planning to major in computer science: Who are they and what makes them unique?” *Computer Science Education*, vol. 26, no. 4, pp. 277-298, January 2017. Available from: DOI: 10.1080/08993408.2016.1271536

[8] J. Margolis and A. Fisher, *Unlocking the Clubhouse: Women in Computing*, Cambridge, MA: MIT Press, 2003.

[9] L. C. Kaczmarczyk, A. Monge, J. Offutt, H. Pon-Barry, and S. Westbrook, “You should (and absolutely can) keep diversity in sharp focus during the enrollment surge”, *Research in Equity and Sustained Participation in Engineering, Computing, and Technology* (RESPECT’15), pp. 1-3, Charlotte, NC: Institute of Electrical and Electronics Engineers Inc. Available from: https://doi.org/10.1109/RESPECT.2015.7296492, 2015.

[10] J. M. Cohoon, “Recruiting and retaining women in undergraduate computing majors”, *SIGCSE Bulletin*, vol. 34, no. 2, pp. 48–52, June 2002. Available from: https://doi.org/10.1145/543812.543829

[11] L. J. Sax, “Year 1 first look: Research findings”, Presentation at the Annual BRAID Summit, Snowbird, UT, 2016.

[12] National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017*. Available from http://www.nsf.gov/statistics/wmpd/, 2017.

[13] B. Tamer and J. G. Stout, *Recruitment and Retention of Undergraduate Students in Computing: Patterns by Gender and Race/Ethnicity*, 2016. Available from: http://cra.org/cerp/research-findings/

[14] S. H. Zweben and E. B. Bizot, “2015 Taulbee Survey: continued booming undergraduate CS enrollment; doctoral degree production dips slightly,” *Computing Research News*, vol. 28, no. 5, pp. 2-60, May 2016.

[15] J. Cohoon, “An introductory course format for promoting diversity and retention”, *ACM SIGCSE Bulletin*, vol. 39, no. 1, pp. 395-399, March 2007.

[16] A. F. Del Rossi and J. Hersch, “Double your major, double your return?” *Economics of Education Review*, vol. 27, no. 4, pp. 375–386, August 2008.

[17] S. W. Hemelt, “The college double major and subsequent earnings,” *Education Economics*, vol. 18, no. 2, pp. 167-189, June 2010. Available from: DOI: 10.1080/09645290802469931

[18] P. Gestwicki and B. McNely, “Interdisciplinary projects in the academic studio”, *ACM Transactions on Computing Education*, vol. 16, no. 2, Article 8, pp. 1-24, March 2016. Available from: https://doi.org/10.1145/2732157

[19] I. Greenberg, D. Kumar, and D. Xu, “Creative coding and visual portfolios for CS1”, *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (SIGCSE’12), New York, NY: ACM Press, 2012, pp. 247-252.

[20] M. Guzdial, “Exploring hypotheses about media computation,” *Proceedings of the 9th International ACM Conference on International Computing Education Research* (ICER’13), New York, NY: ACM press, 2013, pp. 19–26.

[21] M. Haungs, C. Clark, John Clements, and D. Janzen, “Improving first-year success and retention through interest-based CS0 courses”, *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (SIGCSE’12), New York, NY: ACM Press, 2012, pp. 589-594.

[22] C. Kitts and N. Quinn, “An interdisciplinary field robotics program for undergraduate computer science and engineering education”, *Journal for Educational Resources in Computing*, vol. 4, no. 2, pp. 1-22, June 2004. Available from: https://doi.org/10.1145/1071620.1071623

[23] A. Misra, D. Blank, and D. Kumar, “A music context for teaching introductory computing”, *Proceedings of the 14th annual ACM SIGCSE conference on Innovation and technology in computer science education* (ITiCSE’09), New York, NY: ACM Press, 2009, pp. 248-252.

[24] Z. Dodds, R. Libeskind-Hadas, and E. Bush, “When CS 1 is biology 1: Crossdisciplinary collaboration as cs context”, *Proceedings of the 15th Annual Conference on Innovation and Technology in Computer Science Education* (ITiCSE’10), New York, NY: ACM Press, 2010, pp. 219–223. Availble from: https://doi.org/10.1145/1822090.1822152

[25] A. Forte and M. Guzdial, “Motivation and nonmajors in computer science: Identifying discrete audiences for introductory courses”, *IEEE Transactions on Education*, vol. 48, no. 2, pp. 248–253, May 2005.

[26] S. A. Rebelsky, J. Davis, and J. Weinman, “Building knowledge and confidence with mediascripting: A successful interdisciplinary approach to CS1”, *Proceedings of the 44th ACM Technical Symposium on Computer Science Education* (SIGSCE’13), New York, NY: ACM Press, pp. 438-488. Available from: https://doi.org/10.1145/2445196.2445342

[27] A. E. Monge, C. L. Fadjo, B. A. Quinn, and L. J. Barker, “EngageCSEdu: Engaging and retaining CS1 and CS2 students”, *ACM Inroads*, vol. 6, no. 1, pp. 6–11, March 2015. Available from: https://doi.org/10.1145/2714569

[28] NCWIT, *EngageCSEdu: Engage your intro students, share your course materials, and support diversity.* Available from: https://www.ncwit.org/project/engagecsedu.

[29] H. M. Walker, “ACM retention committee: Retention of students in introductory computing courses: Curricular issues and approaches”, *ACM Inroads*, vol. 8, no. 4, pp. 14–16, December 2017. Available from: https://doi.org/10.1145/3151936

[30] R. N. Pitt and S. Tepper, *Double majors: Influences, identities, and impacts (Prepared for The Teagle Foundation)*, Nashville, TN: The Curb Center, Vanderbilt University, 2010. Available from: http://www.vanderbilt.edu/curbcenter/cmswp/wpcontent/uploads/Teagle_Report_Final_3-11-13.pdf

[31] M. J. Chang, J. Sharkness, S. Hurtado, and C. B. Newman, “What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups”, *Journal of Research in Science Teaching*, vol. 51, no. 5, pp. 555–580, May 2014. https://doi.org/10.1002/tea.21146

Assessing the Efficacy of Integrating Computer Science, Math, and Science in a Middle School Sphero Robotics Summer Program

Talese Simley
Psychology
Spelman College
Atlanta, GA 30314, USA
tsimley@scmail.spelman.edu

Naja A. Mack
Computer Science
Morehouse College
Atlanta, GA 30314, USA
naja.mack@morehiouse.edu

Tristian Pittman
Computer Science
Morehouse College
Atlanta, GA 30314, USA
tristian.pittman@morehouse.edu

Chassidy Cook
Computer Science
Morehouse College
Atlanta, GA 30314, USA
chassidy.cook@morehouse.edu

Robert Cummings
Computer Science
Morehouse College
Atlanta, GA 30314, USA
robert.cummings@morehouse.edu

Dekita Moon
Computer & Information Science & Engineering
University of Florida
Gainesville, FL 32611, USA
dekita@ufl.edu

Kinnis Gosha
Computer Science
Morehouse College
Atlanta, GA 30314, USA
kinnis.gosha@morehouse.edu

***Abstract*—There have been many discussions on the significant lack of representation of minorities in computing. Research suggests that an attributing factor to this deficit is a lack of exposure to computing, computing careers, and underrepresented role models. Introducing underrepresented minority students to hands-on computer science activities at an early age is believed to improve students' attitudes in computing. Increasing students' computing attitudes may help encourage participation and minimize deficiencies in retaining underrepresented minority computing students. An interactive summer program was implemented to teach computing to middle-school-aged underrepresented minority students through a unique curriculum using Sphero robotic balls and math and science concepts. Students were assessed to determine the programs' effectiveness in increasing computing attitudes and academic performance of math and science. Results showed that the intervention significantly improved students' academic performances and their confidence in deciding a future career path. Further evaluation is needed to explore longitudinal effects of the varying levels of math, science, and computing rigor used within this intervention. Findings from this study provide recommendations for how to implement computing practices within the existing math and science curriculum in prospective initiatives.**

***Keywords*—computer science, outreach, math, science, robotics, middle school**

I. Introduction

Introducing computer programming to students at an early age aids in the development of transferable skills that will bridge the racial and educational divide [1]. In 2017, only 8% of African Americans, who were enrolled at a 4-year institution, graduated with a degree in computer science. The numbers only get smaller as these students matriculate through graduate school and/or pursue a doctorate [2]. With the growing pervasiveness of technology in our daily lives, coding is becoming a fundamental skill for learning; comparable to skills such as reading, writing, and arithmetic. Over the last several years, 58% of all new jobs in STEM are in computing, but only 10% of students that majored in STEM fields received a degree in computer science [3]. The development and retention of programming skills begin with teaching and providing tasks that encourage more complex diagnostic thinking.

Coding has been proven to develop skills in math, reading, logic, computational-thinking, and applied sciences [4], [5]. These authors believe there is a way to help students understand the underlying computing skills in conjunction with how they process the information on their own. Exposing the students to rigorous and relevant adaptive learning may lead to higher retention of student engagement/involvement in computing. Literature suggests that robotics is becoming a more effective way to engage students with coding and programming. Additionally, robotics helps reinforce soft skills such as teamwork, critical and creative thinking, problem-solving, and algorithmic patterned thinking [6]. Robotic-based programs are often effective at retaining a students' computing knowledge for those who have never programmed before.

The participants in this study are unique because underserved minority middle schoolers are often overlooked and underrepresented when it comes to computing research. Student engagement in computer programming manifests in behaviors that are observable and recurring in middle school students [7], [8]. These behaviors result in:

- Engaging in often short-lived, intense interests
- Preferring interactions with their peers
- Preferring active to passive learning

Previous studies have shown that adolescent students retain

978-1-7281-7172-2/20$31.00 ©2020 IEEE

computing knowledge more effectively when computing is taught through a visceral, "hands-on learning experience" [9]. Implementing teaching strategies, such as problem-based learning within a STEM curriculum, may enhance students' desire to understand the world around them and engage them in classroom instruction [10]. Skills like problem-solving literacy, creativity, and motivation are positively influenced when children access technology in their learning environments. Also, using technology as an instructional tool enhances children's learning and educational outcomes [11]. More specifically, introducing computer science to underrepresented minorities at an early age can influence more positive attitudes towards computing; consequently, attracting more diverse talent to the field of technology and computing [12].

II. BACKGROUND/RELATED WORK

While some minority groups are well represented in technology, others are almost nonexistent, such as African Americans [1], [3], [5], [13]. Connecting with the next generation of minority talent means early introduction, easily accessible resources, and providing a hands-on learning experience. An early introduction to computing may increase the participation of underrepresented groups in the tech field because experiences and exposure in childhood affect desired careers in adulthood [13], [14]. To bridge the gap, which may result in upward mobility, it is necessary to effectively engage racial and ethnic minority groups and other vulnerable and underserved populations, with the help of outreach/bridge programs.

Many programs, similar to ours, cater to fostering awareness and passion for computer science amongst adolescents and/or minorities. An example study was conducted at the Department of Computer and Cyber Sciences at the United States Air Force Academy. They examined how accessibility, early introduction, and hands-on experiences increased students' computing attitudes. They tested a proposed introductory programming curriculum that aligned with the College Board's Advanced Placement Computer Science Principles (AP CSP) course for the Sphero SPRK+. The SPRK+ is the predecessor to the newer Sphero Bolt model used in this study. The purpose of the study at the Academy was to increase student engagement and to "motivate and facilitate the effective learning of introductory programming and problem-solving skills" by using robotics [15].They tailored each lesson plan utilizing a problem-solving methodology called UDIT (Understand – Design – Implement – Test). The UDIT methodology provides specific tasks, goals, and techniques for each of the phases. In addition to similar pedagogies, the curriculum at the academy covered topics such as, but not limited to, the following:

- **Introduction to Programming the SPRK+ using Blocks:** To introduce the students to creating, editing, and running programs in the Blocks canvas, this activity used the Sphero Block activities to teach the Roll, Stop, Delay, Spin, Main LED, Speak, Fade, and Strobe.
- **Selection, Loop Forever, Sensor Data, and Comparators:** To introduce selection and iteration control logic as well as yaw, roll, and pitch sensor readings from the SPRK+ gyroscope.
- **Gyroscopes, Normalization, Lights, and Math Functions:** To develop an understanding of what a gyroscope does and how to normalize data from one range to another.
- **Variables, Operators, Loop Until, Randomization, and Haptic Feedback:** To extend the students' understanding of key programming concepts and techniques, this lesson used the Sphero Blocks 4 activity, from the Sphero website, to teach the concept and use of variables, math operators, loop until construct, and random numbers generation. The Blocks 4 activity had students develop a Hot Potato game which introduced them to haptic feedback by using raw motor settings to vibrate the SPRK+.

The objective of this effort was targeted toward the development of a theme-based curriculum using the Sphero SPRK+ that would effectively achieve the required learning while increasing student interest and engagement, similar to our own course's goal. 63.2% of their students agreed that the activities were interesting and engaging and are helpful for learning how to program and 26.3% of their students strongly agreed that the activities were interesting, engaging and helpful for learning how to program [15].

These results support the idea that younger students are prone to lack the patience and abstract thought necessary to complete activities such as programming [4]. On the other hand, waiting until college to address the issue of minorities in computer science is non-beneficial. Therefore, using robotics early on can provide experience to improve computer science grades in the future [1]. The use of robotics can provide a visceral, "hands-on learning experience" for students who have never programmed before; this is essential in the retention of the students [16]. This is why outreach programs introduce minorities to computing and the tech industry. Outreach programs create an environment where students can learn and retain. Implementing teaching strategies, like problem-based learning within a STEM curriculum, may enhance students' desire to understand the world around them and engage them in classroom instruction. This mitigates the susceptibility of students becoming impatient and creates an environment that supports abstract thinking [6]. Skills like problem-solving literacy, creativity, and motivation are positively influenced when children access technology in their learning environments. Also, using technology as an instructional tool enhances children's learning and educational outcomes [7]. More specifically, introducing computer science to minorities at an early age will not only attract more diverse talent to the field of technology and computing, but will also aid with the retention of said children [17].

III. PROGRAM OVERVIEW

The research team was given an opportunity to participate in a summer program dedicated to the enrichment of gifted and high-achieving students within a local public school district. The goal of this program was to expose the students to the world of coding while integrating relevant science and math concepts. The program provided various courses that were geared towards STEM and fine arts. In this course, rising 6th - 8th graders were introduced to the world of coding, via the Sphero Bolt which is an app-enabled robot. The Sphero Bolt application allows users to code in three separate ways: generate drawings that the robot executes, drag and drop blocks of code to create programs, or write JavaScript programs for execution. For this course, the students began creating programs with the drawing function so they could learn how to manipulate the robot. After becoming familiar with Sphero's functionalities, students were restricted to only using the "drag and drop" method with blocks of code to complete activities for the remainder of the summer program.

The Sphero team (the instructors and observers) began prepping for this course by developing and practicing lesson plans three weeks before the summer program began. In the preparation phase, the Sphero team created PowerPoint slides, worksheets, quizzes on Kahoot! (a game-based learning platform), and Sphero Bolt activities for each lesson. These instructional tools were a combination of projects found on the Sphero website, the Atlanta Public Schools curriculum, and original ideas created by the research team. The content for each project on the Sphero website included instructional materials that were customized to lessons along with the required materials to complete the activity. Materials used during the program included tape, protractors, ramps, string, wooden sticks, and a pool of water.

The instructors practiced and reviewed the lessons and activities multiple times with other members of the lab. During these practice sessions, the instructors presented their instructional materials and received feedback on the content, rigor, appropriateness, and flow of the presentation. Each presentation was followed by a brief review period; identical to the review period students participating in the workshop would experience. The review sessions included worksheets or "Kahoot!" activities to recap the daily lesson. These instructional rehearsals concluded with the team reviewing the Sphero activity for the day in which feedback was obtained and unforeseen challenges were discussed.

A. Structure

The course lasted for four weeks starting on Monday and ending Friday, from 11:30 a.m. to 3:30 p.m. As stated previously, the goal of this program was to expose the students to the world of coding while integrating relevant science and math concepts. The first week of the program focused on Sphero basics, the second focused on math concepts, and the third week focused on science. The students were assigned to teams and each team was assigned an observer to help them during the classes. Each day, the students were introduced to a new topic with a corresponding activity using the Sphero robots. At the beginning of each week, students were given an assessment with content related to the lesson being taught that week. The same assessment was administered at the end of the week. Students completed all the assessments before going to lunch to maintain their interest and limit interruptions and student distractions. Conducting all assessments before lunch also gave the instructors time to briefly look over the results and alter the lesson plan as needed to ensure that the students were gaining an understanding of the lesson content.

Lessons began immediately after their lunch. Each lesson included a PowerPoint and a brief review session, which involved completing a worksheet or a Kahoot! quiz. Overall, the lesson and review period lasted between 45-60 minutes. The lesson and review period was followed by an activity. Each Sphero activity maintained relevance to reinforce and build upon the topic of that day. For example, the review session for the angles math lesson consisted of students creating and identifying angles and shapes on a worksheet. The activity was then followed by students recreating the angles using the Sphero balls. At the end of each class, notes and comments were collected from students with a brief reflection period. This gave students a chance to voice their thoughts about the lesson and activity for that day.

B. Sphero Basics

The first week consisted of ice breaker challenges, grouping the students, and teaching the young coders how to utilize and control the Sphero balls. For the control activities, the students learned how to aim and drive the Sphero Bolt robot. Then, they moved into block coding. Activities, such as bowling and soccer were integrated with each lesson to ensure that everyone had grasped the concept. Since time was limited, students were taught the foundational necessities, including but not limited to, changing the light, adjusting the speed, and aiming the ball. Students also participated in a reflection period at the end of each day, where the most insight was gained on their comfortability with the functions of the robot. An analysis of the reflection responses showed that most of the students felt comfortable controlling the ball within the first day and a half, with only one student having prior experience with Sphero. After three full days, all students reported that they felt comfortable controlling the Sphero balls. The students went from driving the balls to controlling the ball using block coding. The different functionalities were explained and the effects of each block were displayed in the Sphero app, by going through each tab.

C. Math Week

The second week was the start of math week. Beginning on Monday, students were asked to complete a pre-assessment which consisted of 15 questions. Students were given 45-60 minutes to complete the pre-assessment. The lessons consisted of assorted angle questions (e.g. finding the missing angle, labeling the angles, and finding the relationships between two angles), solving algebraic expressions, solving systems of equations (using substitution), and labeling shapes. After the lunch break, if the quizzes showed a high number of students struggling on a topic, the lesson plan for that day would be adjusted to their levels of understanding. Some of the activities for this week included creating and completing mazes, completing a list of shapes, and programming their own hot-potato game with the Sphero. At the end of the week, students completed the post-assessment and were given time to ask any additional questions or finish any activity of their choice from that week.

D. Science Week

The third week was dedicated to science concepts. The pre-assessment was administered on Monday of that week before lunch and students were again, allotted 45-60 minutes. The lessons for this week covered topics that included learning basic physics concepts (i.e. velocity, time, speed, distance, and acceleration), object motion concepts (Newton's Laws, inertia, momentum, force), and friction. The activities for this week also corresponded with the lessons. During this week, an example of a class day would include learning a few basic physics concepts and having a review activity. In relation to the lesson for the Sphero activity, students used formulas to determine the time and speed needed for the robot to go a certain distance and hit a designated spot. Most of the activities for this week incorporated the manipulation of formulas to complete the necessary activities and challenges.

E. Final Challenge

The final challenge was prepared for the last week and conducted on the last day of the program. It encompassed the math and science concepts learned from all three weeks of the course. With this challenge, students were encouraged to work within groups, without the assistance of the instructors and observers. The activity was designed for the different groups of students to compete against each other in different stages of the final challenge, which varied in difficulty. There were four stages in all, covering some of the most challenging, but relevant, concepts discussed during the program. All four stages of the final challenge included an assessment and an activity. The first task in each stage was a paper assessment that the students were allowed to complete as a team. The first group to answer the question(s) correctly was able to start the activity first. Each team had to answer the question(s) correctly to move on to the next activity. The four activities included in the final challenge are as follows:

- Create a shape - Students programmed their ball to make the shape listed on the activity card. First, they were given time to code the shape using the Sphero app. Once, they were ready, they were given paint to dip their ball in and were asked to run the code and place the ball on large white paper so everyone could see the shape that the painted Sphero ball created.
- Bowling - Each team took turns to see who could knock down the most pins with their ball using code only.
- Maze race - A maze was created by the instructors using tape and Legos. For this activity, the students programmed the robot to see who could get the farthest in the maze.

IV. METHOD

A. Participants

All participants were students in this summer program and a part of the Atlanta Public School System (APS). Students in the program were recruited based on the Georgia Board Rule 160-4-2-.38 [18] which says, "a gifted and talented student is defined as one who "demonstrates a high degree of intellectual and/or creative ability(ies), exhibits an exceptionally high degree of motivation, and/or excels in specific academic fields, and who needs special instruction and/or special ancillary services to achieve at levels commensurate with his or her ability". In addition, some students were financially able to attend, while others were given a scholarship.

The targeted participants were rising 6th through 8th graders. Their ages ranged from 10 to 13 years old with the average age of 11 years old. There were a total of 23 students and all of the students identified as African American except for one, who identified as White. Out of the 23 students, 14 were rising 6th graders, one student was a rising 7th grader, 4 students were rising 8th graders, and 4 did not specify. 17 of the students identified as a male and 6 as female.

B. Participants Previous Knowledge of Curriculum

For the scope of this study, we will only focus on the mathematics portion of the Atlanta Public Schools curriculum. Since the majority of the students had not yet completed 6th grade, the standards for 5th grade were added.Those who completed the 5th grade the following school year were registered as 6th graders. As mentioned earlier, most participants were on their way to 6th grade so they had yet to be exposed to any of the 6th-grade curricula. The standards for 8th grade were added to show that the Sphero program also covered some concepts that are not taught until the 8th grade. According to the Atlanta Public Schools mathematics curriculum map [18], [19]:

Upon completion of the 5th-grade, students should be able to...

- Convert like measurement units within a given measurement system.
- Geometric Measurement: understand concepts of volume and relate volume to multiplication and division.

  Upon completion of the 6th grade, students should be able to...
- Apply and extend previous understandings of arithmetic to algebraic expressions.
- Reason about and solve one-variable equations and inequalities.
- Solve real-world and mathematical problems involving area, surface area, and volume.

  Upon completion of the 7th-grade, students should be able to...
- Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
- Analyze proportional relationships and use them to solve real-world and mathematical problems.

- Use properties of operations to generate equivalent expressions.
- Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
- Draw, construct, and describe geometrical figures and describe the relationships between them.
- Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

Upon completion of the 8th-grade, students should be able to...

- Understand and apply the Pythagorean Theorem.
- Use functions to model relationships between quantities.
- Understand the connections between proportional relationships, lines, and linear equations.
- Analyze and solve linear equations and pairs of simultaneous linear equations.
- Understand the connections between proportional relationships, lines, and linear equations.
- Understand congruence and similarity using physical models, transparencies, or geometry software.

C. Research Design

The research component intended to observe middle school students' attitudes towards computing. There were two research methods used: naturalistic observation and an online survey. Before participating, parental/guardian consent forms were distributed and returned to each student. Thirteen student participants completed both the pre-survey and the post-survey in its entirety. Participants completed a pre-survey at the start of the program and a post-survey at the end. The survey consisted of four parts: (1) demographics; (2) computing attitudes; (3) career decision making; (4) and academic resilience. The demographics section collected participants' age, sex, last completed grade level, STEM grades, and future career goals. Participants were asked what computer science meant to them and to describe their previous involvement with coding and/or Sphero (if any).

Computing attitudes were investigated using an adapted version of the Subjective Science Attitude Change Measures–Student Version [16], [17], a 23-item 7-point Likert measurement scale designed to predict motivation and confidence in science. The adoption of the scale allowed science questions to remain STEM-focused but ensured students understood the term computing (computer science and computational thinking) and to incorporate the subjects while answering the questions. Career decision making confidence was examined using the 25-item, 5-point Likert scale Career Decision Making Self-Efficacy Scale-Short Form developed by Betz, Klein, and Taylor [20]. The Academic Resilience Scale developed by Cassidy [21] was used to measure students' grit during academic hardships. The Academic Resilience Scale has 30 items and uses a 5-point Likert scale to answer likelihood questions about how one would react to a scenario when one is failing a course. Naturalistic observations were coded using an inductive thematic analysis [22]. Open-ended questions in the demographic section of the pre-survey and post-survey were analyzed using an inductive-deductive thematic analysis [22]. All scales were analyzed using the recommended descriptive statistics. Three paired-sample t-tests were performed to compare the results of each scale during the pre-survey to post-survey. Individually paired sample t-tests were conducted to compare the pre-post math and science assessments.

V. RESULTS

Before each week started, students were asked if they had ever heard of the concepts or topics that would be discussed. The majority of the class claimed to not know most of the concepts mentioned. After taking both the pre-math and science assessments, the students confirmed that they did not know most, if not all, of the information presented on the assessment.

A. Pre vs Post Math Test

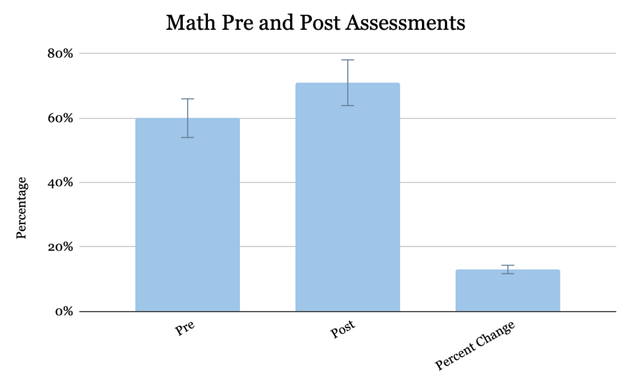


Fig. 1. Math Pre and Post-Assessments

The math assessment was first in the sequence of assessments given during the summer program. As mentioned earlier, both the pre and post-assessments consisted of 15 questions that ranged in difficulty and topic, related to mathematics. The post-assessment consisted of 15 of the same or similarly styled questions. In Figure 1, there was an improvement from the pre- to post-assessment.

The math assessment scores also showed significant growth from an initial average of about 60% to an average of about 72% for the final assessment (see Figure 1). The p-value equals 0.0146 ($t = 2.79$), which is considered statistically significant. The average percent change was about 13%. All lessons showed significant score improvements, respectively (see Figure 2).

In Figure 2, the graph displays the math pre and post-assessments based on the lesson. The assessment was split up by angles, equations, and shapes. The Angles lesson had significant score improvements, with a pre-assessment average of 68% and a post-assessment average of 88%. The Shapes lesson also had significant score improvements, with a pre-assessment average of 63% and a post average of 78%. Both p-values (0.007, t=3.01 and 0.048, t=1.83, respectively) proved

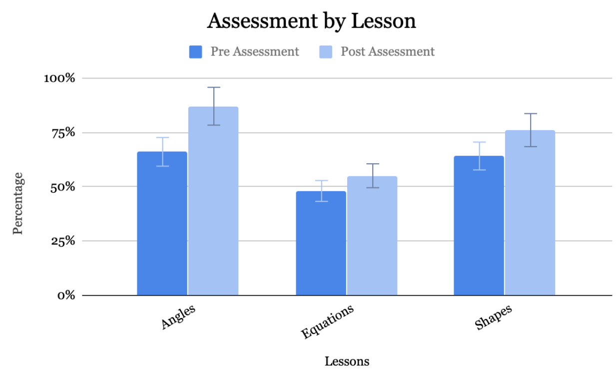


Fig. 2. Math Assessments by Lesson

Fig. 4. Science Assessments by Lesson

to be statistically significant. For the Systems of Equations lesson, participants did not perform significantly better from the pre-assessment(45% average), to the post-assessment(58% average). The p-value equals 0.083 (t=1.49), which is also statistically significant.

1) Pre vs Post Science: The science assessment was the second assessment given. Similar to the math assessment, both the pre- and post-assessments for science ranged in difficulty and topic. As shown in Figure 3, there was considerable improvement from the pre to post-assessment.

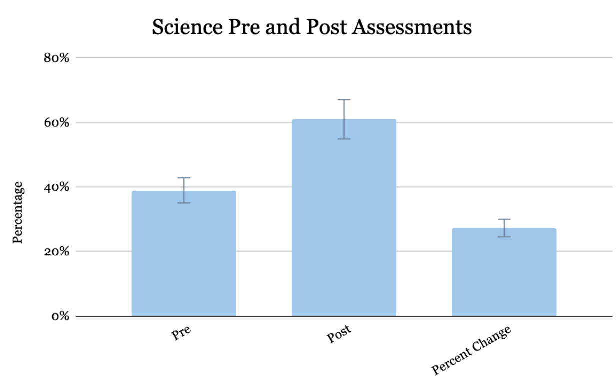


Fig. 3. Science Pre and Post Assessments

Based on this data and the students' observed reaction, they were engaged and retained quite a bit of information. The table below shows the results from the pre- and post-science assessments, in addition to the average percent change from the pre to the post. T-tests were run on all presented data and the results for both the pre and post-assessments were statistically significant, yielding a p-value of .0017. The pre-assessment had an average of about 39% with the post-assessment having an average of about 63%. On average, students did 28% better on the post-assessment and 100% of the students scored better.

Figure 4, examines the science pre and post-assessments based on the lesson. The "S, T, D, V, A" section refers to the basic physics concepts covered: speed, time, distance, velocity, and acceleration. There was a separate section on friction. The p-values for both of these sections showed to be statistically significant with the physics concepts having a p-value of 0.0172 (t = 2.73) and the friction section had a p-value of 0.0002 (t = 5.01). The "Newton, I, M, F" section refers to object motion concepts such as Newton's Laws, inertia, momentum, and force, which held a p-value of 0.0635 (t = 2.03).

Similar to the overall analysis of the pre and post-assessments, there was a 100% increase from pre to post for all sections. Based on the results, students retained the most information from the friction lesson, with an average increase of 48% from pre to post.

Observations were conducted during the assessment process. The assessment format remained constant between the math and science assessments, however, the science assessment had a few more questions. Generally, students were extremely distracted, discouraged, and/or disengaged during all assessments. As a whole, students asked more questions during both math assessments compared to both science assessments.

B. Pre/Post Survey

Thirteen of the twenty-one students completed both the pre-survey and the post-survey. A paired-samples t-test was conducted to determine the program's significance in increasing students' career decision making self-efficacy, computing attitudes, and academic resilience. A noticeable increase in career decision making self-efficacy was prevalent from the pre-survey ($M = 3.75$, $SD = 0.88$) to the post-survey ($M = 4.15$, $SD = 0.72$), $t(11) = 1.976$, $p = .037$ (upper tailed). There were no statistical differences in computing attitudes or academic resilience.

C. Observation/Reflection

There was a substantial knowledge gap with math concepts when compared to science concepts. Because of this, the instructors had to continuously stop and make sure everyone was caught up or not getting too far behind. To combat this, the instructors took a different approach. For example, when systems of equations were being taught, instructors stopped to break the students into smaller groups to teach the concepts on a more intimate level. During the reflection period, 100% of the group agreed that systems of equations were the most challenging lesson up to that point and that the students, overall did not enjoy it. The importance and the purpose of math week altogether came up during reflection often.

During science week, students were noticeably more engaged, most likely because the concepts were more applicable to their experiences. The students were more interested and enthusiastic during this week. This could be due to a number of factors, such as increased comfort levels with the instructors as well as the other students, becoming familiar with the schedule and/or incentives being introduced. Although the results of the science pre-assessments displayed students' lack of knowledge, their post-test and behavior in class showed their alertness and ability to retain the information from the week.

Throughout the weeks, there was an increase in computing jargon being used. Students began using the correct terminology when trying to explain their code. There were also connections being made when they were shown code in Python and compared it to their block coding. The instructors also used the class period to review simple Python code with the students. This code resembled the students' code and helped them to be able to identify each part of the code themselves.

Overall, the students requested more activity time and less lesson time. Towards the end of the program, they realized the role each lesson played in the activity and why it was necessary. During reflection, most stated they were glad they were taught the lessons that correspond to the activities.

VI. DISCUSSION

The summer program was designed to increase students' computing interests, attitudes, and their performance in STEM through interactive applications. Increasing students' computing attitudes is suggested to increase the likelihood that students would pursue careers in computing [12], thereby, supporting the demand for computing careers [3]. This program was successful at strengthening students' confidence in identifying and choosing careers, but it did not necessarily steer students towards computing. There was no significant change in students' attitudes and interests in computing.

The program was highly effective at increasing students' math and science comprehension and performance. To explore these findings, it is necessary to identify how the program directly addressed working with students at the middle school level. Adolescent students respond best to active learning, as active learning often incorporates peer interaction and short lesson plans to hold short-lived interests [7], [8]. Students were notably more engaged in science lessons than math lessons. Students showed more engagement for the physics science lesson than math courses due to the clear, correlating nature of the lesson and activity. This also supports literature suggestions that adolescent students respond strongly to applicable learning [7], [8]. Students were easily able to relate the physics concepts to reality during the lesson whereas math lessons tended to be a bit more abstract and related less to the activity. Consequently, a few students questioned the purpose of the math lessons. The program's use of Sphero robotics facilitated the recommended hands-on learning experience within all activities as students had to program and control their own balls as well as work in teams [9].

Literature suggests that instructing computing at an early age has positive effects on math and applied science performance and retention [23]. The findings directly support the literature, all but one lesson (Systems of Equations) significantly increased students' performances in math and science. As computer programming skills were not directly measured, it is not clear of the impact the program had on simple fundamentals of computing; however, there were findings observed regarding the students' behavior including: computing belongingness through accurate use of field-specific terminology and the ability to identify and locate important content within a few simple lines of code written in Python.

A. Limitations

There were a few limitations in the data collection of the study. Naturalistic observations were recorded, however, there was no validated framework used to deductively observe behaviors. Only thirteen of the twenty-three students participated in the summer program completed the surveys, which causes the conclusion to be less persuasive although the results were based on the calculation of t-statistic and p-value. Additionally, multiple validated scales were used to measure different academic and computing metrics; however, there was no factor analysis performed to eliminate any correlating or overlapping items. Finally, there were no test groups to independently determine the cause of the math and science performance increase. Thus, it is unclear if the increase in math and science scores was directly from the lecture, the activity, or a combination of both. It is also important to note that most students had not been introduced to the system of equations as a math subject prior to this program.

B. Significance of Small Samples and Short Programs

One of the main concerns that stems from utilizing small samples is that it would not be able to predict for the whole population, thus causing higher variability leading to results that are less reliable. However, several studies have been run that show that minorities learn and retain more information in smaller classroom settings, at all ages [24]. The overall goal of the program is to increase achievement amongst underrepresented students and to close achievement gaps between advantaged and disadvantaged students. Therefore, studies and research are in an environment similar to the overall goal. The results in the present study are significant; however, we do acknowledge that larger numbers are needed to generalize.

VII. CONCLUSION

The work performed is important,because it exposes middle school underrepresented students to computing through active learning grounded in existing STEM curricula. Though this program was not effective at increasing computing attitudes at large, it showed promising results in terms of developing students' sense of belonging in the computing field with programming and robotics comfort. The program also served as an effective STEM performance initiative that integrates much-needed computing principles to middle school students. In addition, students that participated in the program will start the year off ahead of their peers. Other research was conducted with this study focusing on developing undergraduate students into STEM near-peer instructors as well as more in-depth observation of how middle school students interact with robotics and learn primary.

A. Strengths

Overall, the Sphero summer program was successful, for both the instructors and students. The most positive result was that the students received the information quickly and retained it. As time progressed, all of the students were more comfortable talking with and asking the instructors for help if they needed further instruction or did not understand. The instructors all had different teaching methods, which gave the kids a tailored learning experience. For the students who were challenged the most, an instructor would break down the lesson to the simplest concept and build on the experiences of that student. For the students that picked up things fairly quickly, an instructor would extend the lesson to keep the fast learners engaged and connected with the group.

The instructors also did a thorough job of planning the lessons and keeping a consistent schedule. Students were able to get into a rhythm, making it easier for the instructors to move through the lesson without complications. This allowed instructors to pay closer attention to what helped the students learn. For example, the instructors realized that when the students felt more comfortable with the lesson and activities they became more creative. The instructors took the initiative to change the activities and lessons to give students more opportunities to use that creativity.

B. Implications

Even though the sample size was small, this work is important. This program, along with past similar programs, allow others to learn and build their own programs or workshops. This program was just one piece of a larger puzzle the lab is working to complete. The lab has been invited back to the same summer program to run another Sphero course with more students. In addition, many other schools, summer programs, and development centers have inquired about bringing one of the Sphero workshops to their students.

REFERENCES

[1] T. Shamma, "Coding while black: Hacking the future of the tech industry," *NPR*, Jun 2016. [Online]. Available: https://www.npr.org/sections/codeswitch/2016/06/04/480630726/coding-while-black-hacking-the-future-of-the-tech-industry

[2] "Bachelor's degrees earned by african americans, by major." [Online]. Available: https://www.aps.org/programs/education/statistics/aamajors.cfm

[3] "Code.org," http://www.code.org, 2019.

[4] E. Kazakoff and M. Bers, "Programming in a robotics context in the kindergarten classroom: The impact on sequencing skills," *Journal of Educational Multimedia and Hypermedia*, vol. 21, no. 4, pp. 371–391, 2012.

[5] E. Schanzer, K. Fisler, S. Krishnamurthi, and M. Felleisen, "Transferring skills at solving word problems from computing to algebra through bootstrap," in *Proceedings of the 46th ACM Technical symposium on computer science education*. ACM, 2015, pp. 616–621.

[6] A. Eguchi, "Educational robotics for promoting 21st century skills," *Journal of Automation Mobile Robotics and Intelligent Systems*, vol. 8, no. 1, pp. 5–11, 2014.

[7] S. D. Branting, "Hic sunt dracones-filling in the gis map for the k-12 classroom," *Journal of the Association for History and Computing Online Journal*, vol. 11, 2008.

[8] M. Ioannou and T. Bratitsis, "Utilizing sphero for a speed related stem activity in kindergarten," in *Hellenic Conference on Innovating STEM Education*, 2016.

[9] B. S. Fagin, L. D. Merkle, and T. W. Eggers, "Teaching computer science with robotics using ada/mindstorms 2.0," in *ACM SIGAda Ada Letters*, vol. 21, no. 4. ACM, 2001, pp. 73–78.

[10] W. Havice, "The power and promise of a stem education: Thriving in a complex technological world," *The overlooked STEM imperatives: Technology and engineering*, pp. 10–17, 2009.

[11] M. Resnick, "Sowing the seeds for a more creative society." *Learning & Leading with Technology*, vol. 35, no. 4, pp. 18–22, 2008.

[12] K. Gosha, T. Ridley, E. Holmes, K. Womack, and J. Scott, "Introduction to computer science for urban african american students using sphero robotics workshop," in *Proceedings of the SouthEast Conference*. ACM, 2017, pp. 252–254.

[13] K. Cannon, M. A. LaPoint, N. Bird, K. Panciera, H. Veeraraghavan, N. Papanikolopoulos, and M. Gini, "No fear: University of minnesota robotics day camp introduces local youth to hands-on technologies," in *Proceedings 2006 IEEE International Conference on Robotics and Automation, 2006. ICRA 2006.*, 2006, pp. 363–368.

[14] P. Lorain, "Brain development in young adolescents, good news for middle school teachers," *National Education Association*, 2002.

[15] S. M. Hadfield, J. T. Raynor, and M. D. Sievers, "Engaging secondary and post-secondary students to learn and explore programming using a theme-based curriculum and the sphero sprk+ robot," in *Proceedings of the 23rd Western Canadian Conference on Computing Education*, ser. WCCCE '18. New York, NY, USA: ACM, 2018, pp. 2:1–2:6. [Online]. Available: http://doi.acm.org/10.1145/3209635.3209643

[16] M. K. R. Stake, Jayne E., "Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation," *Journal of Research in Sciwence Teaching*, vol. 38, no. 10, pp. 1065–1088, 2001.

[17] E. D. Deemer, J. L. Smith, D. B. Thoman, and J. P. Chase, "Precision in career motivation assessment: Testing the subjective science attitude change measures," *Journal of Career Assessment*, vol. 22, no. 3, pp. 489–504, 2014.

[18] "Mathematics georgia standards of excellence (gse) k-5." [Online]. Available: https://www.georgiastandards.org/Georgia-Standards/Pages/Math-K-5.aspx

[19] "Mathematics / curriculum maps." [Online]. Available: https://www.atlantapublicschools.us/Page/50330

[20] N. E. Betz, K. L. Klein, and K. M. Taylor, "Evaluation of a short form of the career decision-making self-efficacy scale," *Journal of Career Assessment*, vol. 4, no. 1, pp. 47–57, 1996.

[21] S. Cassidy, "The academic resilience scale (ars-30): A new multidimensional construct measure," *Frontiers in psychology*, vol. 7, p. 1787, 2016.

[22] J. Fereday and E. Muir-Chochrane, "Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development," *International Journal of Qualitative Methods*, vol. 5, no. 1, pp. 80–92, 2006.

[23] A. Sullivan and M. U. Bers, "Robotics in the early childhood classroom: learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade," *International Journal of Technology and Design Education*, vol. 26, no. 1, pp. 3–20, 2016.

[24] B. Nye, L. V. Hedges, and S. Konstantopoulos, "Do minorities experience larger lasting benefits from small classes?" *The Journal of Educational Research*, vol. 98, no. 2, pp. 94–100, 2004.

A Lightweight Intervention to Decrease Gender Bias in Student Evaluations of Teaching

Susan Fisk
Department of Sociology
Kent State University
Kent, Ohio, USA
sfisk@kent.edu

Kathryn T. Stolee
Department of Computer Science
North Carolina State University
Raleigh, NC, USA
ktstolee@ncsu.edu

Lina Battestilli
Department of Computer Science
North Carolina State University
Raleigh, NC, USA
lbattestilli@ncsu.edu

***Abstract*—Women are underrepresented as instructors in engineering, computing, and technology classes. One factor that disadvantages women in the classroom are student evaluations of teaching (SETs), as research finds they contain significant gender bias. This may contribute to the dearth of women in computing education, as SETs are used in decisions about contract renewals, hiring, tenure, and promotion. The double-bind is one cause of gender bias in SETs, meaning that it is more difficult for women than for men in leadership positions (such as being a professor) to be perceived as both competent and likable. We examine a lightweight intervention's impact on gender bias caused by the double-bind. Specifically, we conducted a field experiment in which the woman professor of a CS1 class for non-majors gave students in the intervention condition additional, positive exam feedback via email. We hypothesized this would increase students' perceptions of the professor's likability, which would then increase her SETs. We find that the intervention increased top-performing students' ratings of the professors' likability. We also find that the professor received significantly higher SETs the semester she sent the intervention emails. While women should not have to alter their behavior to accommodate students' gender biases, this intervention may be a useful survival strategy for women impacted by gender bias in SETs.**

Keywords*— *gender bias in teaching, CS1 education, student evaluations of teaching

I. Introduction

Despite efforts to increase the number of women in STEM (Science, Technology, Engineering, and Math), women constitute only 20.8% of Computer Science (CS) faculty across all faculty positions [1]. While many factors contribute to this dearth of women, student evaluations of teaching (SETs) are one source of disadvantage, as they contain significant gender bias [2] [3]. Gender bias in SETs may contribute to women's under-representation in engineering, computing, and technology classrooms, as SETs are used in in decisions about contract renewals, hiring, tenure, and promotion [4].

In an effort to decrease gender bias in SETs, we evaluate the effect of a lightweight intervention. Students in the intervention group received their exam score in an email from the professor with additional, positive feedback that varied based on their exam performance. Top-performers (those with an exam score in the top 50%) in the intervention condition were explicitly told that they had an above-average exam performance and were doing a good job. Bottom-performers (those with an exam score in the bottom 50%) were given positive feedback about their ability to improve and information on resources to help them do so. Students in the control condition received an email with just their score (with no additional feedback or information). We hypothesized that this positive feedback would cause students in the intervention condition to view the woman professor as more likable, and that her SETs would be improved by these increased perceptions of likeability. This is because research finds a strong positive correlation between likability and SETs [5]. Given that women in leadership positions (such as professors) often face a double-bind in which observers fault them for seeming either inadequately nice or inadequately competent [6], this intervention could help decrease likability bias against women professors.

As a disclaimer, the long-term efficacy of this intervention is limited because it does not decrease systematic gender bias in SETs. We also strongly advise against the mandated use of this intervention, as it places an additional burden on women. Despite its limitations and potential for misuse, we report this intervention because it is easier to implement than other survival strategies used by women to combat gender bias (for instance, over-preparation [7]). As such, this intervention may be a useful survival strategy for women at the mercy of SETs (e.g., assistant professors, adjuncts) within institutional settings that are unwilling to make systematic changes to combat gender bias in SETs.

II. Related Work

A. SETs and Bias Against Women Instructors

In higher education, SETs are frequently used in hiring and personnel decisions [4]. However, a growing body of research finds that they are biased against women [4]. For instance, experimental work in online teaching settings has found that students rate instructors they believe to be men higher than instructors they believe to be women, regardless of the instructor's actual gender [3]. Moreover, a natural experiment found that women receive lower SETs by large and statistically significant amounts, even controlling for learning [2]. These effects vary by student gender, with students who are men

978-1-7281-7172-2/20$31.00 ©2020 IEEE

tending to give higher SETs to instructors who are men than to instructors who are women [8]. Thus, in male-dominated fields like computing (in which a majority of students are men), women instructors are likely to be particularly disadvantaged by SETs.

B. The Double-Bind and Gender Bias in SETs

One contributing factor to gender bias in SETs is the double-bind, a dilemma often faced by women leaders in which they can be perceived as either likable but not competent, or competent but not likable. Gender stereotypes drive this effect, as commonly-held beliefs about gender assert that women should be warm, selfless, and nice, while men should be assertive, bold, and agentic [6]. Thus, the gender stereotypes about how men should act line up neatly with societal expectations for leaders, while the gendered expectations for women are in tension with how society believes that leaders should behave [6]. So when women leaders behave in accordance with societal expectations of leaders, they are seen as insufficiently nice. But when they behave in accordance with the gendered expectations held for women, they are seen as inadequately competent leaders. The double-bind is challenging for women academics because the role of instructor often requires giving negative feedback to students. And indeed, students rate difficult graders more poorly when they are women [9].

C. Likability Interventions and the Double-Bind

Some research has found that women leaders can overcome the double-bind if they act in a competent manner while demonstrating traits consistent with the gender stereotypical expectations of women (e.g., nice, communal, and group-orientated) [7]. For instance, backlash against women who negotiate is negated when women negotiate for others [10].

Thus, we suspect that women instructors who engage in warm, friendly behavior towards their students may be able to overcome the likability bias of the double-bind. We hypothesize that this will improve the SETs of women instructors, as SETs are highly correlated with likability [5] and friendliness towards students has been shown to increase SETs for women instructors but not men instructors [11].

III. Research Questions

We evaluate two research questions:

- **RQ1:** To what degree does additional, positive feedback from the professor delivered via email increase students' perceptions of the woman professor's likability?
- **RQ2:** To what degree does additional, positive feedback from the professor delivered via email increase SETs for a woman professor?

IV. Methods

This study uses two methods to evaluate our research questions. For RQ1, we use data from a controlled A/B study in which half the students got the intervention and half were the control. For RQ2, we use the official University SETs for the semester in which the intervention occurred (considering all students, even those in the control), and compare against a control semester that did not use the intervention at all.[1]

A. Context

This study was conducted in the Fall semester of 2018 in a CS1 course for engineering students (non-majors) at a large public University in the United States. Students took surveys both before (Pretest survey) and after (Posttest survey) their first exam. All students in the Fall 2018 offering of the course were required to complete the Pretest survey at the start of the course.[2] Students were then offered 2 percentage points of extra credit for completing a Posttest survey, which was given after the exam.[3]

B. Assignment of Participants to Intervention Group

After the first exam, students were stratified by exam performance (top 50% or bottom 50%). They were then randomly assigned to either the control or intervention group. While not every student consented to the use of their data for this research, every student was assigned to the control or the treatment group.[4]

1) Control Group Emails: After the exam, students in the control group received an email in which they were only given their numeric grade on the exam followed by information on how to access the survey.

2) Intervention Group Emails: After the exam, students in the intervention group received an email from the professor giving them their numeric grade on the exam, information on how to access the survey, as well as additional feedback that varied based on their exam performance. Top-performers (top 50% of exam scores) in the intervention condition were explicitly told that they had an above-average exam performance and were doing a good job. Bottom-performers (bottom 50% of exam scores) were given positive messaging about their ability to improve and information on resources to help them do so.

C. Metrics

Two metrics were used for the evaluation of the research questions: 1) professor likability (from Pretest and Posttest surveys) and 2) official SETs (administered by the University at the end of every course).

1) Likability of Professor: On both surveys, students were asked, *"How much do you like the instructor of this class?"* and could respond on a 7-point scale (in which 1 = "Greatly dislike," 4 = "Neither like nor dislike," and 7 = "Greatly like"). The mean likability score (across both the Pretest and Posttest survey) was 5.51 with a standard deviation of 1.09. We use linear mixed models to assess the impact of the intervention on student perceptions of professor likability.

[1]Due to the space limitations, full details on the study methods, analyses, and results are available in a technical report [12].

[2]However, students were not required to consent to the use of their data.

[3]All students, independent of test performance and consent for data use, could earn extra credit by completing the surveys.

[4]We did this so that the professor could not know which students had consented to data use.

TABLE I
LINEAR MIXED MODELS WITH REPEATED MEASURES PREDICTING TOP PERFORMING STUDENT RATINGS OF PROFESSOR LIKABILITY

	Coefficient	Standard Error	p-value
Time	0.03	0.13	0.83
Intervention	0.33	0.16	0.04
Intercept	5.66	0.19	0.00

n=148 observations nested in 74 participants.
NOTE: Each model has a random intercept and an AR(1) specification for serial correlation.

2) Student evaluations of teaching: The professor's official SETs were used to assess the impact of the intervention on teaching evaluations. We compared the professor's SETs from Fall 2018 (the semester the intervention occurred) to her Spring 2019 SETs (a semester in which she sent no emails about exam grades). This semester was used because it was most directly comparable to the intervention semester, given its close temporal proximity and the minimal course changes that occurred between the two semesters. For each question in the SETs, students responded on a 5-point scale in which 1 = "strongly disagree" and 5 = "strongly agree". Blank or "not applicable" responses were removed from this analysis.

D. Participants and Response Rates

While there were 185 students in the Fall 2018 class, control and treatment groups were assigned based on the 167 students who consented. However, there was an unequal distribution between the control (67 students) and intervention groups (72 students) because only 139 students completed both the Pretest and Posttest surveys. Thus, we report a response rate of 139/185 (75.1%). Of these 139 students, 74 were classified as top performers (35 control, 39 intervention) and 65 were classified as bottom performers (32 control, 33 intervention). Among students who participated, all identified as either women (29 students) or men (110 students).[5]

For SETs, the response rate was 80/185 (43.2%) for the intervention semester of Fall 2018 and 103/264 (39.0%) for the control semester of Spring 2019.

V. RESULTS

A. RQ1: Impact of Intervention on Professor Likability

Using the data from the Pretest and Posttest surveys from Fall 2018, we find direct evidence that the intervention causes top-performing students to like the professor more. Table I shows the results of the analysis with linear mixed models. Time takes on a value of '1' for the Pretest survey and '2' for the Posttest survey. Intervention takes on a value of '0' for all observations at time 1 (as no students had received the intervention at this time), and takes on a value of '1' at time 2 if the student was in the intervention group. We conduct separate analyses for top and bottom performers, given the differences in the feedback received by these groups.

[5]Gender was balanced across the control and treatment groups. We do not break down the analysis by student gender because student gender did not impact the effect of the intervention.

We find evidence that the intervention increases top-performing student ratings of professor likability by .33 points ($p < .05$). This represents an increase of 5.8% percent, given the average rating of professor likability in the control group was 5.66. While this is a modest increase, it is statistically significant.

We do not find evidence that the intervention increases bottom-performing student ratings of professor likability, with $p = 0.80$, see [12]. Similarly, when considering top performers and bottom performers in aggregate, there is no significant overall effect of the intervention.

B. RQ2: Impact of Intervention on SETs

To determine if the intervention influences SETs, we compare the professor's Fall 2018 SETs (the intervention semester) with her Spring 2019 SETs (the comparison semester). We use a paired t-test in which we treat each of the twelve SET questions as a unit and then use each semester's average value for the question as a repeated measure of the unit. This means that the average SET score received by the professor in the Fall of 2018 (the intervention semester) was 4.13 (with a standard deviation of 0.28 and 12 observations - one for each of the questions), and the average score the professor received in the Spring of 2019 was 3.92 (with a standard deviation of 0.22 and 12 observations - one for each of the questions). This difference was found to be statistically significant, with a t-statistic of -5.84 and a p-value of ¡ 0.001.

VI. DISCUSSION

Women constitute a minority of professors in engineering, computing, and technology courses, and face challenges that their counterparts who are men do not. One of these challenges is that SETs have been found to be biased against women, so much so that the American Sociological Association (ASA) released a statement cautioning against the use of SETs in tenure and promotion cases [4].

In this work, we present a lightweight intervention that appears to decrease gender bias in SETs by mitigating the effects of likability bias against women professors. Although we only found evidence that the intervention increased the top-performing students' perceptions of the professor's likability (RQ1), the positive messaging in the intervention appears to be so effective that the intervention led to significantly higher SETs at the end of the semester (RQ2). Although it might seem unlikely that a single email could have a large impact on SETs, it is well established that a single action can greatly impact observers' attributions and understandings of a person, especially when that action occurs early in the relationship between the person and the observer [13]. Future research should more directly assess the precise mechanisms that caused the intervention email to increase perceptions of the professor's likability and her SETs.

While women should not have to change their behavior to accommodate the gender bias of students, an unfortunate reality is that most institutions of higher learning use SETs to evaluate faculty. This intervention may be helpful to women who are struggling with the effects of gender bias caused by the double-bind, as this intervention may be easier for them to implement than other behavioral adjustments they already use to circumvent gender bias (for instance, over-preparing for class or carefully curating ones appearance [7]).

Given the important role women professors play in the retention of top students who are women, this intervention may also have important downstream effects on women students in STEM. Carrell finds that while professor gender has little impact on students who are men, it does have a powerful effect on the performance and retention of students in STEM courses who are women, especially top performing women [14]. If this intervention helps retain more women instructors in STEM fields, it may also have the additional benefit of increasing the retention of students in STEM who are women.

A. Other Factors At Play

Were the SETs better during the intervention semester because the class size was smaller? One might argue that SETs were better during the intervention semester because there were 79 fewer students enrolled in the intervention semester than the control semester. To assess this hypothesis, we compared the SETs from the Spring 2018 semester (a semester in which an identical email intervention occurred, but that did not include the likeability question on the surveys) and the Fall 2017 semester (its closest control semester). In this case, the Spring 2018 enrollment (the intervention semester) was higher than the Fall 2017 enrollment (the control semester). We again find that the professor's SETs were significantly higher ($p = 0.026$) during the intervention semester (Spring 2018) than the control semester (Fall 2017).

Was the quality of instruction higher during the intervention semester? One might argue that the professor was particularly invested in teaching during the semester of the intervention. However, the intervention did not appear to have an impact on the questions from the SET related to professor explanations, enthusiasm, and preparedness, or course materials [12], which leads us to believe the delivery of material, and the materials themselves, were similar between semesters. Moreover, the professor stated that she did not change the course materials between semesters.

Is the improvement in SETs due to higher response rates? There was a higher response rate for SETs in the of Fall 2018 compared to the Spring of 2019 (See Section IV-D), but using a 2-sample test for equality of proportions with a continuity correction, we find that the difference in response rates is not significant ($p = 0.184$).

B. Threats to Validity

1) External Validity: We studied students in a CS1 course for non-majors at a large research University in the United States and results may not generalize to other populations, such as smaller institutions or courses for majors. Results are reported for one professor who is a woman and may not generalize to other women or professors of other genders.

2) Conclusion Validity: The response rates for the SETs were 43.2% and 39.0% for Fall 2018 and Spring 2019, respectively. It is possible that the results may not hold with a higher response rate.

VII. Conclusion

Research finds that SETs contain significant gender bias, and that professors who are women often receive lower evaluations than men for a similar quality of instruction. We examined the effects of a lightweight email intervention that provides positive exam feedback to students. We find evidence that the intervention improves short-term student perceptions of the women professor's likability. We also find evidence that the intervention increases official SETs, providing further evidence of the intervention's effectiveness. While this intervention does not decrease the gender bias of students, this intervention could be a survival strategy used by women to mitigate bias they experience in SETs.

Acknowledgements

We thank the anonymous reviewers for their time and suggestions. This work was supported in part by NSF #1749936.

References

[1] S. Zweben and B. Bizot, "The taulbee survey," *Computing Research Association*, 2018. [Online]. Available: https://cra.org/resources/taulbee-survey/

[2] A. Boring, K. Ottoboni, and P. Stark, "Student evaluations of teaching (mostly) do not measure teaching effectiveness," *ScienceOpen Research*, 2016.

[3] L. MacNell, A. Driscoll, and A. N. Hunt, "What's in a name: Exposing gender bias in student ratings of teaching," *Innovative Higher Education*, vol. 40, no. 4, pp. 291–303, 2015.

[4] A. S. Association, "Statement on student evaluations of teaching," 2019.

[5] D. Feistauer and T. Richter, "Validity of students' evaluations of teaching: Biasing effects of likability and prior subject interest," *Studies in Educational Evaluation*, vol. 59, pp. 168–178, 2018.

[6] A. H. Eagly, L. L. C. A. H. Eagly, and L. L. Carli, *Through the labyrinth: The truth about how women become leaders*. Harvard Business Press, 2007.

[7] J. C. Williams and R. Dempsey, *What works for women at work: Four patterns working women need to know*. NYU Press, 2018.

[8] J. A. Centra and N. B. Gaubatz, "Is there gender bias in student evaluations of teaching?" *The journal of higher education*, vol. 71, no. 1, pp. 17–33, 2000.

[9] S. A. Basow and N. T. Silberg, "Student evaluations of college professors: Are female and male professors rated differently?" *Journal of educational psychology*, vol. 79, no. 3, p. 308, 1987.

[10] E. T. Amanatullah and M. W. Morris, "Negotiating gender roles: Gender differences in assertive negotiating are mediated by women's fear of backlash and attenuated when negotiating on behalf of others." *Journal of personality and social psychology*, vol. 98, no. 2, p. 256, 2010.

[11] D. Kierstead, P. D'agostino, and H. Dill, "Sex role stereotyping of college professors: Bias in students' ratings of instructors." *Journal of Educational Psychology*, vol. 80, no. 3, p. 342, 1988.

[12] S. Fisk, K. T. Stolee, and L. Battestilli, "A Lightweight Intervention to Decrease Gender Bias in Student Evaluations of Teaching (Full Version)," North Carolina State University, Department of Computer Science, Tech. Rep., 12 2019. [Online]. Available: ftp://ftp.ncsu.edu/pub/unity/lockers/ftp/csc_anon/tech/2019/TR-2019-9.pdf

[13] K. G. Shaver, *An introduction to attribution processes*. Routledge, 2016.

[14] S. E. Carrell, M. E. Page, and J. E. West, "Sex and science: How professor gender perpetuates the gender gap," *The Quarterly Journal of Economics*, vol. 125, no. 3, pp. 1101–1144, 2010.

Intersectional Perspectives on Teaching: Women of Color, Equity, and Computer Science

Stephany RunningHawk Johnson
Department of Education Studies
University of Oregon
Eugene, OR 97403
stephany@uoregon.edu

Allison Ivey
Department of Education Studies
University of Oregon
Eugene, OR 97403
aeckert@uoregon.edu

Jimmy Snyder
Department of Education Studies
University of Oregon
Eugene, OR 97403
jimmys@uoregon.edu

Max Skorodinsky
Department of Education Studies
University of Oregon
Eugene, OR 97403
makseem@uoregon.edu

Joanna Goode
Department of Education Studies
University of Oregon
Eugene, OR 97403
goodej@uoregon.edu

***Abstract*—As high school computer science course offerings have expanded exponentially over the past decade, persistent gaps in terms of race and gender have remained a key characteristic in computer science classroom learning opportunities. This study aims to learn from the perspectives and knowledge of seven women of color who are high school computing teachers. Using ethnographic methods and data collected from professional development observations and interviews, this study examines how the intersectional identities and embodied experiences of these educators can inform efforts at broadening participation in computing for students. The findings of this study point to the importance of not playing it safe, commitment to teaching in historically underserved communities, intersectional identities and impact on teaching, and critical hope as key tenets in these teachers' standpoints towards broadening participation in computing. While some of these tenets can inform other educator's pedagogical efforts at broadening participation in computing, the embodied, gendered, and racialized nature of these findings highlight the need to prepare a diverse teacher cadre as part of building authentic opportunities to learn for all students.**

Keywords—intersectionality, equity, broadening participation in computing (*key words)***

I. Introduction

Despite a great number and variety of efforts to address the participation gap in computer science (CS), it continues to persist. This gap is especially profound at the intersections of race and gender. Women of color currently constitute 39% of the female-identified population in the United States, however, only 7% of all high school students taking Advanced Placement Computer Science in 2017 were girls of color [14] and women of color make up just 10% of bachelor's degrees and 5% of doctorates in computing [14]. Among all women employed in computer and information science occupations, only 12% are Black or Latinx women; in 177 Silicon Valley firms, less than 2% of all workers are Black, Latinx, or Native American/Alaska Native women [14].

National Science Foundation, Grant No. CNS-1837286 and CNS-1743195.

In a democratic country, it is especially imperative that girls and women of color have access to the study of, and employment in, any field that brings them satisfaction. It is equally important that they have access to positions with agencies to define and shape the field of computing, which currently exercises immense influence over most aspects of our lives. While multiple research-based interventions have been forwarded which focus on recruiting girls of color to computing, most of these are single sex, out of school programs, which aim to influence girls' confidence and belongingness in computing [17]. There is a scarcity of research that examines the experience of CS teachers, who are women of color; research that centers their perspectives in grappling with their teaching practices and role in the educational experience of their students. The research questions guiding this work are as follows: *How do women of color understand and approach their role as CS teachers based on their unique standpoint? How do their intersectional identities impact their teaching praxis?*

The aim of this study is to center the voices of CS teachers whose lived experiences as women of color give them a unique perspective regarding the interplay of teachers, students, families, race, gender, CS, community demographics, and school culture. We employ the theoretical frameworks of feminist theories, and in particular standpoint theory, to analyze and elevate the values and praxis of these teachers in order to gain a better understanding of how to support CS education that embraces marginalized students.

II. Theoretical Framework

Within literature on professional development and curriculum, the centering of Eurocentric perspectives is prevalent with little attention paid to those teachers who exist outside of the mythical identity norm [13] of white, middle class male. This is especially prevalent within the field of CS as white males tend to dominate this space both in industry and education [4, 19]. While moving toward a centering of teacher voice is vital within this literature, it becomes a question of

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

whose voice is centered and what questions and conclusions can be drawn. In this, we position this paper within a conceptual framework of Feminist Standpoint theory [11, 18] as a way to counter the common narratives highlighted within the literature [7]. As Alutiiq scholar, Sabzalian argues in her description of feminist standpoint theory, “Particular social locations, given their asymmetrical relationship to power, are epistemically advantageous as they can enable clearer insights into dominant conceptual frameworks and social reality” [15]. Specific to this research project, intersectionality becomes particularly effective in illustrating the experiences of women of color that are “not subsumed within the traditional boundaries of race or gender discrimination as these boundaries are currently understood” [6]. This framework undergirds the analysis of this study, as we understand “that systems of race, social class, gender, sexuality, ethnicity, nation, and age form mutually constructing features of social organization, which shape Black women's experiences and, in turn, are shaped by Black women” [2]. We further draw on the work of Crenshaw [6] who offers intersectionality theories as a way to include intragroup differences. Thus, Feminist Standpoint theories, grounded in notions of intersectionality, offer a generative way to better understand how women of color within CS understand their role, as students [9], and as teachers and change agents.

Prior research in Black feminist literature on the significance of relationships points to the importance of personal accountability and collective responsibility, speaking not only to the importance of one’s relationship to their community, but also the accountability held for each individual within that community [2, 3]. Thomas and colleagues discovered that for Black women in computing, “many of them continue, or persevere, on their journey, because they do work that has some focus on human interactions, which allows for them to give back to their communities and make the world a better place” [18].

III. Methodology

This study took place during a five-day Exploring CS Professional Development delivered on a college campus with participants staying on site for the duration of the professional development (PD). The PD brought together a diverse group of teachers from different regions of the US who planned on teaching the introductory course the following year or had taught this course the year prior. As our study and research questions are undergirded by standpoint theory and the perspective that CS teachers who are women of color have a unique experience where race, gender and CS intersect, we employed field observation and participant interviews as data collection methods. Across three teacher PD classrooms with 24 teachers each, 1-2 researchers observed teacher learning and listened to educator discourse around race, teaching, and CS education over the course of the week. Researchers took field notes in PD and met daily to share notes and their observations from the day.

In addition to the week-long observations, we also asked a number of teachers to participate in interviews outside of PD hours. To answer the research questions in this paper, we selected 7 interviews for analysis, all from women of color. The participants were selected with the aim of examining a diversity of experiences: location, teaching experience, school demographics, background in computing, etc. While there are many other intersecting identity categories, for the purposes of this paper, we focused specifically on race and gender.

TABLE I. PARTICIPANTS

Participant	Teaching Location	Self-Reported Race/Ethnicity	School Site Description
Jennifer	South Carolina	African American	Alternative school, majority black students
Rachel	New York	Latina/Latinx	Majority Latinx students
Nadia	Texas	Indian	Majority Latinx students
Carmen	Connecticut	African American	Career Technical school, 30% Latinx students
Malia	Texas	Half Tongan, half Japanese	Majority Latinx students, all ELLs
Jodi	Oklahoma	Taiwanese	~50% Native students
Ciara	Texas	African American	Talented and Gifted school, diverse students

The seven teacher participants of this study, as shown in Table 1, teach in five different states and all work in schools with large numbers of students of color. The chosen teachers had less than five years of teaching experience and were all novice CS teachers with the majority entering teaching from an outside field. We enacted a grounded theoretical form of analysis by developing a thematic code list and identifying subsequent sub codes based on the following themes: not playing it safe, teaching communities, intersectional identities and impact on teaching, and critical hope [1, 16].

IV. Findings

A. *Not Playing it Safe*

Many of the teachers gave us examples of what we are calling “not playing it safe”. They spoke out about the injustices they see in their schools and how they are dealing with them. Jodi said “in professional development I speak up talking about equity, talking about diversity, questioning those things that people are more so uncomfortable to talk about.” Rachel also talked about pushing back against other adults in her school. Her feeling is that “I don’t care if you like it or not, it’s not about you, it’s about the kids.”

These teachers also spoke about their experience during this PD week and how they are not playing it safe in this environment either. Nadia was the most outspoken on this topic. She told us that the white people in her group were not talking about the more difficult issues, they stayed surface level. She said “they just wouldn’t get into the nitty-gritty; they just want to stay on the searches to talk about statistics” and “they just want to stay safe; they did not want to dig any deeper.” These teachers also included their students in their efforts to not play it safe with examples like Jennifer noting the implementation of restorative circles in her class in an alternative school setting. “I know we’re talking about Exploring CS, but being in an alternative school environment, you have to deal with the other issues before you can get into ECS.” Nadia said, “we talk a lot about how race and power play into a lot of the inequities that we see in the world, especially in science."

B. Choosing to Teach in Specific Communities

Many of the teachers we interviewed went through alternative teacher preparation programs, in part because of their focus on underserved schools. For instance, many of the teachers conveyed that they were drawn to Teach for America because of their desire to impact educational experiences of students. They expressed a commitment to giving back to students from their own communities as well as underserved students in general. As shown in Table 1, many of the teachers work in schools where they do not share the same race/ethnicity with the large populations of students of color. Nonetheless, these teachers spoke of wanting to be role models for their students, being agents of change, and offering perspectives and encouragement from a standpoint of solidarity and shared lived experiences as women of color. Malia stated: "That's why I went into engineering because I was like, little Tongan girls need to see this, too. Little Pacific Islander kids need to see that we're all here trying to do things." Similarly, Jennifer spoke of her commitment to being an agent of change: "I worked at a law firm and [I was] seeing the school to prison pipeline and I said, 'Who's going to do something about this?' It is really up to us as individuals. We can't look for somebody else to do it."

Beyond their commitment to teach at particular schools, teachers enthusiastically described their commitment in working with particular student groups with similar educational backgrounds to their own. Rachel shared her understanding of her students' experiences and appreciation of working with English language learners (ELLs): "I found my love for bilingual Spanish. Those are my kind of kids. I love working with kids who [have] behavioral issues. This year I took on an English Language Arts class myself, all special education and all ELLs. I think the constant reminder that there's somebody that came from where I came from, that can do what I can do, has been really powerful." She added: "Me and you, we're both ELL students. I was an ELL student, you're an ELL student, I understand."

These participating teachers embodied a commitment to improving educational equity on micro and macro levels, a desire to impact their local classrooms and systems at large. Malia stated: "I want to affect those that are directly in front of me at a micro level," while Jodi expressed: "I think my root is in trying to do service and not perpetuating the system that we are living in." Several teachers talked about future work in policy and leadership roles at some point in their careers. Of note, most of these teachers did not enter the profession to teach CS, but they took up CS education as a bigger project of supporting and empowering underserved students. This is reflected in their efforts to support students more holistically, rather than focus on CS content.

C. Intersectional Identities and Impact on Teaching

Teachers commonly discussed how their race and gender identities impacted their teaching. As these participants have first-hand experience of systemic oppression and institutionalized racism throughout their own schooling and career journeys, this situates them with a particular standpoint by which to understand and deconstruct the barriers they see in their schools. During interviews, discussions of systemic racism typically moved toward ideas of creating change. For instance, Carmen reported how she speaks honestly with her Black students regarding the reality of being Black in the United States. As a Black woman with experience working in technology, Carmen feels that she is able to help students see that it is not only white males who are able to do CS. Comments she has overheard, such as "that there's no place for people of color in CS," further motivate Carmen in supporting her students of color in becoming proficient in CS. She believes change will happen by "help[ing them] to... become the people, the citizens that they should be, the better people I know that they can become".

This motivation to break down barriers specific to traditionally marginalized identity categories in CS was also discussed by Malia who works hard to empower her students through breaking the stereotypes of who is viewed as a scientist. As a student, seeing women scientists empowered Malia, and because of this experience she wants to offer the same representation for her students.

Teachers also discussed the impact of their identity on their students as mentors. When discussing how her identity impacts her students, Jennifer noted, "I think it makes a difference because all of my students are Black students so I can talk to them as Black mother and I can build a different type of relationship with them, I think. The relationship that I have with them is a little different than some of the other teachers and so with that, especially in that environment... I can command more from them." This role based on Jennifer's intersecting identity categories was echoed by Rachel who discussed how her Latina identity has provided representation for her students and helps her connect with her students' families. She noted that her identity allows students to see her in a different light in their acknowledgment that "this educator speaks my native language, understands my culture, knows what I'm going through, understands my parents." These examples speak to the importance of having a teacher who matches students' identities in the classroom because for students of color and females in CS, this does not often occur. In fact, a common theme across the interviews was that having a woman of color as their CS educator was, for many students, the first woman of color they had encountered in a classroom.

D. Critical Hope

Finally, we found that as a group, these teachers expressed sentiments of being critically hopeful in their perspectives around teaching CS and their aspirations for their students. Rather than gap-gazing [9] about under-representation in CS, these women of color share an asset-based projection of their students' future experiences in CS, rooted in their own sense of responsibility to share knowledge with students. As Malia noted, "I think they are going to kill it…I know they already have this interest, and to be able to bring the opportunity to them, is going to be super powerful."

Teachers situated their aspirations for themselves and their students within a school system plagued by educator bias and structural racism. For instance, Nadia notes that she talks with her students about the inequities in the world and the connection to science, race, and power "a lot." Nadia then guides her instruction, "to bridge that gap between what they think that they can't reach and show them that it's hands on, you can do it too, is something that I think is important, because that gives them power in their own hands to be like, 'No, I can do this. I can use it to my advantage.'" For Nadia, being critically hopeful for her students requires her students to understand and be informed about inequities related to computing, while simultaneously providing students opportunities to learn CS.

Teachers also explained instances of having critical hope in the face of inequity and racial bias taking place more locally. For instance, Carmen described how she launched the first Advanced Placement course ever at her school, and other educators expressed deficit notions the mismatch of the advanced material and their perceptions of the low abilities of "those kids". Carmen, adamant to counter these narratives, told her students about this prevailing attitude, saying "You are going to be the ones to prove them wrong, we're going to do this together. We're going to do this right. We worked our tails off all year." Despite this school context of lack of support and low expectations, Carmen maintained her high expectations of her students and a critical hope they would "prove them wrong" and produce a counternarrative wherein students belong in advanced classes.

V. Discussion

According to the teachers in this study, representation matters. They pointed out that it is imperative for students of color and girls to see people like themselves doing CS. They urged the importance of schools and teacher education programs be more intentional about recruiting teachers of color. The analysis of our observations and interviews revealed that teachers who are women of color bring an authentic and rich set of strategies to their engagement with CS students. They bring firsthand awareness of the intersection of race, gender, and CS and facilitate conversations about race and gender with colleagues and students.

This way of viewing and embodying teaching CS helps us to rethink the traditional notion of CS as being transactional, apolitical, and grounded in individual success and instead to revision a narrative of CS instruction that is grounded in relationships and radical honesty [5] where teachers move beyond transaction and toward a praxis of critical hope [8] and an ethic of love [12]. By thinking outside of traditional notions of individual success and toward community and collective success, this can move CS education to a space of revisioning in partnership with our students and with communities to catalyze change beyond the four walls of the classroom. While this revisioning and reimagining is possible for teachers of varying identities, this particular study demonstrates the particular subjectivity of female teachers of color within CS classrooms, a subjectivity that impacts their teaching practice in material and transformative ways.

VI. Conclusion

The current movement of CS education "for all" has focused almost exclusively on the inclusion of students of color, without a consideration of how teachers' identities and lived experiences shape equitable learning opportunities in computing classrooms. This study revealed how women of color, in particular, approach their role as computing teachers with a sense of collective responsibility and a commitment to social justice. Given the importance of these teachers' gender and racial representations as well as their lived experiences in driving their commitments to inclusion, this study highlights the importance of recruiting, retaining, and supporting women of color to be computing teachers in school classrooms.

Acknowledgment

We thank the research participants who participated in this study.

References

[1] K. Charmaz, *Constructing grounded theory: A practical guide through qualitative analysis.* London: Sage Publications, 2006.
[2] P.H. Collins, *Black feminist thought: Knowledge, consciousness and the politics of Empowerment,* New York: Routledge, 1990.
[3] Combahee River Collective. (2014). "A black feminist statement" *Women's Studies Quarterly*, 271-280, 2014.
[4] Computing Research Association, *2018 Taubee Survey*, 2018.
[5] B. Cooper, *Eloquent rage: A black feminist discovers her superpower*, New York: St. Martin's Press, 2018.
[6] K.W. Crenshaw, Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, 43(6), 1991, 1241.
[7] R. Delgado, and J. Stefancic, *Critical race theory: The cutting edge* Philadelphia: Templeton University Press, 1995.
[8] J. Duncan-Andrade,. "Note to Educators: Hope Required When Growing Roses in Concrete" *Harvard Educational Review*, 79(2), 2009, 181-194.
[9] P. Garcia, and K. Scott, Traversing a political pipeline: An intersectional and social constructionist approach toward technology education for girls of color. *InterActions: UCLA Journal of Education and Information Studies*, *12*(2), 2016.
[10] R. Gutiérrez, "A 'gap-gazing' fetish in mathematics education? Problematizing research on the achievement gap", *Journal for Research in Mathematics Education*, 2008, 357-364.
[11] S. Harding, *The feminist standpoint theory reader: Intellectual and political controversies*. New York: Routledge, 2004.
[12] b. hooks, *Feminist theory: From margin to center.* Pluto Press, 2004.
[13] A. Lorde, "The Master's Tools Never Dismantle the Master's House." *Feminist Theory: A Reader* (1984).
[14] F. McAlear, A. Scott, K. Scott, and S. Weiss, Data Brief: *Women of Color in Computing.* http://wocincomputing.org. 2018.
[15] L. Sabzalian, "Curricular standpoints and native feminist theories: Why native feminist theories should matter to curriculum studies", *Curriculum Inquiry*, 48(3), 2018, 359-382.
[16] J. Saldaña, (2013). *The coding manual for qualitative researcher*s. Los Angeles: SAGE Publications.
[17] K. Scott, and M. White,, COMPUGIRLS' Standpoint: Culturally responsive computing and its effect on girls of color. *Urban Education*, 48(5), 2013, 657–681.
[18] J. Thomas, N. Joseph, A. Williams, and J. Burge, "Speaking Truth to Power: Exploring the Intersectional Experiences of Black Women in Computing." In *Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*, IEEE, 2018.
[19] U.S. Equal Employment Opportunity Commission, *Diversity in High-Tech,* 2016. Retrieved from https://www.eeoc.gov/eeoc/statistics/reports/hightech/

Understanding Parents' Perceived Barriers to Engaging Their Children in Out-of-School STEM Programs

Bo Ju
School of Design
DePaul University
Chicago, USA
bju1@depaul.edu

Olivia Ravenscroft
School of Design
DePaul University
Chicago, USA
oravensc@depaul.edu

Evelyn Flores
School of Education and Social Policy
Northwestern University
Evanston, USA
evelyn.flores@northwestern.edu

Denise Nacu
School of Design
DePaul University
Chicago, USA
dnacu@depaul.edu

Sheena Erete
School of Design
DePaul University
Chicago, USA
serete@depaul.edu

Nichole Pinkard
School of Education and Social Policy
Northwestern University
Evanston, USA
nichole.pinkard@northwestern.edu

***Abstract*— To encourage youth from diverse backgrounds to participate in science, technology, engineering, and math (STEM) fields, it is important to take an ecological approach. Outside of school, parents' values and knowledge have a strong influence in the development of their children's learning in STEM related fields. Based in Digital Youth Divas (DYD), an out-of-school time (OST) STEM program for underserved middle grade girls in Evanston, IL, this exploratory study examined parents' decision-making process when selecting OST STEM programs for their children. We facilitated a parent workshop and conducted interviews with five parents of DYD participants and two staff members. Participants in the study expressed preferences for programs that are free, situated in locations that are easily accessible, and run by highly regarded educational institutions. Parents also identified barriers to participation such as the lack of a parent network, conflicting schedules with other OST activities, and difficulties in understanding the term "STEM". These results suggest several recommendations for programs to address these barriers, such as designing intriguing program flyers, fostering a parent network, and providing accessible program locations. For researchers and designers of OST STEM programs, this study highlights the importance of taking a family and community-based approach to understanding parent perceptions and challenges.**

Keywords—out-of-school STEM program, learning ecosystem, parents, barriers

I. INTRODUCTION

Mirroring computing related college majors and careers, out-of-school time (OST) STEM programs are filled with a majority of males from dominant populations [1]. To enhance equity in those fields, it is important to invite more youth from underrepresented populations (e.g. girls, ethnic minority populations). In an ecological view of learning, learners are strongly influenced by the environment around them, including the people they interact with, resources they encounter, and various physical and virtual spaces where they spend time [2].

Home is viewed as an influential environment in a child's learning ecosystem. Parents' values, knowledge, and interests have a huge impact on their children's learning in STEM fields [3], especially in how they consider and decide to enroll in programs. Despite the increasing number of STEM programs targeting underrepresented populations in those fields, underrepresented groups of youth still face difficulties participating in them. The research focus in this study is identifying what types of barriers parents perceive when they consider OST STEM programs for their children.

II. BACKGROUND

In the concept of Activity Theory, an ecological system consists of a microsystem (individual environments), mesosystem (interactions of two or more micro environments), exosystem, (an outer level operating indirectly on the environment), and macrosystem (outermost level defining the global context). Each system is situated in a broader context of networks of interacting systems [4]. Given their interconnectedness, changes in one system cause changes in another. According to Barron, an ecological view of learning addresses how youth interests develop through dynamic interaction across spaces of home, school, and community [2].

Scholars have been studying how, in home environments, parent involvement impacts youth interest, motivation, and persistence in STEM. Parent involvement in youth STEM learning could be challenging due to the fact that many parents may lack the expertise. However, one study indicated that the impact on youth success and persistence in STEM was not necessarily determined by parents' prior STEM knowledge [5].

Building parents' technological confidence, expanding family social networks, and encouraging parent-child collaboration on STEM invite new opportunities and resources for youth STEM learning [6]. Barron and her

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

colleagues also described various ways parents can support their children's STEM learning, such as collaborating with children on STEM projects, brokering new learning opportunities through relevant networks, and providing non-technical support [7].

Although an increasing amount of OST STEM programs have emerged, youth from ethnic minorities and female populations are still underrepresented in those programs. Prior research has identified structural barriers to participation, such as registration fees, a lack of transportation, competitive application processes, and inability to demonstrate preexisting interest in science [8]. This study extends prior literature by looking into potential barriers from parents' perspectives that can subsequently impact youth participation in such programs.

III. METHODS

There are two parts of our study: a parent workshop and individual interviews. All the parent participants identified as either Hispanic, African American, or Asian and lived in an underserved geographical area.

We first facilitated a 120-minute workshop for nine parents (6 females, 3 males) of eight girls in DYD (see Table 1). The workshop took place at the same time as one of the DYD sessions in MetaMedia, one of the arts-focused community centers in which DYD was held. The workshop sought to spark conversations between researchers and parents about the role that parents (which we define as guardians and primary caretakers) played in their children's learning. We also wanted to give parents an opportunity to share their feedback and experiences with the program and begin to identify barriers they faced when enrolling their children in DYD. Throughout the workshop, we took field notes, which we then used to inform our interview protocol design. We recruited workshop participants for individual interviews at the end of the workshop session.

Using the Activity Theory framework and the insights we collected from the workshop, we created interview protocols for parents and staff members. We later conducted interviews with five parents of five girls and two DYD staff members (see Table 2) to understand parents' perceptions that could impact OST program selection. Three of the interviews were done in person in a quiet lounge at MetaMedia, and two were conducted over the phone. Four of the interviews were conducted in English, and one was conducted in Mandarin. Interview questions for parents centered around their program selection process and challenges they faced when engaging their child in DYD, as well as how they engage with other parents in their community and within the context of Divas.

We also interviewed two DYD staff members. The interview questions for staff members focused on identifying instances where parents declined to or were not able to enroll their children in DYD as well as observed parent behavior at DYD open house events.

We audio recorded all the interviews and manually transcribed them. Using an inductive coding method, we analyzed and synthesized the qualitative field notes and interview data and developed themes that emerged from our research question.

TABLE 1. WORKSHOP PARTICIPANTS

Total Participants	9
Gender	6 women, 3 men
Language(s) Spoken	8 English, 1 Spanish and Mandarin

TABLE 2. INTERVIEW PARTICIPANTS

Interviewees	**Number of Participants**	**Gender**	**Languages Used**
Parents	5	3 women, 2 men	4 English, 1 Mandarin
Program Staff	2	2 women	2 English

IV. RESULTS

This section summarizes results from analyzing our field notes and interview data. In our findings, parents identified several major barriers they faced when considering STEM programs for their children.

Affordability and location accessibility were the two main factors mentioned. All the families we interviewed were economically underserved. One parent remarked, "I like that it's free, that's important. I'm a single parent and resources get really tight." Location was also critical as parents are often the primary transport for middle-school aged children, balancing their children's OST activities with other commitments. For example, one parent stated, "Accessibility, sometimes you know the travel or commute to and from are difficult for parents."

Parents encountered difficulties in understanding what the acronym "STEM" means and what kinds of activities these programs involve. They expressed that they would often not pay attention to advertising for STEM programming because they did not have prior knowledge of what the acronym stood for and were looking for a simple and clear explanation of what it involves, with one parent stating that "[OST program advertising] isn't giving me a visual of what STEM is." Another parent said, "I can only recall it just saying STEM. I can't tell what it said...It's cute but what is STEM?"

In addition, unattractive promotional materials and an overwhelming amount of information were concerns. One parent expressed that they did not have time to dig into some of the information about programs they received due to the sheer volume of it, saying "We get bombarded with information from the school. Sometimes you put it in your delete folder." Another parent explained, "If the text font or the image doesn't draw my attention, I probably won't even look at the details on the flyer," while another suggested, "Make a little 30 second visual presentation and send out the link so [parents] can get a visual."

Conflicting schedules with other activities proved to be another significant barrier, with one parent sharing that they struggle to make DYD work for their child because of its Saturday sessions: "Unfortunately, Saturdays are popular for extracurriculars, leisure as well...We are signing up for too much stuff, after school programs, they go to the Y, have swimming, so it's non-stop, there's always something."

Parents in this study found it hard to make time in their schedule to network with other parents and build a strong parent community, even though they expressed that they found it to be beneficial, as they often hear trustworthy recommendations about opportunities for their children from other parents. One parent said, "We have to get information from other parents, since we've only been here for a couple of years. Communicating with other parents, we will know of some events or activities or some benefits for kids. Most of the information it's from other parents...I just don't have time."

Our interviews with parents also illuminated some additional criteria that, while not being explicit barriers, impact their selection of OST programs for their children. Parents seek out and commit to programs based on their children's interests. Parents shared that they do not typically try to persuade their children to join particular programs, but rather are guided by what their children express an affinity towards. One parent remarked, "It really depends on whether they are willing to come or not." Parents also emphasized the learning aspect in OST STEM programs, expressing frustration with previous experiences in programs that lacked academic structure. One parent mentioned the importance of curriculum in a program, "Just have an actual curriculum, something that she's going to learn, something that benefits". Parents also prefer programs that are run by higher educational institutions. When asked about programs that are facilitated by their child's elementary school, a parent shared, "[As opposed to elementary school], we will pick one in middle school or high school that we think will provide a higher quality program."

V. DISCUSSION

Given the low participation rate of ethnic minority groups and girls in OST STEM programs, understanding what might keep them from enrolling in a program is critical to addressing this problem. The findings of this study support some findings from our literature review. For example, fees are one of the top factors that prevent some youth from participating in programs. Our findings also extend the literature, indicating that barriers like inaccessible locations, difficulty in understanding the term "STEM", lack of a parent network, and conflicting schedules with other extracurriculars can also prevent parents from engaging their children in those programs. Furthermore, this study provides implications for DYD and future studies by suggesting ways that program facilitators can better design their offerings to recruit and retain children in their target demographic.

A. Implications for DYD

To attract more parents' attention in emails or flyers, it is necessary to emphasize elements they care about an OST STEM program, such as being free or reasonably priced, operated at a convenient location, run by trustworthy academic organizations, and implementing a curriculum and hands-on learning. Regarding information presentation style of promotional materials such as flyers, using images to display girls' projects and an explanation of the program narrative can help to clarify what the program is about and what girls' experience might be like in it. With these design decisions in mind, parents will be less likely to feel confused about what the term STEM refers to and will have a better understanding of what the program entails.

An important area DYD has been focusing on in program development is the concept of the parent network, which provides parents with a space to network, share resources, and help their children. Our results suggest that DYD should create more opportunities to foster a parent network, such as workshops and social events. When asked "What do you think could be done to foster more community among parents?" one parent said, "Last time, the school organized an activity where parents come to school to have lunch with students. Then, there's time for parents to meet each other and talk." Because many parents have full schedules throughout the week, creating networking events that are already built into regularly occurring weekly activities can make them easier to attend. Additionally, DYD should keep looking into how to use social media to help connect parents, how trustworthy the information shared among parents is, and what communication channels parents feel comfortable using.

Another avenue of research that could be pursued is assessing what other kinds of OST programs the target youth in the area are already involved in. By identifying popular activities and practices among a particular community, program facilitators can better schedule their own sessions to accommodate for the issue of program conflicts. Furthermore, partnering with community centers (e.g., churches, libraries) and other programs (e.g., YMCA, Y.O.U) can help not only to promote DYD but also support youth's learning ecosystem, and even solve the problem of conflicting schedules. By having a presence in these communal areas, programs can better target the populations they are looking to recruit and make it easier for youth to attend because they are already spending time in those spaces.

B. Limitations and Future Research

This study has some limitations that will help inform future research. First, the sample size used is very small and not representative of the entire population of DYD. It will be beneficial to interview more people for a better understanding of this topic. Also, parent interviewees were from the same group of people who attended the parent workshop. We believe that parents who were not able to attend the workshop will be able to provide more insight as to the barriers that parents face, as they have more difficulty attending DYD events. In addition, interviewees, all of whom were either Hispanic, African American, or Asian were all from one neighborhood, so it will be helpful to talk to people in other demographic groups, communities, or cities.

The parents in this study have at least one child that was already in a STEM program. While they have expressed that they experienced difficulties and barriers when trying to engage their children in out-of-school programming, they were able to overcome some of the barriers in this instance. Conducting interviews with those who have been trying to but have not been able to enroll their children in OST STEM programs or have never thought about engaging their children in those programs will be useful in providing a more comprehensive view regarding this matter.

In this study, we interviewed only parents and staff members. According to the Activity Theory, perspectives of other stakeholders such as youth, siblings, mentors, and program leaders should also be taken into consideration for a more comprehensive understanding of barriers to participation.

We were not fully prepared for interviewing participants whose native language is not English. Fortunately, we had a native Mandarin speaker on the team who was able to conduct the interview with the parent who only speaks Mandarin. In the future, we should ask interviewees' preferred language for their interview and prepare for a translated protocol as needed.

Lastly, we did not have any photo or video documentation from the workshop. In the future, we will take photos or even record audio, especially during events like workshops, which may reveal unnoticed findings later on and provide context to others who may not be familiar with the program.

VI. CONCLUSION

This work identified barriers that parents face when they consider enrolling their children in OST STEM programs, such as high fees, inaccessible locations, conflicting schedules with other activities, an overwhelming amount of emails about programs, and difficulty in understanding the term "STEM" or program activities. Additional insights were identified surrounding aspects of programs that parents value, including having subject matter or activities that are interesting to their child, affiliation with highly regarded educational institutions, and an emphasis on curriculum. To better recruit and retain youth from populations that are underrepresented in STEM fields, designers and researchers of these types of programs must consider and address these challenges and aspects in their recruitment strategies and programs design.

ACKNOWLEDGEMENT

We would like to thank Digital Youth Network for providing space to host the parent workshop. We would also like to thank the parents and staff who participated in the workshop and interviews for their time and insights.

REFERENCES

[1] A.V. Maltese, and R.H. Tai, "Pipeline persistence: examining the association of educational experiences with earned degrees in STEM among US student," Science Education, vol. 95, pp. 877–907, 2011.

[2] B. Barron, "Interest and self-sustained learning as catalysts of development: a learning ecologies perspective," Human Development, vol. 49, pp.193–224, 2006.

[3] J. Wang, H. Hong, J. Ravitz, and S. H. Moghadam, "Gender differences in factors influencing pursuit of computer science and related fields," Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education, pp. 117-122, July 2015.

[4] G. Gay, and H. Hembrooke, Activity-Centered Design: An Ecological Approach to Designing Smart Tools and Usably Systems. Cambridge, MA: The MIT Press, 2004.

[5] J. Wang, H. Hong, J. Ravitz, and S. H. Moghadam, "Landscape of K-12 computer science education in the U.S.: perceptions, access, and barriers," Proceedings of the 47th ACM Technical Symposium on Computing Science Education, pp. 645-650, March 2016.

[6] S. Livingstone, G. Mascheroni, M. Dreier, S. Chaudron, and K. Lagae, "How parents of young children manage digital devices at home: the role of income, education and parental style," London: EU Kids Online, LSE, 2015.

[7] B. Barron, C. K. Martin, L. Takeuchi, and R. Fithian, "Parents as learning partners in the development of technological fluency," International Journal of Learning and Media, vol. 1, pp. 55–77, 2009.

[8] G. H. Lyon, J. Jafri, and K. St. Louis, "Beyond the pipeline: STEM pathways for youth development," Afterschool Matters, vol. 16, pp. 48-57, 2012.

eCSR: Creating Intensive Research Experiences that Cultivate Community for Undergraduate Women & Women of Color

Audrey S. Rorrer
CS Department
UNC Charlotte
Charlotte, NC USA
audrey.rorrer@uncc.edu

Sepi Hejazi Moghadam
University Relations
Google
Mountain View, CA, USA
shmoghadam@google.com

Breauana Spencer
Sociology Department
UC Irvine
Irvine, CA, USA
bspencer@uci.edu

Ting Sun
Education Evaluation Dept.
UNC Charlotte
Charlotte, NC, USA
tsun4@uncc.edu

***Abstract*— The *explore CS Research (eCSR)* program is a university awards program created to support the design, development, and execution of research-focused workshops that provide opportunities for undergraduate women in Computer Science to learn more about research pathways and work on exploratory research problems. During the inaugural year of 2018-19, the program funded intensive research (IREs) workshops at fifteen universities across the nation, with 1,103 total student participants, 83% of whom were females, with a majority indicating Women of Color status. The intent of these workshops is to offer accessible research experiences to students who would not ordinarily participate in research, i.e. students from groups traditionally less exposed to computing (women, Women of Color, lower socio-economic status). The overall research questions guiding the study of the program are: does the program foster a sense of community, build skills, confidence and motivation among women to pursue computer science research; and, how do Women of Color experience this program? In this paper, we present findings from a mixed-methods study which demonstrate that IREs are effective at creating a positive research culture for undergraduate women. Factors that were found to be particularly salient for Women of Color are presented.**

Keywords*— *Broadening Participation in Computing, Computer Science Education, Gender and Diversity, Undergraduate Research, Women of Color

I. Introduction

Women remain severely underrepresented in computer science degree attainment, despite a multitude of efforts across the country to attract and retain women in computer science (CS). Degree attainment in CS is 21% women for bachelor's degrees, 26% for master's degrees, and 19% for doctoral degrees [1]. Women of Color are severely underrepresented in CS, with 10% attaining bachelor's degrees [2]. Unless we change the current trajectory of women in CS pathways, it is predicted that faculty gender parity won't be attained until 2075 [3]. Gender parity in CS research is an essential goal because inclusive research teams increase innovation and creativity in the field [4], and democratize access to and application of computing [5]. Achieving parity among Women of Color in computing is especially important as it would greatly increase the economic output in the tech sector, given the propensity for Women of Color to lead small businesses [2].

One approach to broadening participation of women in CS research is through undergraduate research programs (UREs). While UREs are generally effective recruiting and retention tools [6], mixed results have been shown regarding interest in pursuing graduate school [6][7]. Conditions that have been demonstrated beneficial to women in UREs include sense of belonging [8], mentoring [9], participation in technical conferences [10], and hands-on experiences [11][12]. Information about the graduate school admissions process, spotlighting gender topics, and applying research to social good, attracts women to research careers [12]. Creating a peer and faculty community that is warm and empathetic both within and outside the computing environment is essential [12][13][14].

Women of Color, i.e. Black and Latina women, face additional obstacles when pursuing CS, that pertain to intersectional identities and the 'double-bind' [15], yet most research treats women as a homogenous group, with Women of Color as 'invisible' [16]. Access to technology and anxiety are related to financial hurdles [17]. Psychosocial hurdles such as isolation and stereotype threat [18] contribute to conflicts with social identity and the lack of support from family and friends [16]. Particular to Women of Color, personable mentoring is critically important to bridge the social support divide [14].

II. II. Program Rationale and Design

This study seeks to investigate distinctions for women and Women of Color that motivate and support the pursuit of CS research, in order to shed light on practical features that support the inclusion of women from all ethnic backgrounds. The overall hypothesis guiding the investigation of the eCSR program is that Intensive Research Experiences (IREs) can be designed specifically for undergraduate women and scaled to create a supportive community of women to open pathways to CS research. Questions guiding this study include: does eCSR foster a sense of community, build skills, confidence and motivation among women to pursue CS research; how do Women of Color

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

experience eCSR; what encourages or hinders Women of Color in pursuit of CS research? Because women are not a homogenous group, this study explores salient factors for women across ethnic groups.

The distinguishing educational features of the eCSR program are the length of the experience, the engagement level, and the increased capacity for community. *The program innovation is in the scale and reach to the female undergraduate population*. While its design is based upon two exemplary IREs [19][20], eCSR has replicated these best practices at a national scale across a wide variety of institutional contexts, making this program unique in its reach to students of all backgrounds and exposure levels to CS.

Traditional undergraduate research programs offer 8 to 10 - week summer research experiences to small cohorts of approximately ten students from different colleges and universities, all of whom return to their respective institutions at the end of the program. The participation levels of women in these programs are marginal, hovering just below 30% among NSF funded programs [7]. Since CS degree enrollments across the country lack gender parity, research-based academic courses will not provide the critical mass of women to form community. The eCSR program provides IREs within a semester or academic year, and with large cohorts of students where women are in the majority, ranging from 40 to over 100 women at each program. Students are connected to peers and faculty while participating in hands-on research, to facilitate deep engagement in CS research.

Each of the 15 workshops was an intensive research experience (IRE), sharing common structural features to enable implementation fidelity across the program and addressing key factors known to support women and Women of Color (e.g. psychosocial support, graduate school seminars, socially relevant research projects). There were two structural options: a multi-day continuous workshop (n=10), or a sequential series of workshops throughout the academic year (n=5). Both workshop types were structured like a professional conference, with keynote speakers, panels, and breakout sessions. Breakout sessions focused on the research expertise from the institution and provided hands-on research activities for student teams. Collaborative team projects and mentoring occurred at all IREs, with many workshops culminating in project showcases. Research career planning topics were offered across all workshops, including graduate school financing, planning, and expectations. Workshops also included gender-focused topics such as work-life balance, stereotype threat, and imposter syndrome. A range of CS research areas was addressed, all framed within socially relevant applications. Structural decisions were made by the faculty leading the IREs at each institution and were based upon contextual factors pertinent to their respective student populations.

III. Methodology

A mixed-methods repeated measures study design was implemented using a pre/post survey of student participants, along with participant interviews. Surveys and interviews focused on these overarching indicators of program success for women in CS research: student perceptions of the research experience (self-efficacy, attitudes towards computing, mentoring), skill development (research), and career identity (intent to pursue graduate school, scientific leadership and identity). The researchers met with the faculty workshop leaders prior to conducting the study to discuss implementation fidelity. Institutional Research Reviews were approved prior to the data collection at the primary researchers' respective institutions.

A. Survey Instrument

Surveys were administered via Qualtrics prior to the start of the workshop and repeated at the conclusion of the workshop. The instrument measured the following constructs: Self-Efficacy, Interest in Graduate School, Attitudes about Computer Science, Research Skills, Professional Identity. Additionally, there were two items designed to capture career and academic plans. Mentoring and Program Evaluation items were included at the post-survey, with the addition of open-ended items about likes and dislikes. All items were rated on a 5-point Likert type scale, with 5 being the most positive rating. Demographic items were included to capture gender, ethnicity, level in school, and socio-economic status (SES). Thirteen workshops elected to pilot a Sense of Belonging scale to measure connection to the CS research community. The survey instrument [21] is available upon request to the authors.

B. Interviews

Interviews were conducted at all workshops, using a semi-structured interview process that followed the six core constructs. Student interviews were conducted either during workshop events or shortly following the workshop events. Volunteer participants received a $20 Amazon gift card. Interview protocols are available upon request to the authors

IV. Participants

A total of 525 students participated in the pre-survey (65% Women of Color, 21% low SES) and 365 participated in the post-survey (71% Women of Color, 19% low SES). Demographic information was closely matched for respondents at pre and post- survey. Response rates were 48% at pre-survey and 33% at post-survey. The SES item was collapsed into three categories of low, medium and high. Program evaluation items were collapsed into two thematic areas, connecting with others, and overall sentiments about the program. A total of 23 students were interviewed across the workshops. All participants were female; 77% identified as Women of Color and over half (55%) indicated they fell on the lower socio-economic scale.

V. Analyses

A t-test was performed to measure changes in the constructs between pre- and post-survey collection. Two multivariate analysis of variance (MANOVA) were conducted at pre and post- survey to examine differences in constructs by ethnicity; the ethnicity category was recoded into three types: White, Asian, and Women of Color. The Women of Color category contained students who selected African American, Hispanic/Latinx, Native Hawaiian/Pacific Islander, Native

American/American Indians, and Multi-ethnic. All analyses were performed in SPSS.

A semi-structured interview process was employed for workshop participants. Participants were recruited by announcements at the workshops and via a survey item. The phenomenological approach [22] was used to analyze data using Dedoose software to produce emergent thematic codes from all interviews.

VI. Limitations

As with all educational research, there are contextual confounds, e.g. prior research exposure, levels of participation, self-selection, and self-report bias. The assumption was that all participants engaged in the workshops as intended. Self-selection is mitigated by low construct scores at pre-assessment, an indication that the students were exploring their academic and career options and not firmly committed to CS research. A repeated measures design was selected to account for within subject populations, but matched pairs were not possible in all cases due to the voluntary participation in the survey. Combining ethnic groups obscures the particular cultural context of each identity, i.e. Hipanic/Latinx women undoubtedly have distinctive experiences from African American women. This choice was made in order to provide similar group sizes for statistical analysis. Self-report bias was addressed via qualitative investigation. It is beyond the scope of this study to examine any nuanced structural features that may relate to participant outcomes.

VII. Results

Results from the survey indicate that all constructs increased at post-survey, with self-efficacy, graduate school interest, research skills and professional identity as a scientist increasing significantly (Table 1). Sense of Belonging was piloted at 13 of the workshops (and therefore omitted from the table), for which statistically significant positive gains were observed between pre- and post-survey. The mean score at pre-survey was 3.79 ($SD = .83$) and was 4.05 ($SD = .74$) at post-survey, p = .001. Mentoring and Program Satisfaction were offered at post-only, and were positive mean scores, 3.58 and 4.23 respectively.

The omnibus Wilks's lambda (Λ) was significant, $\Lambda = .883$, $F(12, 754) = 3.07$, $p < .001$, indicating the combined dependent variables differed, on average, between White, Asian, and Women of Color students at pre-survey. Follow-up univariate F, statistics suggested significant differences as a function of ethnicity in graduate school interest, research skills and scientific identity. Specifically, Women of Color students had significantly higher levels of graduate school interest and scientific identity than White and Asian students, respectively. Women of Color students also had significantly higher levels of research skills than their White peers. At the post-survey, only graduate school interest showed a significant difference as a function of ethnicity, with Women of Color students having higher graduate school intention than White women.

Open-ended survey comments (Table 2) were examined resulting in four themes: Connecting with Others, Research Achievements, Learning, and Mentoring. Connecting with others was conveyed by comments such as "collaborating with girls on the same boat as me;" and "becoming part of a new community." Research achievement was a distinguishable theme from Learning in that resesearch achievements noted specific research tasks that were accomplished, e.g. "getting to know the research process," and "finishing the research project and seeing the results;" whereas Learning referred to generalized learning in CS and career options (e.g. "learning new programming languages," "learning how to fund masters").

TABLE I. Survey Construct Means, Standard Deviations

Construct	Pre Mean/SD	Post Mean/SD
	(n=525)	***(n=365)***
Self-Efficacy	3.96 (0.82)	4.07* (0.72)
Graduate School Interest	3.64 (0.90)	3.80* (0.85)
CS Attitudes	4.46 (0.54)	4.48 (0.55)
Research Skills	3.05 (1.04)	3.84* (0.86)
Identity as Scientist	2.85 (0.97)	3.20* (1.03)
Mentoring	NA	3.58 (0.82)
Program: network	NA	4.34 (0.63)
Program: sentiment	NA	4.11 (0.77)
Response Rate	48%	33%

**indicates statistical significance at p<.05.*

For the item about most rewarding experiences of the workshop, 55% of Women of Color indicated connecting with others, compared to 29% of white women and 48% of Asian women. White and Asian women reported research achievement as rewards, 20% and 12% respectively; Women of Color did not mention research achievements at all. When responding to the prompt for the least useful workshop components, half of the Women of Color indicated responses that the entire workshop was useful, with only 20% indicating specific components that were not useful. Comparatively, 38% of White and Asian women noted 'not applicable' responses, and 35% specified unhelpful components.

Interviews corroborated survey findings in that students increased their research skills, understanding of graduate school and how to apply, and developed a strong sense of community. The Women of Color indicated the benefits to be in becoming connected to a community of other Women of Color in CS. Many of the Women of Color discussed that they had *never had any mentors in the field of CS* prior to their attendance at these workshops and that the mentorship they received focused specifically on the challenges and biases that they face as Women of Color. *Mentoring by Women of Color* was crucial for developing a sense of belonging to the field. Feeling affirmed in the field *as Women of Color* was highly valued by the Women of Color, who attributed this affirmation to the relationships that they were able to develop with peers and faculty *who were also Women of Color*. A strong desire was voiced by most Women of Color interviewed to move the field forward, i.e.; not to move themselves or their careers further, but to make computing (the field, the tools, the products) good for others.

TABLE II. SURVEY COMMENT THEMES BY ETHNIC GROUPS

Theme	Asian Women	White Women	Women of Color
Connections with Others	48%	29%	55%
Research Achievement	12%	20%	0
Learning	34%	27%	30%
Mentoring	4%	7%	7%

VIII. DISCUSSION AND CONCLUSION

This study contributes to the conversation about how women experience the CS research community and explores the nuances of women across ethnic groups. The eCSR program demonstrates that a positive research culture, so critical to women [11], was established at a large scale, replicated within various institutional settings, and provide a localized supportive community. Findings point to new implications for recruiting, community building, and mentoring Women of Color.

At pre-survey, Women of Color reported significantly higher interest in graduate school, research skills and scientific identity, a suggestion that recruiting Women of Color needs attention (e.g., recruiting for potential vs. confirmed interest). Personal relationships that extend beyond tactical advising are critically important, especially for Women of Color. Additionally, linking CS research to social good, advocacy and social welfare has been shown to be important for Women of Color [14]. The contribution of this work is in demonstrating that IREs are a unique and effective way of providing undergraduate women with peer engagement, so that they feel that they fit in CS research by engaging with others like themselves, which is particularly salient for Women of Color. These workshops are uniquely positioned to offer the critical mass of women needed for fostering sense of belonging [9].

Future investigation will consist of longitudinal participant follow up to measure degree and career attainment, and will include the examination of the influence of specific program features on outcomes, in an effort to better understand the conditions that work best for the myriad of intersectional identities of women.

REFERENCES

[1] S. Zweben & B. Bizot. (2019). The Taulbee Survey 2018. Computing Research Association, May 2019, 31(5). https://cra.org/wp-content/uploads/2019/05/2018_Taulbee_Survey.pdf.

[2] Kapor Center (2018) Data Brief: Women and Girls of Color in Computing. https://www.wocincomputing.org/wp-content/uploads/2018/08/WOCinComputingDataBrief.pdf. Accessed October 15, 2019.

[3] S.F. Way, D.B.Larremore & A. Clauset. (2016). Gender, productivity and prestige in Computer Science faculty hiring networks. Proc. 2016 World Wide Web Conference (WWW), 1169-1179 (2016). arXiv:1602.00795.

[4] D. Rock, & H. Grant. (2016). Why diverse teams are smarter, Harvard Business Review, November 4, 2016. https://hbr.org/2016/11/why-diverse-teams-are-smarter.

[5] J. Margolis, & A. Fisher. (2001). Unlocking the clubhouse: Women in Computing. MIT Press.

[6] S. Laursen, A. Hunter, E. Seymour, H. Thiry, & G. Melton. (2010). Undergraduate Research in the Sciences: Engaging Students in Real Science. San Francisco, CA: Jossey-Bass.

[7] A. Rorrer, J. Allen, & H. Zuo. (2018). A national study of undergraduate research experiences in computing: Implications for culturally relevant pedagogy. In Proceedings of SIGCSE'18: the 49th ACM Technical Symposium on Computer Science Education, Baltimore, MD, USA, Feb 21-24, 6 pages. DOI: 10.1145/3159450.3159510.

[8] K. Lewis, J. Stout, N. Finkelstein, S. Pollock, A. Miyake, G. Cohen, & T. Ito. (2017). Fitting in to move forward: Belonging, gender and persistence in the physical sciences, technology, engineering and mathematics (pSTEM). Psychology of Women Quarterly, Dec. 2017, 41(4), 1-17. DOI: 10.1177/03616843117720186.

[9] K. Kim, A. Fann, & K. Misa-Escalante. (2011). Engaging women in computer science and engineering: Promising practices for promoting gender equity in undergraduate research experiences. ACM Transactions on Computing Education, 11(2), Article 8, (July 2011), 19 pages. DOI: 101145/1993069.1993072.

[10] H. Wright & B. Tamer. (2019). Can sending first and second year computing students to technical conferences help retention? In Proceedings of the ACM Technical Symposium on Computer Science Education (SIGCSE '19), February 27- March 2, 2019, Minneapolis, MN, USA. DOI:10.1145/3287324.3287349.

[11] L. Barker. (2009). Student and faculty perceptions of undergraduate research experiences in computing. ACM Transactions on Computing Education, 9, 1, Article 5 (March 2009), 28 pages.

[12] A. Q. Gates, P.J. Teller, A. Bernat, & N. Delgado. (1998). Meeting the challenge of expanding participation in the undergraduate research experience. In Proceedings of the Frontiers in Education Conference, 1998.

[13] K. Card & L. Herling. (2011). Hispanic women overcoming deterrants to computer science: a phenomenological study. University of South Dakota Vermillion, DS, USA ISBM: 978-1-267-30520-6.

[14] A. Hodari, M. Ong, L. Ko, & R. Kachchaf. (2014). New enactments of mentoring and activism: US Women of Color in computng education and careers. Proceedings of the 10th Annual Conference on International Computing Education Research, Augus 11-13, 2014, Glasgow, United Kingdom.

[15] M. Ong. (2011). Broadening Participation: the Status of Women of Color in Computer Science. Communications of the ACM, 54 (7), July 2011. DOI:10.1145/1965724.1965737.

[16] A. Solomon, D. Moon, A. Roberts, and J. Gilbert. (2018). Not just black and not just a woman: black women belonging in computing. IEEE 2018 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT). DOI: 10.1109/RESPECT.2018.8491700.

[17] R. Varma. (2010). "Why So Few Women Enroll in Computing? Gender and Ethnic Differences in Students' Perception" *Computers Science Education*, 20(4), 301-316.

[18] L. V. Charleston, M. N. Lang, R.P. Adserias & J. Jackson. (2014). Intersectionality and STEM:The role of race and gender in the academic pursuits of African American women in STEM. Journal of Progressive Policy and Practice, 2(3), Fall 2014. http://caarpweb.org/wp-content/uploads/2014/12/Charleston-Adserias-Lang-Jackson-2014.pdf.

[19] S. Menzel, K. Siek, & D. Crandall. (2019).Hello Research! Developing an intensive research experience for undergraduate women. In Proceedings of the 50th ACM Technical Symposium on Computer Science Education (SIGCSE '19), February 27-March 2, 2019, Minneapolis, MN, USA. DOI:10.1145/3287324.3287493.

[20] OurCS at Carnegie Mellon University. 2019. Retrieved August 2019 fromhttp://www.cs.cmu.edu/ourcs.

[21] A. Rorrer. (2016). An evaluation capacity building toolkit for principal investigators of undergraduate research experiences: A demonstration of transforming theory to practice. Evaluation and Program Planning, 55, 103-111, April 2016. DOI: 10.1016/j.evalprogplan.2015.12.006.

[22] C. Moustakas. (1994). Phenomenological Research Methods. Sage: Thousand Oaks, CA.

Tackling the Underreprentation of Women in Computing and Finding Novel Help in Athletics

Gloria Childress Townsend
Department of Computer Science
DePauw University
Greencastle, IN, USA
gct@depauw.edu

Khadija Jirari Stewart
Department of Computer Science
DePauw University
Greencastle, IN, USA
khadijastewart@depauw.edu

Sharmin Tunguz
Department of Psychology and Neuroscience
DePauw University
Greencastle, IN, USA
sharmintunguz@depauw.edu

***Abstract*—Researchers address the underrepresentation of women in computer science by conducting a four-year longitudinal study to explore the relationships among athletics, personality measures, gender, and performance in Computer Science I (CS1). The study explores personality traits (openness, persistence, and endurance) that enhance women's performance and persistence in both athletics and computer science, according to a literature review. Experimental results show female athletes out-perform (measured by CS1 grades) all other groups: male athletes, male non-athletes, and female non-athletes. The authors report results from statistical analyses to support hypotheses regarding reasons for female athletes' superior performance in CS1. The paper closes with a Future Work section that indicates how the lessons learned from female athletes in computer science might be applied to addressing the underrepresentation of all women in computing.**

***Keywords*—Gender issues, under-representation in computing, athletics, personality traits, Computer Science I, resiliency in computing**

I. Introduction

During the ten years between 2007 and 2016, the percents of computer and information sciences bachelor's degrees awarded to women hovered between 18% and 19% [6]. The National Center for Educational Statistics recently released the corresponding 2017 percent, 19%. Fig. 1 shows the 11 data points from 2007 to 2017 graphed slightly below the 20% axis. The plateau challenges researchers in gender issues within computing – especially because all other STEM fields, including engineering, [6] exhibit increases over the same period of time. The remaining STEM disciplines break the 20% barrier that restrains computing. The sense of urgency implied by the flat line in Fig. 1 encourages novel research.

During their combined 50 years of computer science teaching experience, the authors observed that female athletes, exhibit resilience in computer science classrooms and seem to thrive on the challenges that projects present. The authors then designed an experiment to explore the relationships among athletics; gender; computing performance; and traits of confidence, intimidation, competitiveness, openness (curiosity), endurance, and persistence. **The research questions: How are female athletes' personality traits similar to or different from those of male athletes, and of non-athletes? How do personality traits, gender, athletic team membership, and grades interact?**

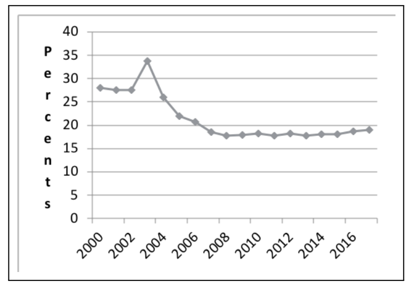


Fig. 1. Percents of female computer and information sciences bachelor's degrees in the US from 2000 to 2017.

II. Literature Review

Psychologists identify five personality traits in the Five Factor Model [1] which provides a widely-accepted taxonomy. The authors examined the literature regarding two of the five traits, openness and conscientiousness, to investigate the relationship of the two traits to success in athletics and to success in computer science.

A. Openness or Curiosity

Some studies associate openness/curiosity with athletes who engage in non-risk sports. Non-risk athletes scored significantly ($p<0.05$) higher in openness than non-athletes, using the Five Factor Scale [4]. Another study [10] also used the Five Factor Scale and found that individual-sport athletes scored higher than team-sport athletes. Moving to the relationship between openness/curiosity and performance in computing: "A meta-analysis on 19 independent samples (total N = 1,695) highlighted that programming aptitude was associated with three personality traits, conscientiousness, openness, and introversion" [3].

B. Conscientiousness or Persistence

Athletes' self-ratings on the Five Factor Scale correlated with coaches' composite scores for conscientiousness ($p<0.05$) and with game statistics ($p<0.01$) [8]. With respect to computing performance, a survey of literature regarding personality and programming found that all 19 reviewed studies

978-1-7281-7172-2/20$31.00

demonstrated positive correlations between conscientiousness and computer programming [5]. The study [3] emphasized in Section A above also points to the association between conscientiousness and programming aptitude.

C. Endurance or Growth Mindset

Coaches foster endurance through long hours of practice. Researchers [9] state that with a growth mindset promoted by practice "…motivation is optimized, participants are invested in the task and persist longer, performance is higher…" The Growth Mindset principle finds its way into current research curated by the National Center for Women & IT [7]. For decades Dweck [2] has investigated the concept that students' intelligence is not "fixed" but is instead "elastic" – the mind can "grow" with hard work and practice.

III. METHODS

A. Procedure

Students (457) from a small liberal arts college in the Midwest USA participated in an anonymous survey (available from the authors). Survey invitations were distributed to all (approximately 500) students enrolled in CS1, and to a random sample of students enrolled in courses belonging to all divisions of the university. Students (191 women; 220 men; 26 did not specify gender) indicated current or past enrollment in CS1; and 20 stated that they had not previously enrolled in CS1. Of the 191 females, 49 were athletes with 45 obtaining a "B" or better in CS1; 141 were not athletes with 111 obtaining a "B" or better in CS1; and one student left the athletics category blank. Of the 220 males, 90 were athletes with 69 obtaining a "B" or better in CS1; 128 were not athletes with 106 obtaining a "B" or better in CS1; and two students left the athletics category blank. The survey was administered at the ends of fall and spring semesters over a five-year period (May 2015 through May 2019). The survey took 15 minutes to complete.

B. Participants

Participants ranged in age from 18-22; 15% belonged to an ethnic minority; 23% were international students; and 18.5% were first generation college students. 12% students had at least one parent who worked in an information technology field.

C. Measures

Academic and athletic measures. Participants answered a range of questions that assessed their majors, overall GPA, graduate school plans, academic interests and experience in computer science courses, as well as their participation and level of involvement in an athletic sport.

Personality Measures. Participants completed a personality measure composed of six items designed to tap into their general propensity for resiliency. The items required participants to indicate their overall standing on each of the following traits: confidence, competitiveness, intimidation (reverse scored), **openness to experiences, persistence, and endurance**. Each trait was measured on a Likert scale that ranged from 1 (rarely or not at all) to 5 (almost always). This paper addresses the last three (bolded) personality traits. The researchers created the survey items pertaining to these traits for the purposes of this study and based the survey items on traits which the literature (Section II) indicates that successful computer science majors display. The literature also points to successful athletes' sharing these same three traits. When linking these results, it follows that computer science major athletes should score high on these traits and should outperform computer science non-athletes.

The authors conducted statistical correlations (Pearson's correlation coefficient) for each pair of the three personality traits – in order to strengthen the argument that the three survey items collectively measure what the researchers identify as a resilient personality. The results in Table I reveal five strong correlation coefficients and one marginally strong coefficient.

TABLE I
PEARSON'S CORRELATION COEFFICIENTS CALCULATED FOR ALL PAIRS OF PERSONALITY TRAITS MEASURED IN THIS PAPER

Correlated Traits	Female Athletes	Female Non-Athletes
Persistence & endurance	0.67	0.74
Openness & endurance	0.73	0.79
Openness & persistence	0.83	0.93

IV. EXPERIMENTAL RESULTS AND ANALYSES

A. Traits without Grades

Results for the research question **"How do the traits of openness, persistence and endurance for women and men, athletes and non-athletes interact?"** are graphed in Fig. 2 by first calculating the percents of positive survey responses for each category. Next, a set of t-test results (Table II) compares male and female athletes with respect to each of the three traits.

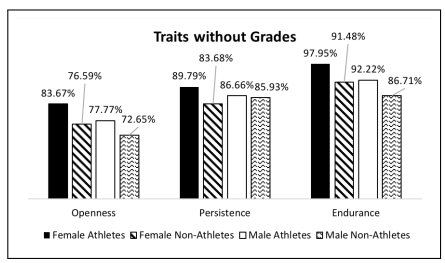


Fig. 2. Percents of positive responses to questions regarding traits of openness, persistence, and endurance for male and female athletes and non-athletes.

TABLE II
THREE T-TEST RESULTS FOR FOUR SETS OF POPULATIONS

p-values	MA/ MNA	FA/ FNA	FA/ MA	FA/ MNA
0penness	0.370	0.107	0.0399	0.0559
Persistence	0.404	0.0057	0.0089	0.0042
Endurance	0.221	0.0082	0.0007	xxxx

Female athletes self-report higher percents of all three traits compared to the other three groups – female non-athletes, male athletes, and male non-athletes. With respect to openness, women athletes report being open or curious at a rate of 6% higher than male athletes, who self-report only 1% higher than female non-athletes. Male non-athletes report the lowest percent – about 4% lower than female non-athletes). Overall, comparisons indicate the highest percent of positive responses to the openness survey item for female athletes.

With regards to persistence, female athletes again self-report the highest percent of persistence (defined as persisting in problem solving). The second-highest group is male athletes (at about 3% less than female athletes), followed by male non-athletes and female non-athletes. Female athletes rate their own endurance traits 5% higher than male athletes do and 6% more than female non-athletes. Male non-athletes self-report the lowest percent of endurance (5% lower than women non-athletes and 6% lower than male athletes).

The researchers expanded exploration of descriptive statistics reported in the preceding three paragraphs by conducting t-tests to compare female and male subgroups of athletes and non-athletes. Table II shows no statistically significant differences between male athletes (MA) and male non-athletes (MNA) for all three traits. However, t-tests comparing female athletes (FA) to female non-athletes (FNA) show strong evidence that athletics has an impact on women with respect to the traits of persistence and endurance ($p<0.01$), but the tests show only marginal significance with respect to the trait of openness.

T-tests comparing female athletes to male athletes and to male non-athletes reveal the same trend with respect to persistence and endurance: significant differences ($p<0.01$) for the traits of endurance and persistence. However, there is a significant difference ($p<0.05$) between the two groups with respect to openness.

Finally, t-tests comparing female athletes to male non-athletes show a marginally significant openness result, a significant persistence result ($p<0.01$), and an invalid endurance result. Variance among female athletes scores for endurance is 0.198; male non-athletes, 0.59. Variance for male non-athletes is more than twice the variance for female athletes, creating an invalid statistic. Remaining variances satisfy constraints.

Discussion. Why do female athletes score the three traits so highly? The authors speculate that the worldview of female athletes is different from that of non-athletes. Athletes experience competition essentially daily; they are open to new experiences, because few limits exist in their athletic lives (in part, due to Title IX). Female athletes practice and compete on the same literal playing fields as men do, so they view computer science as a figuratively level playing field, as well.

Female athletes work long hours on and off the courts/fields to hone their skills. A subject such as CS1 which their peers and the media may describe as "hard" seems less daunting to one used to "hard" work in a sporting "classroom". Adopting the preceding sentence's premise indicates why endurance (growth mindset) might be so prevalent among female athletes in CS1.

The researchers conjecture that the coaching relationship translates to the CS1 classroom. Coaches instruct players to improve their performance. Professors take over teaching responsibilities and inspire students (much in the same way as coaches do) to learn algorithmic and problem solving skills. Female athletes conscientiously follow both kinds of "coaches".

B. Traits with Grades

Female athletes receive higher grades than any other subgroup. Results for the research question **"How do the traits of openness, persistence, and endurance for women and men, athletes and non-athletes interact with grades?"** are graphed in Fig. 3 by first calculating the percents of positive survey responses for each category. Next, a set of t-tests compares male and female athletes and non-athletes (with CS1 grades that are "B" or better) with respect to each of the study's three traits. This section examines survey results for 346 students who received a "B" or better in CS1. Fig. 3 provides the portions of those students who record a 4 or a 5 Likert Scale measure in openness, persistence, and endurance.

In Fig. 3, female athletes report the highest percent of openness, about 4% higher than the remaining three groups, which differ about 1% from each other. Male athletes score the highest percent in persistence, followed very closely by female athletes (a difference less than 0.2%) and then male non-athletes (at about the same percent). Female non-athletes self-report much lower levels of persistence than the top groups (a difference of 7%). Endurance follows the same pattern as openness. Female athletes score 6% more positive responses for endurance than male athletes, who score slightly better than female athletes (a difference of less than 3%). Male non-athletes are in the last position at a little over 3% less than female non-athletes.

The authors again conducted t-tests (Table III) for the same four subgroups. The t-test results display no significant openness and persistence differences between male athletes and non-athletes. When contrasting female athletes and female non-athletes, t-tests give evidence that athletics significantly ($p<0.01$) relates to persistence in women who obtained a "B" or better in CS1 – with a marginal p-value for openness. Once again, the variances for female and male athletes with respect to endurance were extremely small (especially for women), disallowing t-test computation for the personality trait of endurance.

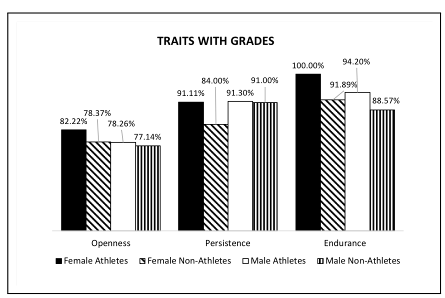


Fig. 3. Traits of Openness, Persistence, and Endurance for men and women, athletes and non-athletes who received a "B" or better.

When comparing female athletes to male athletes and male non-athletes, t-tests show evidence that there is a significant difference in persistence (compared to both male athletes and

TABLE III
T-TESTS FOR STUDENTS WITH CS1 GRADES OF "B" OR BETTER

p-values	MA/ MNA	FA/ FNA	FA/ MA	FA/ MNA
0penness	0.2041	0.0902	0.0885	0.2388
Persistence	0.4682	0.0027	0.0476	0.0376
Endurance	xxxx	xxxx	xxxx	xxxx

male non-athletes). However, in Fig. 3, male athletes self-report persistence at a percent slightly higher than women athletes. This observation warranted a closer look at the self-reported percents of persistence for female athletes, male athletes and male non-athletes. Table IV gives the percents of self-reported persistence for each of the three groups, separated for Likert scales 3, 4 and 5.

TABLE IV
PERCENTS OF SELF-REPORTED PERSISTENCE FOR FEMALE ATHLETES, MALE ATHLETES AND NON-ATHLETES WITH "B" CS1 GRADES

Persistence Level	FA	MA	MNA
Likert scale 5	57.7%	37.68%	40%
Likert scale 4	33.33%	53.6%	51.4%
Likert scale 3	8.8%	7.2%	4.76%

Table IV shows that women self-report a Likert scale 5 on persistence at a much higher percent than both male athletes and male non-athletes (by over 17%). The researchers believe that this large difference is what led to the significance in the t-tests. When the scores of 4 and 5 were combined in Fig. 3, the total masked the large numbers of 5 scores reported by the female athletes.

Discussion. Discussions of the differences (both descriptive statistics and t-tests) between female athletes and female non-athletes are similar in this section concerning student grades to those in the last section, where grades were not measured. The authors add new explanations (now concerning grades alone) to the preceding discussion (without grades) – explanations to account for the large percents of positive scores for the three personality traits and for the statistically significant differences obtained from t-tests.

The researchers reviewed the descriptive statistics and the t-test results from the analyses in the preceding paragraphs to pose some explanations for the success of female athletes in computer science classes – where 92% of female athletes reported grades of "B" or better. First of all, female athletes know that practice is key for game/match preparation; the growth mindset (endurance) trait within the CS1 classroom is a natural extension of practicing for success on courts and fields.

Similarly, in a nod to persistence/conscientiousness, female athletes experience both wins and losses in their sports. The athletes internalize the inevitability of loss and its ability to build a resilient personality. The authors anecdotally report that many female students bemoan a grade that is less than an "A" and feel they are unsuited for computer science with such a grade. Student athletes may better understand "wins and losses" in the "sport" of computing.

Finally, many athletes develop a philosophy whereby they want to compete or practice with players that may be more talented than they are. The athletes understand that playing or practicing with more skilled players improves their own games; they care more about improving than losing. Once again endurance – or a slightly different interpretation of the growth mindset – within sport may translate to the CS1 classroom, where students engage in challenging practice (from supplemental reading to extra website instruction/practice). This desire to improve by utilizing the most strenuous computing "workouts" may lead to better CS1 grades.

V. CONCLUSION AND FUTURE WORK

Conclusion: Among all subgroups (female athletes and non-athletes; male athletes and non-athletes), female athletes report the highest positive rates of curiosity, conscientiousness, and endurance. Female athletes differ significantly from other subgroups in terms of persistence.

Limitations:

- The study's geographic environment is Midwest USA
- The study's school is a selective national-level small liberal arts school
- The student body size is approximately 2000
- The school's athletes play in Division III of the NCAA
- Students do not receive athletic scholarships
- Underrepresented and international students each account for 20% of the student body
- Although the total sample size (457) is large, some subgroups are small
- Students declare majors as sophomores

The authors wish to conduct more quantitative studies, along with qualitative studies, before they launch projects that will leverage conclusions gained from their current research. The group considers both recruiting from athletic teams and also forming "CS1 teams" that resemble athletic teams.

REFERENCES

[1] J. M. Digman, "Personality structure: Emergence of the five-factor model," Annu Rev. Psychol., vol. 41, pp. 417-440, January 1990.
[2] C. Dweck, Mindset. New York, NY: Random House, 2006.
[3] T. Gnambs, "What makes a computer wiz? Linking personality traits and programming aptitude," J. Res. Pers., vol. 58, pp. 31-34, September 2015.
[4] T. Kajtna, M. Tusak, R. Baric, and S. Burnik, "Personality in high risk sports athletes," Kinesiology, vol. 36, pp. 24-34, May 2004.
[5] Z. Karimi and S. Wagner, "The influence of personality on computer programming: a summary of a systematic literature review," Publication Server of the University of Stuttgart, pp. 1-19, http://dx.doi.org/10/18419/opus-3243, 2014.
[6] National Center for Education Statistics, Digest of Educational Statistics. Retrieved from https://nces.ed.gov.
[7] NCWIT. National Center for Women & IT. Retrieved from NCWIT.org/.
[8] R. Piedmont, D. Hill, and S. Blanco, "Predicting athletic performance using the five-factor model of personality," Pers. Individual Diff., vol.27, pp. 769-777, October 1999.
[9] G. C. Roberts, "Motivation in sport and exercise from an achievement goal theory perspective: After thirty years, where are we?", in Advances in Motivation in Sport and Exercise, G. C. Roberts and D. Treasure, Eds. Third Edition, Champaign, IL: Human Kinetics, Inc., 2012, pp. 5-58.
[10] P. Steca, D. Baretta, A. Grecco, M. D'Addario, and D. Monzani, "Associations between personality, sports participation and athletic success. A comparison of Big Five in sporting and non-sporting adults," J. Pers. Soc. Psychol., vol. 121, pp. 176-183, January 2018.

The iAAMCS Ecosystem: Retaining Blacks/African-Americans in CS PhD Programs

Jeremy A. M. Waisome
Department of Computer & Information Science & Engineering
University of Florida
Gainesville, Florida, USA
jam323@ufl.edu

Jerlando F. L. Jackson
Department of Educational Leadership & Policy Analysis
University of Wisconsin-Madison
Madison, Wisconsin, USA
jjackson@education.wisc.edu

Juan E. Gilbert
Department of Computer & Information Science & Engineering
University of Florida
Gainesville, Florida, USA
juan@ufl.edu

***Abstract*— A persistent challenge in computer science (CS) graduate education is the lack of representation, retention, and graduation of certain racial and ethnic groups. Despite increased enrollment in computer science departments across the United States, the persistence of Black/African-American students remains primarily unchanged since the mid-1990s, particularly at the doctoral degree level. The Institute for African-American Mentoring in Computing Sciences (iAAMCS) is an NSF Broadening Participation in Computing Alliance (BPC-A) that provides a national ecosystem by connecting students and faculty through short and long-term programmatic activities to build community and advance Blacks/African-Americans in computing research. This paper presents an analysis of admissions and graduation data of Black/African-American CS PhD students from the CRA Taulbee surveys from 1995 to 2018. The findings suggest that less than 50 percent of the Black/African-American students that enter CS PhD programs finish. However, of those Black/African-American CS PhD students that have engaged in iAAMCS activities, 86 percent completed their PhD.**

Keywords—broadening participation, mentoring, retention, engagement

I. Introduction

Between 2005-2006 the National Science Foundation (NSF) launched the Broadening Participation in Computing Alliance (BPC-A) program to address the limited diversity in computing and computationally intensive degree programs across the country. The program was designed to reach students traditionally underrepresented in computing, including women, persons with disabilities, African-Americans, Hispanics, Native Americans, and indigenous peoples as the target population [1]. With a majority of the United States (US) population represented by these categories, the BPC-A program touted the opportunity to prepare the next generation of computing students with the skills and competencies needed for the 21st century workforce [1].

Several BPC-A proposals have been awarded since 2006, and their activities and engagements are designed to reach underrepresented computing students in K-20 pathways. The Institute for African-American Mentoring in Computing Sciences (iAAMCS) was awarded in 2013, and serves as a national resource for Black/African-American computing students and faculty. It began as a merger of several NSF BPC-A awards including: The Alliance for the Advancement of African-American Researchers in Computing (A4RC), The Advancing Robotics Technology for Societal Impact (ARTSI) Alliance, and The Empowering Leadership Alliance, as well as the BPC Demonstration Project entitled, African-American Researchers in Computing Sciences (AARCS) [2]. Each of these projects utilized different strategies toward broadening the participation of African-Americans in computing.

Today, iAAMCS remains a collaborative effort between faculty at several institutions who serve as the leadership team. Originally housed at Clemson University, the award moved in 2014 with the principal investigator to the University of Florida and in its final year involved leaders from Auburn University, University of Alabama, Winston Salem State University, Morehouse College, Morgan State University and an evaluation team from the University of Wisconsin-Madison. And while some institutions are no longer a part of the organization's leadership team, they maintain interactions through the programming and events which take place nationally.

Through the years, iAAMCS events touched the lives of over 649 core participants. This is through a systematic effort to create an ecosystem of resources accessible to students who traditionally exist in isolation on their college campuses.

A. The iAAMCS Ecosystem

One of the initial primary goals of iAAMCS programming was to add more advanced researchers into the advanced technology workforce. To do this, interventions were designed for undergraduate and graduate students that leverage the expertise of faculty and industry professionals. Additionally, programs involved collaboration with complimentary BPC-A's and other national initiatives that focus on diversifying science, technology, engineering, mathematics, and computing (STEM+C) workforce. iAAMCS signature programs have included:

1) Collaborative Research Experiences for Undergraduates (CREU): an undergraduate research program that provides stipends to teams of students working on research projects under the guidance of a mentor at their home institution. Students supported by CREU collaborate with each other and with their mentors during the academic year and, in some cases, the following summer. Students are strongly encouraged to present their CREU research at national or regional conferences. This program is in partnership with the Computing Research Association's Committee on Widening Participation in Computing Research (CRA-WP).

2) Distinguished Fellowship Writing Workshop: a writing workshop that guides undergraduate and graduate students through the process of writing a competitive application for summer internships, graduate school, and/or external funding. The targeted audience are junior and senior-level undergraduates, first- and second-year graduate students, and includes faculty who advise and/or mentor these students.

This material is based upon work supported by the National Science Foundation under Grant No. 1457855.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

3) Distributed Research Experiences for Undergraduates (DREU): this program accepts applications from both interested students and mentors who are matched based on their interests and backgrounds. During DREU, students complete a 10-week summer research experience that consists of several checkpoints in the process to ensure uniform expectations and outcomes. This program is run in partnership with CRA-WP.

4) Future Faculty and Research Scientist Mentoring Program: a mentoring program which provides guidance and mentorship through the faculty and/or research scientist job search. It is designed for doctoral students who have reached candidacy.

5) iAAMCS Distinguished Lecture Series (DLS): this series of programs features opportunities for Black faculty and graduate students to give lectures at Historically Black Colleges and Universities (HBCUs). The purpose of the iAAMCS DLS is to provide mentoring through role modeling, while also exposing students at HBCUs to faculty and graduate students of Black descent. This program is run in partnership with CRA-WP.

6) iAAMCS MentorNet: iAAMCS established a partnership with MentorNet, a division of Great Minds in STEM, to recruit Black mentors in computing while yielding more opportunities for Black students to receive mentoring. This effort also supports the DREU and CREU programs, along with graduate students connected to iAAMCS programming, while also providing training for participating mentors. Diverse mentors are invited to learn how to effectively mentor Black students through a series of training modules. Mentors are paired with students through a detailed profile matching process.

7) Morehouse-Spelman Virtual Mentoring Program: this program uses an integrated messaging ecosystem to expand mentorship opportunities for Black undergraduate and graduate students in computing through virtual interactions.

8) National Society of Blacks in Computing Conference: this conference provides mentoring and networking opportunities for Black undergraduate and graduate students, faculty, postdoctoral researchers, and research scientists. It is a platform for participants to engage in face-to-face interactions to develop personal and professonal networks, to learn how to identify and develop productive mentoring relationships, and to acquire a productive mentorship that may be lacking from their current environments.

Beyond the signature programs of iAAMCS, efforts to encourage student engagement have also been supported by the organization through scholarships, targeted presentations, and strategies for science communication:

- Travel scholarships: students are sponsored to attend a diverse array of affinity and professional conferences in their discipline to network beyond the confines of their institution.
- The African-American PhDs in Computing Sciences (AAPHDCS) Listserv: a virtual network consisting of more than 490 members. The listserv is a primary source of information sharing for students, faculty, and researchers.
- Modern Figures Podcast: a conversational-style podcast elevating the voices of Black women in computing to inspire the next generation of the advanced technology workforce. The podcast was developed in collaboration with the National Center for Women & Information Technology (NCWIT) and was designed to be understood by everyone, regardless of their experience with computing and technology. Guests from and allies for the Black Women in Computing (BWIC) community are invited to share their stories and perspectives on technical, societal, and personal topics.
- iAAMCS Workshops: these workshops are presented by iAAMCS leadership to target underrepresented students in computing. Topics include methods for successfully applying to graduate schools, how to successfully navigate graduate school, and guidelines for successfully mentoring Black CS PhD students, among others.
- iAAMCS Guidelines: The Guidelines for Successfully Mentoring Black/African-American Computing Sciences PhD Students were released 2018 with the goal to articulate successful strategies for mentoring African-American doctoral students in Computing Sciences (CS).

Along with these efforts, iAAMCS scholarly journal publications and conference proceedings have expanded the literature on Black computing students in the US. Since its inception, iAAMCS has championed new approaches to support Black/African-American students across the country. Yet, while overall doctoral student enrollment in the computing disciplines continues to grow, limited gains have been seen in the recruitment and retention of Black doctoral students on a national scale [3].

II. The Problem

Black graduate students in computing remain underrepresented in computer science (CS) doctoral programs in the US. Through the interventions provided by iAAMCS, doctoral students are more likely to persist through the completion of their degree program.

III. Research Approach

iAAMCS leadership maintains data from each of its signature programs on the participants reached by the intervention. Researchers from the iAAMCS evaluation team collaborate with these iAAMCS stakeholders to manage the quantitative data collection of participants as well as non-participants. The iAAMCS evaluation team designed the evaluation instruments to capture data that respond to iAAMCS needs and general national questions in computing sciences. Additional data is collected by the evaluation team through a comprehensive research and evaluation plan, which includes participant tracking. The objectives of the iAAMCS research and evaluation plan are as follows:

1) To measure the effect of iAAMCS on increasing the number of students pursuing and completing PhDs in computing science in comparison to control group;

2) To assess the feasibility of iAAMCS as an effective national mentoring intervention for potential and declared African American majors in computing science; and

3) To examine whether the iAAMCS interventions changes attitudes of African Americans toward computing science majors and careers.

This work aims to address, in part, the first and second aims of the iAAMCS research and evaluation plan. For the purposes of this research the information presented focuses on portions of the quantitative data collected, as they relate to graduation and retention rates, and time to degree for computing graduate students who participated in iAAMCS activities. This data is compared to national data from the CRA Taulbee survey on students pursuing doctoral degrees in CS in the U.S.

The CRA Taulbee survey is the leading source for data on enrollment, production, and employment of PhDs in information, CS and computer engineering in North America [3]. Each year, surveys are administered to all academic units that grant doctorates in the disciplines previously mentioned. Analysis of the historical CRA Taulbee data will be presented and discussed in the following sections. However, to compare the iAAMCS and CRA Taulbee data, it is important to note that since the survey is voluntary, some iAAMCS participants were excluded from the analysis as a result of their institution not being represented in CRA Taulbee survey data to provide an accurate comparison.

IV. Data Analysis

Data from 2008-2018 were analyzed from CRA Taulbee surveys. These years were chosen to understand the impact of the funding period (2013-2018) of iAAMCS on graduation and attrition rates of Black/African-American computing doctoral students. Due to the small numbers of participants in iAAMCS, some data was restricted from publication to reduce risk of identifying individuals who participated in iAAMCS activities.

A. Graduation Rates

iAAMCS data presented in this paper include the number of students who participated in any iAAMCS program during their doctoral degree attainment. Year of enrollment, graduation year, and inherently, their time to degree attainment are recorded for each participant. From 2013-2018, there were 42 Black/African-American CS PhD students that participated in iAAMCS activities that ended their PhD program. Of those 42, 36 completed their PhD and 6 left the PhD program. The overall average to degree attainment for iAAMCS participants is 5.5 years, while the median time to degree completion is 5.0 years. According to the 2017 Survey of Earned Doctorates, the median time to degree completion for any doctoral degree is 5.8 years [4]. The authors chose to use a 6-year graduate rate to better compare with CRA Taulbee survey data.

Data was attained from CRA Taulbee surveys from 2008-2018 for US CS departments [3]. Data on newly admitted PhD students, the number of PhD graduates, and the percentage of PhD student enrollment were extracted from relevant tables. For each variable, the data by ethnicity and overall were recorded. Table 1 reports the number of Black/African-American CS PhD graduates from 2013-2018 with the number of iAAMCS PhD students that graduated. Notice that iAAMCS impacted 36% of those graduates during those 5 years.

TABLE I. Black doctoral graduates from CRA Taulbee and iAAMCS

Year	Black CRA Taulbee graduates	iAAMCS graduates	Percent iAAMCS graduates
2013	22	5	23%
2014	17	6	35%
2015	15	10	67%
2016	17	2	12%
2017	10	5	50%
2018	19	8	42%
Total	100	36	36%

The CRA Taulbee survey does not report newly admitted PhD students by ethnicity, so this value was calculated by using the percentage of enrollment by ethnicity, and the total number of students admitted. Thus, the calculated enrollment by ethnicity is an estimate, since there is no accurate measure of this provided in the survey. For example, in 2013 the Taulbee Survey reported 145 Black/African-American PhD students enrolled, which was 1.3% of all the CS PhD students enrolled. The 2013 Taulbee Survey also reported 2,010 students were admitted into CS PhD programs. Therefore, to estimate the number of Black/African-American CS PhD students admitted in 2013, the percentage of Black/African-American CS PhD enrolled was used to calculate the number admitted as follows: 0.013 * 2,010, yielding an estimate of 26 Black/African-American PhD students were admitted. This calculation was selected because overtime, the percentage of Black/African-American CS PhD students enrolled didn't change much over the entire time the CRA Taulbee survey has been reported. The estimated admitted PhD students was then used to calculate a 6-year graduation rate by dividing the students who graduated 6 years in the future, by the estimated admitted students. Similarly, the 6-year graduation rate overall was calculated.

Table 2 shows the 6-year graduation rates by ethnicity of all the data analyzed from the CRA Taulbee survey from 2013-2018. The average rate of graduation over these 6 years was calculated for each category. The Black graduation rates from the CRA Taulbee survey indicate that 50% of the students who entered into PhD programs in CS completed their degree within a 6-year period. This is the lowest rate of all demographics, with nearest demographic of White, and Hispanic students graduating at a rate of 59% and 63% respectively. All other demographics meet or exceed the overall 6-year graduation rate of 76%. Of particular interest is the multi-racial demographic, which is not defined by the Taulbee survey in great detail. These students complete their degrees in twice the time as their ethnic counterparts at a rate of 165%. This is likely due to the low numbers of these students and a longer than 6-year graduation rate where a cluster of them graduated in a single year to significantly increase the calculated graduation rate.

B. Attrition Rates

As iAAMCS tracks all of its participants, data is readily accessible on students who choose to leave their doctoral programs. This is not true of the CRA Taulbee survey data.

TABLE II. 6-YEAR GRADUATE RATES BY ETHNICITY FROM 2013-2018

Year	Inter-national	White	American Indian	Asian	Black	Hawaiian/ Pacific Islander	Multiracial	Hispanic	All CS PhDs
2013	72%	57%	76%	81%	57%	47%	23%	59%	76%
2014	81%	61%	76%	72%	47%	28%	118%	39%	76%
2015	82%	66%	74%	60%	37%	95%	520%	84%	74%
2016	84%	63%	81%	68%	52%	246%	33%	53%	81%
2017	69%	47%	72%	107%	31%	46%	62%	69%	72%
2018	74%	61%	76%	68%	73%	0%	236%	73%	76%
Average:	77%	59%	76%	76%	50%	77%	165%	63%	76%

In order to calculate the loss of students, the graduation rate was subtracted from 1.0. For example, in 2013, the 6-year graduation rate for Black/African-American PhD students was 57%; therefore, the attrition rate was calculated as 1.0 - 0.57, yielding 0.43, or 43%. The calculated attrition rates from the CRA Taulbee Survey are in Table 3. As previously noted, iAAMCS had 42 Black/African-American CS PhD students complete their PhD program or leave the PhD program. Overall, there 36 out of the 42 that completed their PhD. This yields an 86% graduation rate or 14% attrition rate. From Table 3, the average is attrition rate is 50% for all Black/African-American CS PhD students versus the 14% for iAAMCS. In other words, iAAMCS participants have an 86% graduation rate versus a 50% graduation rate for all Black/African-American CS PhD students. Note that the overall graduation rate includes the iAAMCS graduates.

TABLE III. BLACK DOCTORAL ATTRITION RATES FROM CRA TAULBEE

Year	Attrition Rate
2013	43%
2014	53%
2015	63%
2016	48%
2017	69%
2018	27%
Average:	50%

V. CONCLUSION

iAAMCS has established a national ecosystem of activities that fosters community and shares information through mentoring. The quantitative data presented here suggest that iAAMCS is having an impact on Black/African-American CS PhD students versus those that are not connected to iAAMCS. And according to this analysis, iAAMCS has reached 36% of the Black/African-American doctoral CS graduates from CRA Taulbee survey institutions. It is our hypothesis that isolation, lack of community and lack of strategies regarding the PhD program, career options, etc. are significant factors in the attrition of Black/African-American CS PhD students. The results of this may be manifested in the difference in attrition rates for iAAMCS participants (14%) versus the attrition rates of Black/African-American students from the CRA Taulbee survey institutions (50%). In moving forward, qualitative analysis will be conducted to explore this hypothesis.

ACKNOWLEDGMENT

This material is based upon work supported by the National Science Foundation under Grant No. 1457855. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] National Science Foundation, *Broadening Participation in Computing Alliance Program (BPC-A),* Accessed on: Oct. 22, 2019. [Online]. Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503593.

[2] National Science Foundation, *NSF BPC-A: Institute for African-American Mentoring in Computing Sciences (iAAMCS),* Accessed on: Oct. 22, 2019. [Online]. Available: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1303156.

[3] Computing Research Association, *The CRA Taulbee Survey,* Accessed on: Aug. 26, 2019. [Online]. Available: https://cra.org/resources/taulbee-survey.

[4] National Science Foundation, Survey of Earned Doctorates, Accessed on: Sept. 16, 2019. [Online]. Available: https://www.nsf.gov/statistics/srvydoctorates.

EXPERIENCE REPORTS

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Portland, Oregon & Online Virtual Conference
March 11, 2020

Computing to Change the World for the Better: A Research-Focused Workshop for Women

Shadnaz Asgari
Dept. of Computer Engineering and Computer Science
California State University, Long Beach
Long Beach, CA, USA
ORCID# 0000-0002-7801-0853

Birgit Penzenstadler
Dept. of Computer Engineering and Computer Science
Caliofrnia State University, Long Beach
Long Beach, CA USA
Birgit@penzenstadler.de

Alvaro Monge
Dept. of Computer Engineering and Computer Science
Caliofrnia State University, Long Beach
Long Beach, CA USA
Alvaro.Monge@csulb.edu

Debra Richardson
School of Informatics and Computer Sciences
University of California, Irvine
Irvine, CA USA
djr@ics.uci.edu

***Abstract*—Women's underrepresentation in Computer Science (CS) can be attributed to various factors including lack of self-efficacy, role models, encouragement, awareness of the discipline and existing research pathways. In February 2019, we hosted a Google-sponsored research-focused workshop at California State University, Long Beach to raise female undergraduates' awareness and confidence in CS research pathways and careers. Forty-six students from several universities in Southern California participated in the workshop. Over the course of three days, students worked on research problems with clear real-world applications in teams led by faculty and assisted by graduate students. Additional sessions were held to inspire female undergraduates, increase their confidence and enrich their knowledge about research and graduate programs. In this paper, we report about our experience and the lessons we learned. We also present evidence of success in strengthening the research interests of our participants based on the results of the pre- and post-surveys that were designed and administered by the evaluators of our funding agency (Google Inc.) to better understand the impact of these workshops.**

Keywords— Recruitment and Retention, Broadening of Participation, Equity and Inclusion, Research-Focused Workshop

I. Introduction

Scientific breakthroughs and innovation require outside-of-the-box thinking, which can be fostered by diversity and gender equity [1, 2]. Nevertheless, women's underrepresentation in Computer Science (CS) and their considerable higher attrition rate, not due to lack of ability or lower grades, have been well documented [3-5] .Various factors can contribute to this underrepresentation including (but not limited to): stereotype threat, a lack of sense of belonging or having a community, lack of role models and encouragement, pedagogical issues, and problems with work-life balance that disproportionately affect women [6, 7]. All these factors have varying ramifications and implications for the corresponding interventions [8].

Per 2018 Taulbee survey– conducted annually by the Computing Research Association – women comprised only 22.3% of the CS doctoral enrollment and 19.3% of CS doctoral graduates in academic year 2017-2018 [9]. This gender disparity at the doctoral program level would continue into research careers or senior high-tech positions. Thus, encouraging more women to pursue research careers and advocating their advancement into senior tech roles and CS field leaders should be of high priority. Studies have shown that prior research experience at the undergraduate level can promote pursuing doctoral program and research careers instead of going directly to industry after graduation [10, 11]. Recently, CS Research-focused workshops have shown to be effective in raising awareness and confidence in CS research and its career pathways for undergraduates [12, 13]. They also improve students' retention in the major and their ability to work independently and to communicate well with a team. These benefits are of particular importance for minorities in computing (including women) who are more likely to see research careers as "not for them" because of the lack of role models or encouragement to pursue research careers and pathway.

Leveraging on our institution's diverse body of students (in terms of ethnicity and socioeconomic factors) and its prime location in Southern California, a research-focused workshop for undergraduate women from Southern California was hosted at California State University, Long Beach (CSULB)–in partnership with two other regional institutions: University of California, Irvine (UCI) and University of California (UCSD). The workshop was funded by Google ExploreCSR program [14]. In the following sections, we explain in detail the workshop goals and structure, assessment results and lessons learned.

II. Workshop Goals and Structure

We designed, developed and hosted a three-day regional research-focused workshop for undergraduates to work on research problems in teams consisting of 6 undergrads–each led by a faculty from CSULB, UCI or UCSD and assisted by 2-3 of their graduate students (majority Ph.D. students). Inclusion of graduate students was also intended to provide an opportunity for the undergrads to network with them and

This work was supported by Google's ExploreCSR program.

learn firsthand about graduate student life and pathways. CSULB is a Masters-granting university, however we have a limited joint PhD program in Engineering and computer science with Claremont graduate university. Due to this limitation, most PhD students who performed as project mentors were from UCI and UCSD. Our main goal for the workshop–aligned with those of the Google's ExploreCSR program– was to enhance the undergraduate research experience and increase women's motivation to pursue graduate study and research careers in CS. More specifically, the workshop aimed to achieve the following:

- Community: Foster a sense of community and support from peer groups and both near-peer and faculty mentors.
- Skills: Provide practical skills and know-how to help women succeed both in their undergraduate program and beyond.
- Confidence: Instill confidence that comes from knowing women have the skills to contribute to problem solving beyond the classroom.
- Motivation: Motivate, inspire and challenge women through exposure to real-world research problems in computer science.

Studies have shown that in contrast to men, women contextualize their interest in computer science within a larger purpose [15]: How can they change the world for the better? In fact, many females would like to learn how to employ computing within a broader context of education, communication, medicine, art and music [16]. Based on this observation, for the workshop, we planned to have carefully designed multi-disciplinary and practical projects with clear real-world applications. Brief descriptions of workshop research projects, spanning a wide variety of topics, are included on the workshop website [17]. To have an intense and authentic research experience, the workshop schedule was framed around total of 10 hours workshop sessions, spread out over three days, where the students learned how to tackle a real-world group project by formulating relevant research questions, proposing various approaches for the solution, analyzing them and collecting evidence while considering the problem's limitations. The scope of the projects was designed in a fashion that the group effort was sustainable over all three days. On the last day of the workshop, during a two-hour session, each team (including all its undergrad team members) gave an oral presentation to workshop participants about their projects results.

Furthermore, we held 3 one-hour plenary panel sessions, where PhD. students talked about their main motivations to attend a PhD program and shared their personal stories including challenges they confronted and ways they overcame these challenges. Several other topics of importance (e.g. imposter syndrome, life-work balance, research ethics and gender bias in the workplace) were also discussed. Having these open and honest conversations in a friendly and safe environment were aimed at providing clarity and context about life of a CS researcher to the undergraduate participants.

Another session was allocated to graduate school application process where the undergraduate students learned how to make a successful Ph.D. application package including C.V., personal statement, letter of recommendation or how to prepare for the GRE exam. In addition, information about various available funding opportunities for the financial support of a Ph.D. student were presented.

Finally, we invited three successful female computer scientists as keynote speakers (one from academia, two from industry) to talk about their research work, personal/professional journey and the importance of diversity in CS workplace. The students had opportunities to interact one-on-one or in small group discussions with the speakers at the end of their presentations. We believe that having direct interaction with these successful female computer scientists (potential future role models) and seeking their advice can play an important role in encouraging the female undergrads and increasing their resilience in the field.

III. Implmentation of the Workshop

Logistical planning for the workshop started 6 months in advance (on August 2018). The workshop website was designed and went live at the end of October 2018. We prepared some workshop flyers that included general information about its learning objective, date, location, and the targeted participants. To be inclusive, we mentioned that while we welcome applications from female undergraduates, male students can also apply, and that preference will be given to first-generation students and those from groups underrepresented in computing. As advertisement, we sent emails to CS department Chairs and undergraduate advisors of 10 regional universities in southern California attaching the flyer and asking them to share the information about our workshop with their students. A simple application form was created on the website to collect general information (demographic and a brief statement on their interest in CS and their goal for workshop participation) about those interested in participating at the workshop.

We received total of 110 applications by mid-December 2018. A rubric was developed to evaluate the applications mainly based on the applicants' statements of purpose while giving preference to minorities in CS (in terms of gender, ethnicity or socioeconomics). Each application was reviewed separately by two faculty using the developed rubric. If the two scores assigned to an application had large discrepancy, the case was discussed in detail among the faculty to resolve the discrepancy (if possible). Then all applications were sorted based on their average scores. Our targeted number of participants was 70 students. Thus, we notified the top 85 applicants of their acceptance to register for the workshop. The registration fee was kept at $50 to guarantee registrants' attendance. However, we let the accepted applicants know that we would waive the fee for those who are serious about attending but cannot afford to pay (self-declare). As a result, the fee was waived for 5 registrants. Accommodation at a local hotel was provided to those students who were living more than 50 miles away from CSULB campus. The workshop also provided 3 meals a day for the workshop participants. In terms of transportation, we helped those students who were interested in carpooling to find a joint ride to the workshop venue. Paid parking was provided to the participants over 3 days of the workshop. Out of 85 accepted applicants, 54 of them registered for the workshop by the end of January 2019. The list of research project leaders and their descriptions were finalized on the workshop website and the registrants were asked to rank their projects selection by mid-February 2019. Each student was then assigned to one of their top 3 selected projects in a team of 6 students per project.

At the end, 46 undergraduate students, 17 graduate students and 9 project leaders (faculty) participated in our three-day workshop. They worked on their projects, presented their results and received a certificate acknowledging their efforts and participation (Fig.1)

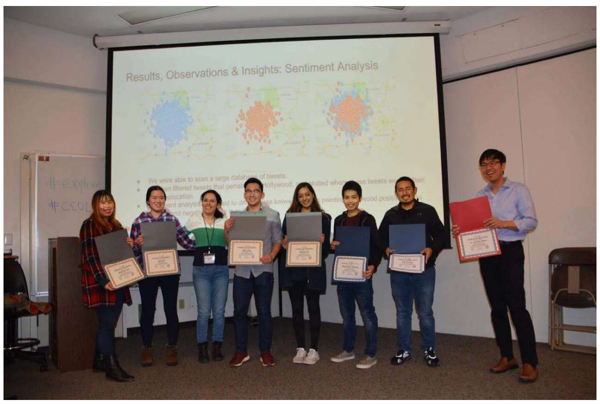


Fig. 1 Dr. Moon from CSULB and his team members received certificates for completion of the project: "Where is Hollywood?: An artificial inteligence approach.". This project was the most popular one based on the students' responses on a workshop preparation survey.

A majority of the faculty (56%) and graduate students (82%) involved with the workshop were women to facilitate creating a sense of belonging and community among the female undergrad participants (93%). Fig. 2 presents the demographic information of the undergrads in terms of ethnicity and university they were attending. With respect to socioeconomics factors, 43% of our participants were first generation. These numbers demonstrate the diverse body of the workshop participants.40% of the undergraduate students were Freshman or Sophomore.

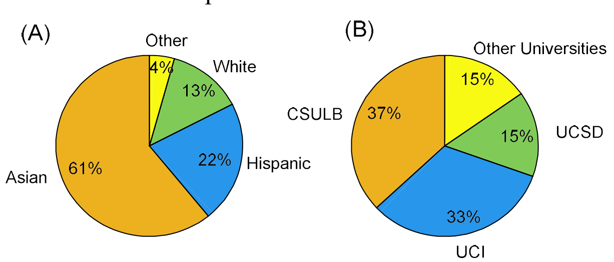


Fig.2 Demographic information of the workshop participants: (A) Ethnicity; (B) University

IV. WORKSHOP EFFICACY ASSESSMENT

The workshop efficacy assessment plan was designed [18] and implemented by independent evaluators of Google's ExploreCSR program. A mixed methods approach was employed to evaluate each workshop via surveys and interviews conducted with workshop participants using the four key aims discussed in section II. Self-efficacy and attitudes about computing have been shown to correlate with academic retention in computing disciplines for all students [19], and specially for women [20]. Thus, the survey and interviews focused on these overarching indicators of the ExploreCSR program success for women in computing research: student perceptions of the research experience (self-efficacy, attitudes towards computing, mentoring), skill development (research), and career identity (intent to pursue graduate school, scientific leadership and identity). These surveys were approved by Intuitional Review board (IRB).

Pre- and post-surveys were administered prior to the start and at the end of the workshop via a Qualtrics survey link, distributed directly to the students. Workshop observations were conducted when possible, and where applicable interviews were conducted of student participants. The surveys measured: (A) Self-Efficacy, (B) Interest in Graduate School, (C) Attitudes about Computer Science, (D) Research Skills, (E) Professional Identity, (F) Sense of Belonging, (G) Grit, (H) Teamwork/Leadership, (I) Mindset, and (J) Peer Relationships. Items were rated on a 5-point Likert type scale, with 5 being most positive rating. Fig. 3 summarizes the responses from 43 and 35 students that completed the pre-/post-surveys, respectively. We observe that all constructs increased at post-survey except for (C) Attitudes about Computer Science. One possible explanation is that since the students self-selected to attend the workshop, they might have been already predisposed on their attitude about CS. sing an independent sample t-test indicated that the increase of (D) Research Skills and (E) Professional Identity have been statistically significant with both p-values<0.01.

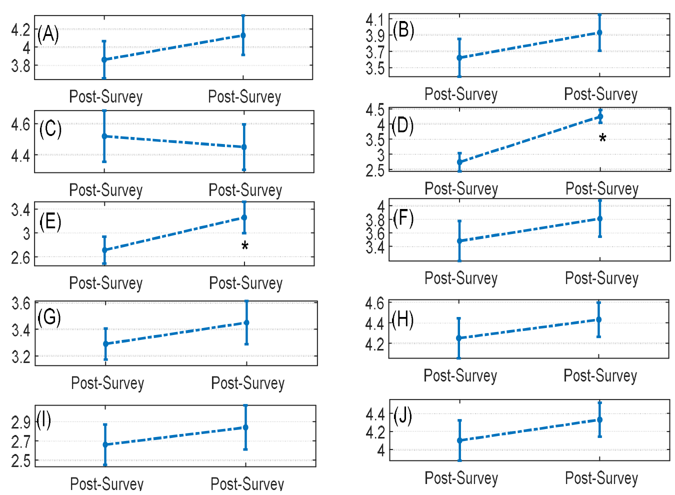


Fig. 3 Mean and 95% confidence intervals of the scores (on a 5-point scale) of pre-survey and post-survey results: (A) Self-Efficacy, (B) Interest in Graduate School, (C) Attitudes about Computer Science, (D) Research Skills, (E) Professional Identity, (F) Sense of Belonging, (G) Grit, (HI Teamwork/Leadership, (I) Mindset, and (J) Peer Relationships. *indicates significant difference with p-value<0.01.

Additional findings from the ethnographic observation and qualitative interviews include:

- Students gained extensive research experience and believed that their workshop mentors promoted critical thinking and reasoning skills.
- Mentors created a culture of intellectual curiosity.
- A strong sense of community and belongingness was developed.
- Students learned about how to apply to graduate school, which was very beneficial for them as they plan out their career goals and aspirations post-graduation.

V. Recommendations Based on the Lessons Learned

In order to help with identification of key components of our workshop that can be scaled to transfer to other schools, here we also share some of the lessons we learned from our experience that might improve the workshop outcomes by others who organize similar workshops:

Enhancement of participation: Around 37% of our accepted applicants did not register for the workshop. This was mainly due to the timing of the workshop which happened to have coincidence with midterm exam week in some of the regional universities. 15% of our registrants also changed their mind about attending. However, this ratio is consistent with those reported in [12]. The majority of our attendees were from the universities whose faculty were among the project leaders. Thus, in a case of multi-institutional workshop, involvement of at least one faculty from each institution can enhance the students' confidence and trust in the workshop and consequently increase their attendance. Reimbursement of the registration fee to those who attend the workshop might be another effective strategy to decrease the last-minute dropouts.

Pre- and Post-survey: While 94% of our attendees completed the pre-survey (mainly during the workshop registration on the first day), only 76% completed the post-survey as it became available few days after the workshop. Incentivizing strategies (e.g., gift cards) might have helped in recruiting a larger number of students in completing the post survey.

Research projects: Evaluating students' responses on the project preference survey, we noticed that simple, practical and relatable projects were more popular among the students. Early announcement of the project descriptions and their leader faculty can help both students and the workshop organizing committee to make a better-informed decision about the project selection.

VI. Conclusion

Our workshop engaged a regional cohort of undergraduate women in an inclusive computing research learning environment. The attendees were able to enhance their research skills and professional identity significantly. A strong sense of community was developed, and students were encouraged and guided to continue their education to a Ph.D. program.

Acknowledgment

The authors would like to thank Dr. Bo Fu and Dr. Wenlu Zhang from CSULB for their assistance in initial logistics planning and their help with evaluation of participants' applications. We also thank Dr. Audrey Rorrer from University of North Carolina, Charlotte and Breauna Spencer from UCI for their independent evaluation of our workshop. Last but not the least, this workshop could not happen without valuable help and guidance of Dr. Sepehr Hejazi Moghadam, the Head of University relations at Google Inc.

References

[1] E. Mannix and M. A. Neale, "What differences make a difference? The promise and reality of diverse teams in organizations," *Psychological science in the public interest,* vol. 6, pp. 31-55, 2005.

[2] S. Beyer, "Why are women underrepresented in Computer Science? Gender differences in stereotypes, self-efficacy, values, and interests and predictors of future CS course-taking and grades," *Computer Science Education,* vol. 24, pp. 153-192, 2014.

[3] A. Fisher and J. Margolis, "Unlocking the clubhouse: the Carnegie Mellon experience," *ACM SIGCSE Bulletin,* vol. 34, pp. 79-83, 2002.

[4] J. M. Cohoon, "Toward improving female retention in the computer science major," *Communications of the ACM,* vol. 44, pp. 108-114, 2001.

[5] A. Monge, P. Marayong, S. Asgari, B. Penzenstadler, and P. Shankar, "Recruitment and Retention Efforts to Broaden Participation in Four Computing and Engineering Programs," presented at the American Society for Engineering Education (ASEE), Pacific Southwest Section Meeting, Tempe, Arizona, 2017.

[6] C. M. Steele, "A threat in the air: How stereotypes shape intellectual identity and performance," *American psychologist,* vol. 52, p. 613, 1997.

[7] S. Cheryan, V. C. Plaut, C. Handron, and L. Hudson, "The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women," *Sex roles,* vol. 69, pp. 58-71, 2013.

[8] S. Beyer, *Women and science, technology, engineering, and math (STEM)*: Oxford University Press, 2015.

[9] S. Zweben and B. Bizot. (2019, May) 2018 Taulbee Survey Undergrad Enrollment Continues Upward; Doctoral Degree Production Declines but Doctoral Enrollment Rises. *Computing Research News*. 3-74. Available at: https://cra.org/wp-content/uploads/2018/05/2017-Taulbee-Survey-Report.pdf

[10] C. R. Madan and B. D. Teitge, "The benefits of undergraduate research: the student's perspective," 2013.

[11] M. Harchol-Balter, "Applying to Ph. D. Programs in Computer Science," ed, 2002.

[12] S. Menzel and C. Frieze, "Experiencing Research Through OurCS: Opportunities for Undergraduate Research in Computer Science," in *2018 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*, 2018, pp. 1-4.

[13] L. Barker, "Student and faculty perceptions of undergraduate research experiences in computing," *ACM Transactions on Computing Education (TOCE),* vol. 9, p. 5, 2009.

[14] S. H. Moghadam, "Fifteen grants to support computing research for undergraduate women," in *Google Education Blog*, ed, 2018.

[15] J. Margolis, A. Fisher, and F. Miller, "The anatomy of interest: Women in undergraduate computer science," *Women's Studies Quarterly,* vol. 28, pp. 104-127, 2000.

[16] A. Fisher, J. Margolis, and F. Miller, "Undergraduate women in computer science: experience, motivation and culture," *ACM SIGCSE Bulletin,* vol. 29, pp. 106-110, 1997.

[17] *Computing to Change the World for the Better: Research-focused Workshop for Women*. Available at: www.csulb.edu/college-of-engineering/research-workshop-for-women

[18] A. S. Rorrer, "An evaluation capacity building toolkit for principal investigators of undergraduate research experiences: A demonstration of transforming theory into practice," *Evaluation and program planning,* vol. 55, pp. 103-111, 2016.

[19] T. Dahlberg, T. Barnes, K. Buch, and A. Rorrer, "The STARS alliance: Viable strategies for broadening participation in computing," *ACM Transactions on Computing Education (TOCE),* vol. 11, p. 18, 2011.

[20] J. M. Cohoon, Z. Wu, and L. Luo, "Will they stay or will they go?," presented at the Proceedings of the 39th SIGCSE technical symposium on Computer science education, Portland, OR, USA, 2008.

From Camp to Conferences: Experiences in Leveraging Tech Conferences to Inspire Black and Latinx Girls to Pursue Coding and Tech Careers

Khalia M. Braswell
College of Science and Technology
Temple University
Philadelphia, PA USA
khalia@temple.edu

***Abstract*—This experience report highlights the impact of taking Black and Latinx middle and high school girls to tech conferences. INTech Camp for Girls took five girls who previously participated in our summer camps and after school program to the #blackcomputeHER Conference in Washington, DC where they were able to network with Black women in tech, participate in a coding workshop designed just for them, and hear from Black Girls ROCK! Founder and DJ, Beverly Bond. Additionally, four INTech High School scholars earned an all expenses paid trip to the Facebook Achievement Summit as a result of their project submission and participation in the Facebook Engineer for the Week program. While at the summit, Team INTech participated in a one day hackathon where worked along Facebook engineers to build an app called "Air to Spare" using Scratch. Our team placed top eight in the country amongst twenty teams, as well as, won the Best Pitch Award. While in Silicon Valley, they were also able to meet 13 Apple Engineers, as well as, receive a tour of the Netflix HQ and speak with two engineers and a User Experience designer about what life in tech is like. This report describes how these experiences inspired INTech girls to pursue coding and technical careers.**

Keywords*—*Broadening Participation in Computing, Hackathon, Tech Conference

I. Introduction

Computer science education provides a gateway to high-paying career opportunities and upward economic mobility. Across the nation, there is a significant and growing demand for professionals who understand how to apply fundamental computer science principles to solve problems across many disciplines and industries. According to the US Bureau of Labor Statistics, jobs that require computing knowledge and skills represent the top source of new wages in the United States. Growth in employment opportunities related to computer and information science is projected to continue over the next several years, outstripping job openings in all other occupation at twice the growth rate [1]. In the state of North Carolina, specifically, there are more than 15,100 unfilled computer science jobs in the state of North Carolina, with the average salary for those jobs being $91,422 [2].

Most of the high-paying career opportunities require a bachelor's in computer science or related field, or the equivalent. A recent report shows that, overall, students who take a computer science course in high school are 6 times more likely to pursue a computer science major in college; women who study computer science in high school are 10 times more likely to study in college [2]. However, only 15% of North Carolina high schools offered an Advanced Placement computer science course during the 2016-17 school year [2].

The INTech Camp for Girls was founded in order to ensure that students, particularly those from underrepresented groups, have opportunities to learn about engineering, technology, and computer science and to have access to lucrative tech-focused career paths. A 501(c)(3) non-profit organization, the mission of INTech is to *i*nform and *i*nspire girls of color to *i*nnovate in the technology industry. Specifically, INTech engages Black and Latina girls in grades 6-12 across North Carolina in out-of-school time experiences, typically through summer camps and after school programs. Through an after school program called INTech Academy, high school girls are able to gain the education that they may miss by not having AP Computer Science in their high school. These INTech experiences are designed around 3 pillars:

- **Inform.** INTech provides girls with opportunities to master essential computer science concepts, such as creativity, abstraction, algorithms, and programming, and to learn about different potential pathways for technology careers.
- **Inspire.** INTech introduces young women of color to women with a background in the technology industry, who share their educational and career experiences.
- **Innovate.** INTech provides girls with opportunities to work together in lightweight teams [3] in which they learn how to create and implement technology solutions. Working in a team setting, girls reap the benefits of peer teaching, peer learning, and increased student engagement [3].

Funding for the trip to Facebook was made possible through Facebook.

INTech has recently introduced conference attendance as a new component of the INTech Academy, with the goal of fostering community building, providing exposure to real-world views of industry professionals and settings, and building skills in computing. This report describes the motivation, design, and experiences in developing this new component as part of INTech Academy.

II. Program Description

INTech offers two different types of out-of-school opportunities for Black and Latina girls to learn about computing and tech careers: INTech summer camps and the INTech Academy.

A. INTech Summer Camp

The INTech Summer Camp is a 5-day experience for Black and Latina girls who are in middle school. There are two different tracks:

- **Track 1 - HTML/CSS** in which girls who are new to INTech learn how to build a website about a social issue of their choice
- **Track 2 - User Experience Design** in which girls who have attended INTech previously learn how to design and prototype mobile applications

In the morning of each camp day, girls spend time in teams of 3 to 4 where they build a tech product, depending on their track, about a social issue that they would like to research during their time at camp. Project topics include racism, LGBTQ+ issues, homelessness, animal poaching, etc.

In the afternoon, we visit tech companies local to Charlotte, NC and Raleigh, NC so that our middle school girls can make the connection between what they learn in the classroom and what a career could look like for them. So far, we have visited Google Fiber, Microsoft, Red Ventures, AvidXchange, Red Hat, SAS, Lithios, IBM, Bank of America, Google, Accenture and Komplex Creative.

Additionally, we also increase the social capital of our scholars by introducing them to Black and Latina women in tech who share their journey of how they got into tech. At the end of the week, we celebrate the work they have done with a community celebration where students are able to present their projects to their family and community partners.

B. INTech Academy

During the fall of 2018, INTech hosted a pilot after-school program, called INTech Academy, where eight high school girls met on Tuesdays and Thursdays after-school from 3pm-5pm for 9 weeks to learn about game development, mobile app development, and User Experience Design. During the first three weeks of the program, we implemented the nationwide Facebook Engineer for the Week (EFTW) program. EFTW aims to demystify the world of tech, empowering teens to build a working tech product and develop computer science skills [4].

There are two project tracks that can be selected for the EFTW program: Play for Impact and Chatbots for Change. INTech Academy chose the Play for Impact track where two girls built a game called ”Playing for Equality” using Scratch, where they addressed the issue of racism, sexism, and education insensitivity within a soccer game. The game had several levels and as you advanced to a new level, you learned about a new issue. Determined to create a great game, the girls spent time outside of the allotted INTech Academy time to fine tune the game for a final submission. As a result of their submission, the team was selected to attend the Facebook Achievement Summit to participate in a hackathon at Facebook's Headquarters in Menlo Park, CA.

III. Conference Attendance

In order to create a culminating experience for girls who have participated in INTech programs, we decided that attending tech conferences would be a great way to expand upon our 3 pillars (inform, inspire, innovate) and truly allow our scholars to build their tech community [5], learn about tech careers, gain additional tech skills, and tour tech companies outside of the cities in which they live.

#blackcomputeHER Conference 2019: blackcomputeHER.org is dedicated to supporting computing+tech education and workforce development for black women and girls. The aim for blackcomputeHER.org is to generate knowledge and disseminate information that creates a spirit of urgency around the lack of sustainable diversity. blackcomputeHER.org organizes the annual #blackcomputeHER conference and supports the community of black women and girls in computing+technology through education and workforce development [6].

INTech took two middle school girls and three high school girls who previously attended INTech Camps to the 2019 #blackcomputeHER conference in Washington, DC where nearly 200 black women technologists attended and experienced masterclasses for professional development on topics including entrepreneurship, data science, and career development.

Facebook Achievement Summit: The Facebook Achievement Summit is 2-days of learning, collaboration, and celebration for the Engineer for the Week finalist teams and facilitators at Facebook Headquarters in Menlo Park, CA. The summit includes a 2-day hackathon, panels with Facebook teams, facilitator workshops and more [7]. INTech took four high school girls, the INTech Academy program lead instructor, and an INTech parent who also serves as a school partner.

Next, I will discuss the experience of the two conferences in regards to INTech's three pillars - inform, inspire, innovate.

A. Inform

Through our inform pillar, girls learn about various forms of technology and how it impact their daily lives. While at the Facebook Achievement Summit, our INTech girls soaked up valuable knowledge during several interactive STEM workshops. They were introduced to the Agile Methodology where they created a kanban board with swim lanes titled To-Do, In-Progress, To-Verify, and Done to keep up with their tasks. They also learned story boarding concepts to thoughtfully plan out the flow of their game, keeping in mind the different levels a user would have to go through and the goal of each level. Additionally, they participated in a Oculus Virtual Reality (VR) Demo where they learned from Oculus engineers about how VR technology works.

B. Inspire

While there has been a decline in the amount of Computer Science Bachelor's degrees earned by Black women [8]–[10], it is our goal at INTech to expose our scholars to as many women who look like them as possible. The #blackcomputeHER conference, with over 200 women in attendance, gave our girls multiple opportunities to interact with women in tech who look like them through various workshops.

A Conversation with Beverly Bond: On the first day of the #blackcomputeHER Conference, Beverly Bond, DJ and Founder of Black Girls ROCK!, participated in a lunch time fireside chat where she discussed GIRLS ROCK! TECH, an after-school program for STEM development through music, media and digital technologies [11]. One of our high school girls became so inspired that she purchased the Black Girls ROCK! book, received an autograph and picture with Beverly Bond, and shared with her that she was inspired to become a DJ.

Beyond Black Girl Magic!: In this workshop, Dr. Siobahn Day and Pamela Gibbs explored the life dynamics of black women as well as their identities outside of technology. The workshop provided tools and techniques fostered a healthy discussion regarding balancing everyday demands and maintaining our unique identities [12]. All five of our girls attended this workshop and they left inspired and excited about their future. One of our high school students who now attends North Carolina A&T State University became inspired by Dr. Day, as she was the first Black woman to graduate with a Computer Science degree from North Carolina A&T State University.

Silicon Valley Visit: In order to make the most of our trip to Silicon Valley during the Facebook Achievement Summit, we planned a lunch with 13 Apple engineers, a tour of the new Apple Company store, a behind the scenes tour of Netflix where they had an intimate discussion with two engineers and a user experience designer, and a tour of Stanford University. Since we had girls on the trip who are interested in user experience design and software engineering, we wanted to provide them with the opportunity to hear from employees at companies whose products they use every day. They were able to ask questions about living far away from home, adjusting to California, working at a large tech company, and what classes they should think about taking in order to prepare them for a tech career.

C. Innovate

Inspiring and Supporting the Next Generation of Black Women in Computing+Tech: The #blackcomputeHER 2019 Student Track included a two-hour hands-on workshop designed to engage middle/high school students with computing skills and technological applications. This session fostered early connections and exposure to the sisterhood of Black women in computing. During the session, our girls were able to use Scratch to begin building a game. While the time period for building the game was short, our girls were able to become familiar with the Scratch platform and gain gaming concepts that they could build on later.

Achievement Summit Hackathon: During the two-day event, INTech girls participated in a hackathon in which they competed against 100 students from all over the country. INTech girls used Scratch to develop "Air to Spare", an environmental app inspired by their concerns about pollution in Charlotte. The game tasks players with finding alternative modes of transportation producing the least amount of pollution during a simulated work commute. During the hackathon, each team was assigned a Facebook Engineer who served as a mentor to assist them with their project.

Once the hackathon was over, each team prepared a two-minute pitch to share out in a science fair style session where Facebook engineers walked around to judge the pitches to determine who would make the top eight teams to pitch during the dinner celebration. Out of the 20 teams, INTech advanced to the top eight teams to do a final pitch and shared their two-minute pitch on stage in front of everyone at the dinner celebration. There were four awards given: Most Creative, Best Social Value, Best Pitch, and Best Overall. Out of the eight teams, team INTech received the award for Best Pitch.

IV. Reflections

While each conference experience provided multiple opportunities for INTech girls to be informed, inspired, and to innovate, when looking back, the inspiration from those around them had the largest impact.

Two of our middle school girls, who were the youngest attendees of the #blackcomputeHER conference, has participated in all of the INTech Summer Camp's in Raleigh, NC. They stated:

> I enjoyed the #blackcomputeHER conference because it gave me an opportunity to talk to other women in the computer science field. Listening to all the different jobs people did broadened my aspects on what I would like to do in the future.
>
> It was [also] very exciting meeting Beverly Bond. Among all women employed in computer and information science occupations, only 12% are Black or Latina women, and some of the women in that room made up that 12%.

While at the #blackcomputeHER conference, two INTech Board Members received awards. Dr. Denae Ford Robinson received the Rising Star award and I received the Lift As You Climb award. This moment was also inspiring to one of the girls who stated:

> It was extra special because Ms. Khalia received an award and it felt good to know that one of my mentors received recognition for her hard work. It

> made it “real” that I can do anything I set my mind to do.

The four high school students who attended the Facebook Achievement Summit also reflected on how inspiring the trip and summit was for them.

> [While] in California, I was able to get deeper into technology. It was great to hear minorities speak about how they turned negative outcomes into positive outcomes. I loved listening to their stories. They made me realize this is what I want to do!!
>
> EFTW and the California experience overall was very motivating and exciting. I met several friendly people from similar backgrounds that ended up going to extraordinary places. The Facebook team and competition was welcoming and my team worked well together and efficiently. All the places we got to see were life-changing and amazing.

Teamwork was another theme of the Facebook Achievement reflections. One of the students stated:

> I can honestly say that I enjoyed my time at the EFTW Achievement Summit. Learning and interacting with my teammates was the highlight of my experience. I learned how to work under pressure and complete an app within a short amount of time. This is something I will never forget and inspires me to learn more about coding.

The parent of the middle school students reflected:

> The excitement in my two daughter’s voices telling me about their experience at the#blackomputeHER conference was one of my happy and proud moments as a parent. The description of how they felt being among all the other attendees was priceless...I look forward to what they gained and what they will continue to learn from this exposure.

We also had a parent come to California with us who was my former Chemistry teacher and is now the Career and Technical Education facilitator for the school we held INTech Academy. She stated:

> The biggest impact for me...a former student mentoring my daughter!! It takes a village and my village has come full circle. Thank you Khalia Braswell!

V. Lessons Learned and Future Work

A. Planning

The Facebook Achievement Summit was an all expenses paid trip in which Facebook coordinated the flights and hotel rooms for four students and two facilitators to attend. We also had a parent attend who paid for her own flight expenses.

The #blackcomputeHER Conference took more planning since it was largely funded by INTech. We sent out an interest form to 11 past INTech camp participants (middle and high school students) in both Raleigh and Charlotte North Carolina. Out of the 11, we received eight responses to attend and was able to take five students (three from Charlotte and two from Raleigh) and two chaperones. In the future, we would start the planning sooner so that parents can plan around their students being out of school and hopefully increase the number of girls who can attend.

We asked parents if they would be willing to pay to supplement some costs and all of them responded that they would be able to pay. For the families that decided to attend, we offered a discount for our summer camp registration fee. Expenses included the hotel, two rental cars and gas, and dinner on the first night. Fees from the parents went towards conference registration and hotel expenses.

B. Future Work

In the future, we would like to seek out sponsorship opportunities so that more INTech girls can attend the #blackcomputeHER Conference.

Three of the girls who attended the Facebook Achievement Summit attend the same high school and have decided to participate in the EFTW program again in order to attend another Achievement Summit. They have the support of their school staff, former INTech facilitator, and INTech.

Acknowledgment

INTech Camp for Girls thanks Facebook for providing an all-expenses paid trip for our scholars and facilitators to attend the Achievement Summit.

References

[1] U. B. of Labor Statistics. (2019) Computer and information technology occupations. [Online]. Available: https://www.bls.gov/ooh/computer-and-information-technology/home.htm

[2] code.org. (2018) Support k-12 computer science education in north carolina. [Online]. Available: https://code.org/advocacy/state-facts/NC.pdf

[3] C. Latulipe, N. B. Long, and C. E. Seminario, “Structuring flipped classes with lightweight teams and gamification,” in *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, ser. SIGCSE ’15. New York, NY, USA: ACM, 2015, pp. 392–397. [Online]. Available: http://doi.acm.org/10.1145/2676723.2677240

[4] E. for the Week. (2019) Engineer for the week official page. [Online]. Available: https://engineerfortheweek.fb.com/about/

[5] G. C. Townsend and K. Sloan, “An effective alternative to the grace hopper celebration,” in *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, ser. SIGCSE ’15. New York, NY, USA: ACM, 2015, pp. 197–202. [Online]. Available: http://doi.acm.org/10.1145/2676723.2677233

[6] #blackcomputeHER. (2019) #blackcomputeher 2020 conference. [Online]. Available: https://blackcomputeher.org/2020-conference/

[7] E. F. T. W. A. Summit. (2019) Frequently asked questions. [Online]. Available: https://bit.ly/344DX0r

[8] N. C. f. S. National Science Foundation and E. Statistics, “Women, minorities, and persons with disabilities in science and engineering,” National Science Foundation, Alexandria, VA, Tech. Rep., 2019.

[9] A. DuBow, W. & Pruitt, “Ncwit scorecard: The status of women in technology,” NCWIT, Boulder, CO, Tech. Rep., 2018.

[10] . B. B. Zweben, B. S., “2018 taulbee survey undergrad enrollment continues upward; doctoral degree production declines but doctoral enrollment rises,” Computing Research Association, Tech. Rep., 2019.

[11] B. G. Rock. (2019) The girls rock! tech (grt) initiative. [Online]. Available: https://blackgirlsrock.com/what-we-do/imagine-future-scholarship/

[12] blackcomputeher.org. (2019) 2019 conference agenda. [Online]. Available: https://blackcomputeher.org/2019-conference-agenda/

Maximizing BPC Through Maryland's Annual State Summits

Megean Garvin, Ph.D.
Maryland Center for Computing Education
Adelphi, MD, USA
mgarvin@usmd.edu

Rebecca Zarch
SageFox Consulting Group
Amherst, MA, USA
rzarch@sagefoxgroup.com

Jeff Xavier
SageFox Consulting Group
Amherst, MA, USA
jxavier@sagefoxgroup.com

Sarah Dunton
ECEP Alliance
Holyoke, MA, USA
sdunton@mghpcc.org

***Abstract*— Computer Science (CS) education advocates have worked within states to change K-12 education policies in order to broaden participation in computing (BPC) and grow CS as a content discipline within K-12 classrooms. Statewide summits, which convene a variety of stakeholders across levels of education, are pivotal events that build momentum for change. Maryland has utilized annual summits to leverage statewide advocacy in order to continue CS K-12 education growth. Summit evaluations provided valuable data to strategically plan additional events and advocacy activities. Data from the past four annual summits are analyzed and discussed. State advocacy outcomes include: 1) increased statewide CS education awareness, 2) the establishment of the Maryland Center for Computing Education, 3) seven million dollars of state funds dedicated to K-12 CS education professional development and pre-service teacher preparation program reform, and 4) the enactment of Securing the Future: Computer Science for All law. This law requires all Maryland public high schools to offer CS, make efforts at the middle and elementary levels to include CS, and broaden participation in computing in K-12 classrooms. Valuable insights are provided for other states to consider as they build BPC advocacy efforts through statewide summits in their own states.**

Keywords— Broadening participation in computing, K-12, state summit

I. INTRODUCTION

The computing education state summit has become a valuable event for individual state teams to engage stakeholders in critical discourse. State advocates who plan and lead the organization of summits intentionally include Broadening Participation in Computing (BPC) as a focal point. BPC moves beyond access to technology to provide more (and more engaging) opportunities for all students, especially underrepresented students to learn CS [1]. Underrepresented students include female, racial/ ethnic minorities, specifically African Americans, Hispanic Americans, Indigenous Americans, Alaska Natives, Native Hawaiians, Native Pacific Islanders, students from low socioeconomic backgrounds, and students with disabilities [2]. The National Science Foundation (NSF) has addressed BPC by funding research projects which directly study how to decrease the gaps and increase equitable learning opportunities for all students [3].

Each state needs to recognize that changing K-12 education state policies is a complex endeavor and building collaborative efforts among a variety of stakeholders is required to democratize K-12 CS [2]. Therefore, the summit planning team needs to examine the state governance levels and decision-making mechanisms [4]. The state summit is a pivotal, often data driven, event that convenes the key stakeholders and energizes attendees to become BPC advocates, leading to sustainable statewide change. Maryland began to convene annual BPC state summits in 2016. Maryland has 25 local education agencies (LEAs) which serve a variety of communities (urban, suburban, and rural) from the Appalachian Mountain range to Washington, D.C. and Baltimore metropolitan areas to the Eastern Shore along the Atlantic Ocean. The LEAs also have local control of curriculum and course offerings.

II. STATE SUMMIT DATA

Stakeholders in BPC include a wide variety of advocates. The Maryland state planning team strategically included higher education, K-12 educators, industry, non-profit, and government representatives. The government professionals represented the Maryland State Department of Education (MSDE), the legislature, and the Governor's Workforce Development Board. Within MSDE, there was not a designated CS office or CS specialist from 2016 through the spring of 2019 [4]. Several different MSDE offices and individual specialists participated in the summits including the Career Technology Education Specialists, Educator Effectiveness Specialists (teacher certification and credentialing), Accessibility Specialist, and the Director of Instructional Technology, School Library Media, and Mathematics. The annual summits from 2016-2019 had an interesting pattern of overall attendance with 223 participants attending in 2016 and 221 participants in 2018 as opposed to 121 participants in 2017 and 145 participants in 2019. (See Tables 1 and 2.) There appears to be significantly more attendance every other year.

The annual summit surveys were designed to obtain feedback from summit participants. Participant perceptions including session ratings and advocacy outcomes were collected through the summit surveys. Most survey items remained the same each year with only slight modifications based on sessions offered and additional advocacy efforts. The survey return rates were low with 31% and 36% in 2016 and 2017. (See Table 1.) After the low return rate in 2016, the planning team changed from paper and electronic surveys to just a paper survey. This only increased return rate slightly. Since many participants left and did not attend the afternoon sessions, the survey was split into two surveys in 2018. As an incentive to provide feedback, participants received their lunch ticket when they submitted the morning survey and a door prize raffle ticket when they submitted the afternoon survey. Paper rather than electronic surveys increases the workload for the evaluators to manually enter the data, but the tradeoff is additional data with participants recording their observations and feedback as they progress through the summit. As shown in Table 2, the survey return rates were significantly higher for the morning surveys with 77% and 76% in 2018 and 2019 respectively; however, the return rates were still low in the afternoon with 52% and 33% in 2018 and 2019 respectively. This is mainly due to participants still leaving after lunch.

TABLE I. SUMMUT PARTICIPANTS 2016-2017

Primary Roles	2016 Participants	2016 Survey	2017 Participants	2017 Survey
Government Agency	16	6	10	2
Higher Education	33	27	15	4
Industry	4	1	8	3
LEA Administrator	51	15	23	7
Legislative	5	4	1	0
Non-profit	19	1	14	3
Pre-K-12 Teacher	71	5	43	15
School Administrator	5	2	0	0
Student	16	7	6	3
Other	3	2	1	7
Total	**223**	**70**	**121**	**44**

TABLE 2. SUMMUT PARTICIPANTS 2018-2019

Primary Roles	2018 Participants	2018 A.M. Survey	2018 P.M. Survey	2019 Participants	2019 A.M. Survey	2019 P.M. Survey
Government Agency	10	6	3	6	2	1
Higher Education	24	12	5	21	15	4
Industry	9	4	3	5	0	0
LEA Administrator	24	13	7	20	16	9
Legislative	0	0	0	0	0	0
Non-profit	31	17	8	16	6	1
Pre-K-12 Teacher	101	92	69	70	54	22
School Administrator	4	5	2	5	5	0
Student	15	14	0	2	0	0
Other/Not Specified	3	2	2	0	12	11
Total	**221**	**170**	**114**	**145**	**110**	**48**

III. Summit Goals

The overarching goals for each summit from 2016 through 2019 evolved as the BPC advocacy efforts matured. In 2016, the goal was to engage more stakeholders, increase BPC awareness, and begin to organize next steps. Then, the idea of providing a central location for state advocacy efforts led to the establishment of the Maryland Center for Computing Education (MCCE), and it was promoted by the steering committee members and presented to the stakeholders at the 2017 state summit. Another critical goal was to examine how policy reform might advance the BPC efforts. In 2018, the summit occurred after the end of the legislative session. MCCE was formally established in statute and state funding for BPC began in July 2018. Summit goals for 2018 included defining how MCCE would function as a centralized entity for CS education coordination, strategize how to increase professional development for in-service teachers, and provide access to turn-key solutions for teachers attending the summit. The same goals drove the content of the 2019 summit.

IV. Summit Formats

The summit format is driven by BPC advocacy efforts each year building upon the efforts and successes of the previous summit and advocacy activities occurring throughout the year. The summit planning team sets each annual one-day agenda. (See Table 3.) Each year, the agenda was altered based on the feedback from the prior summits which was provided primarily through the evaluation surveys and additional topics that emerged as the advocacy efforts shifted. The summit started at 8:00 a.m. each year, but the ending time has changed annually. This is due to travel time for participants as well as other school, business, or professional commitments. The changes in times forced the planning team to also change the number of breakout sessions from four in 2016 down to three each of the following years.

The concurrent breakout sessions are planned and strategically placed within the agenda to accommodate the various stakeholder groups. In Table 3, each column provides the agenda for each summit. The placement in the schedule varied based on feedback from prior surveys, availability of the session facilitators, and avoidance of sessions drawing upon the same stakeholder group.

TABLE 3. SUMMUT AGENDAS 2016-2019

April 12, 2016 (8:00 a.m. – 4:30 p.m.) UMBC	**April 27, 2017 (8:00 a.m. – 4:00 p.m.) CCBC**	**April 18, 2018 (8:00 a.m. – 2:30 p.m.) La Fontaine Bleue**	**April 2, 2019 (8:00 a.m. – 3:30 p.m.) Bowie State University**
Welcome and Continental Breakfast	Welcome, Continental Breakfast and **Keynote Speaker: Ruthe Farmer**	Welcome, Continental Breakfast and **Address: Chancellor Caret**	Welcome and Continental Breakfast
1.) High School CS Curriculum 2.) PLTW Launch Program 3.) Maryland PreK-12 CSFramework 4.) Diversity and Equity: Why is CS Education So Important?	1.) MCCE Statewide CS support 2.) PLTW 3.) High School Student Panel 4.) National CS Framework and Standards	1.) CS Teacher Preparation 2.) CS Student Panel 3.) IT CTE Programs of Study 4.) National CS Framework and Standards	**Keynote: Langenberg Lecture: Wes Bush, Northrop Grumman chairman and former CEO**
1.) CS Teacher Preparation 2.) CodeStudio and Other P-5 CS Resources	1.) Employer Industry Panel 2.) CS Resources (K-8) 3.) AP CS Curriculum 4.) CS Diversity and Equity	1.) CS Resources (K-8) 2.) MCCE Statewide CS support 3.) CS Diversity and Equity 4.) AP CS Curriculum	1.) Middle School CT 2.) MD HS CS Standards 3.) Elementary Coaches Session 4.) Student Panel
1.) CS Professional Development for In-Service Teachers 2.) Industry Resources for CS Education 3.) PLTW Gateway and CS 4.) Undergraduates Speak Out: CS Student Panel	**Lunch Table Topics**	**Keynote: Jan Cuny Lunch**	**Lunch**
Lunch Keynote: UMBC President Freeman A. Hrabowski, III "Unsession" Working Discussions	1.) Cybersecurity 2.) Industry Resources for CS Education 3.) Undergraduates Speak Out: CS Student Panel 4.) CS Teacher Preparation	1.) Employer Industry Panel 2.) Cybersecurity 3.) Out-of-school CS Providers 4.) CS Educator Network	1.) Cybersecurity 2.) MD K-8 CS Standards 3.) SCRUM Project Management with Students 4.) Employer Industry Panel
1.) Maryland PreK-12 CSFramework 2.) CS Matters in Maryland: AP CS Principles 3.) CS Outside of School 4.) Computing After PreK-12: Higher Education and Careers in Computing	Conclusion & Reception	Wrap-up, Conclusion, & Next Directions	1.) HS AP CS 2.) CS Pre-service programs planning 3.) Diversity & Inclusion Panel 4..) Out-of-school CS Providers
Wrap-Up Plenary and Reception			Closing

V. Summit Survey Results

The surveys provided both qualitative and quantitative feedback. This data not only impacted the planning for the next summit but provided valuable data for planning additional advocacy events and activities. The survey respondents each year indicated that the summits were well organized. (See Fig.1.)

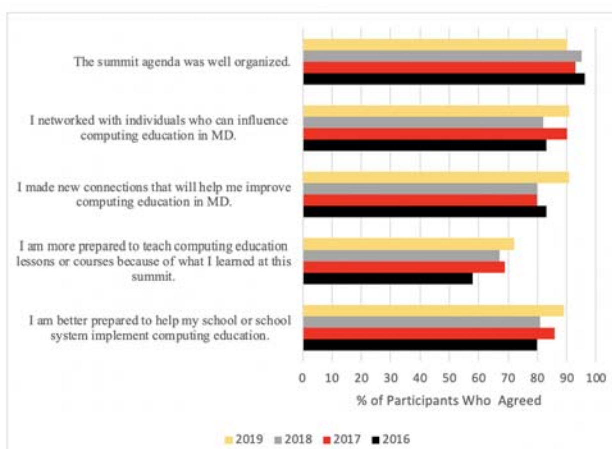


Fig. 1: The percentage of Maryland Computing Education Summits survey respondents who agreed with each statement on the evaluation surveys from 2016-2019.

Each participant indicated sessions that they attended and provided the overall value ranking (poor, fair, good, very good, and excellent) of the session. As shown in Table 3, the popularity of the sessions in a concurrent session block are listed by the number of participants who attend and the value ranking. Many session topics were repeated annually; however, each year the content of the session changed to include new information, resources, or even facilitators. Overall, most sessions, even those with lower attendance were rated favorably by participants. Teachers indicated each year that they preferred hands-on sessions with new classroom ideas and resources. Administrators (system and school) appreciated the state level updates such as the CS frameworks and standards and teacher certification.

A. Networking

The different types of sessions enabled time for stakeholder groups to network within their own group and across other stakeholder groups. The conversations and connections that occur each year provide idea generation and new connections between individuals and organizations. As shown in Figure 1, survey respondents agreed that they 1.) networked with individuals who can influence computing education in Maryland and 2.) made new connections that would help them to improve computing education in Maryland. The summits provided the time, space, and focus for stakeholders to learn others' perspectives. A 2017 survey respondent noted that they appreciated "Having the opportunity to confer with people from my district about what we were learning and how to use it or take it back to our district." This reminds us that too often we work through our professional tasks day to day and do not have the time or energy to work with the other professionals within our own school or school system. The summit provides the educators with this needed time to connect with each other.

Another 2018 survey respondent wrote, "Getting to speak to the code.org representative was very helpful. I really learned a lot from other teachers as well." Code.org is a non-profit organization which hosts professional development for teachers. Presumably, this educator has had training from the non-profit, and was able to capitalize on networking time with a representative from a national organization as well as local teachers.

B. Professional Development

In the case of Maryland, the decision was made to include professional development in order to meet the needs of educators who would attend the summits. CS teachers are needed in order to broaden participation in computing across the state. The lack of trained teachers has continued to be a limiting factor to the growth of CS at the K-12 level [4]. Professional development takes time and resources (facilitators, supplies, and funding). Educators who attend the summits are searching for more training opportunities. The summit provides the educators with a glimpse into the types of professional development offerings that are available, but the limited time does not provide them with the types of robust professional development workshops that convene during the summer. This effort was recognized in the survey results. The percentage of respondents who agreed that they were more prepared to teach computing lessons or courses because of what was learned at the summit increased from 58% in 2016 to 72% in 2019.

The ongoing efforts to provide professional development to in-service teachers across the state helps to promote CS and increase the number of schools offering CS and the number and types of CS classes that can be offered. CS is an exciting and dynamic content discipline. Unlike many other content areas, CS requires that teachers stay current and continue professional development to learn updated content and skills.

C. Advocacy Empowerment

Social change cannot occur without advocates who are willing and able to take action. BPC requires that individuals as well as groups of stakeholders feel compelled and empowered to take action. This begins with each stakeholder understanding their self-efficacy, particularly control over their own motivation, behavior, and social environment [5,6]. Empowerment either enhances their self-efficacy, the belief that they are able to act, or it significantly weakens their sense of powerlessness [7]. Either way, the collective efficacy, or a group's shared belief of goal attainment [8], begins as a result of the networking, collaborating, and sharing of experiences during state summits. In order for participants to feel empowered to take action as BPC advocates after the summit, they must find the relevant information and collective efficacy inspiring enough to take actions on their own.

Each survey contained two particular items used to gauge advocacy empowerment. First, respondents consider if they agreed with the following statement: "I am better prepared to help my school or school district implement computing education." The results were 80% in 2016, 86% in 2017, 81% in 2018, and 89% in 2019. Next, each respondent was asked to "describe the actions you see yourself taking part in to improve computing education in Maryland." The variety of answers ranged from participating in more professional development, providing more professional development for teachers, consciously recruiting more underrepresented students to take CS classes, and continuing to network with other stakeholders to advocate for computing education.

Particular comments highlight the advocacy empowerment of the summit participants. In 2016, a participant wrote, "I am hoping to be a driving force in Queen Anne's County making these changes happen." Queen Anne's County is a small school district located on the Eastern Shore of Maryland. Unlike the technology corridor between Baltimore and Washington, D.C., the community including parents and students require particular messaging and advocacy efforts for BPC. Another 2016 participant shared, "I have been asking folks to sign up for the Code.org and Scratch Meet Ups offered. I try to model and offer support in my building." This advocate tried the "bring a friend with you to professional development" approach and also supports colleagues in his/her school. This is consistent with data from our state landscape surveys in which teachers, who are advocates, are attending training and incorporating CS into their classroom but feel isolated within their school [9]. In 2018, a respondent wrote, "Working to integrate CS into other content areas. Help school staff develop a deeper understanding of the breadth of CS." Each of these statements demonstrate that individuals can think about how to begin advocacy efforts in their own schools.

Other advocates begin to think more broadly by looking beyond the classroom and school levels of advocacy. In 2017, a respondent noted, "I want to present to counselors what we do and how we can reach students. I want to hold meetings for 8th grade girls and African American males to interest them in CS." This advocate wants to make sure that professional school counselors are aware of CS and at the same time he/she wants to actively recruit female and African American male students at the middle level to engage them before they reach high school. Another respondent in 2019 positioned himself/herself, "To be the point of contact for my district on implementation of CSforAll and computational thinking." In 2018, a respondent intended to be an advocate who worked across stakeholder groups, focusing on: "Advocacy of STEM and art (STEAM ED) in and out of the classroom setting via K-12 districts, high education institutions, and non-profit organizations." The advocacy empowerment shown through these statements provides a window into how the summit can kickstart advocacy at many levels to include a variety of ways for stakeholders to contribute to the state BPC mission.

VI. State Advocacy Outcomes

The summits are one piece to a large puzzle that state advocates use in order to more efficiently and effectively progress BPC efforts. Following the 2016 summit, more advocates joined the Maryland Computing Education Steering Committee. This committee engages stakeholders throughout the year in addition to the annual summit. It was during one of the steering committee meetings when the idea to have a center emerged. However, it took more time, energy, and direct advocacy with the Governor and legislature until the enactment of *Securing the Future: Computer Science for All* law. The advocates who went to Annapolis to testify were identified by stakeholders who regularly met and discussed computing education during steering committee meetings and at the annual summits. The feedback loops and discussions among and between stakeholder groups during each summit, each steering committee meeting, and through other correspondence provided the needed momentum to have the bill successfully passed and signed into law in one legislative session. This law formally established of the Maryland Center for Computing Education and provided 7 million dollars of state funds dedicated to K-12 CS education professional development and pre-service teacher preparation program reform. The law mandates that all Maryland public high schools offer CS, make efforts at the middle and elementary levels to include CS, and broaden participation in computing in K-12 classrooms. Remarkably, the law passed with only one opposed in the legislature, and it was signed into law by Governor Larry Hogan. This was a true bi-partisan effort.

VII. Implications for Other States

BPC state summits coordinate reform efforts by empowering participants to become advocates. States should consider beginning with a smaller, more focused convening with key stakeholders who are dedicated to the mission of BPC. While it is important for this initial planning team to have shared goals, it is not necessary for the group to be formalized or all located within the same organization. In fact, the more diverse the team with varied representatives, the more voices will be heard and engaged in creating the shared mission and goals [2, 10]. This can also engage a planning team who can tackle a larger summit as advocacy efforts move forward in the state

Next, state BPC advocates need to understand the education governance levels in the state and the autonomy of decision-making that occurs within and between each level [4]. For example, identifying which level (state department of education, local school board, school system central administrators, school administrators, or classroom teachers) selects curriculum for a computing course provides the advocates with the information of which stakeholders to engage in curriculum advocacy. Understanding how decisions are made and by which levels enables the BPC state advocacy leadership team to create a state strategic plan with specific and measurable goals. This in turn will assist in identifying additional key stakeholders who are decision makers in each level and for each BPC effort. While Maryland chose to focus on increasing awareness and professional development for educators, other states might determine that having a CS graduation requirement, a CS admission requirement for higher education, or building CS infrastructure with designated CS positions at each governing level within the state are needed more immediately in their own states [11].

Maryland's state summits have effectively launched BPC reform efforts. Gathering the various stakeholders enabled the planning team to identify the unique challenges within the state, assess the resources available through the summit survey data, create a state BPC shared message, and energize participants to become BPC advocates [2]. The valuable networking within and between stakeholder groups provided new connections and further developed the conversations between summits to hold additional advocacy activities. Finally, if a state identifies any particular type of advocacy effort to further BPC, such as professional development for educators, the summit is the perfect venue to introduce the effort and provide follow-up information and correspondence to further the effort after the summit.

Acknowledgment

We would like to thank the National Science Foundation ECEP Alliance for supporting the Maryland summit from 2016 through 2018.

References

[1] J. Margolis, J. Holme, R. Estrella, J. Goode, K. Nao, and S. Stumme, "The computer science pipeline in urban high schools: access to what? for whom?," *IEEE Technology and Society Magazine*, vol. 22, no. 3, pp.12–48, 2003.

[2] ECEP and NCWIT. "Organize: Broadening participation in computing state summit toolkit." Retrieved from www.ncwit.org/organize, 2019.

[3] National Science Foundation. "Broadening participation in computing." Retrieved from https://www.nsf/cise/bpc, 2019.

[4]. M. Garvin, M. Neary, and M. Desjardins, "State Case Study of Computing Education Governance," ACM Transactions on Computing Education, vol. 19, no. 4, pp. 1–21, 2019.

[5] A. Bandura. "Self-efficacy: Toward a unifying theory of behavioral change." Psychological Review, vol. 84, pp. 191-215, 1977.

[6] A. Bandura. Social foundations of thought and action: A social-cognitive view. Englewood Cliffs, NJ: Prentice-Hall, 1986.

[7] J. Conger and R. Hanungo. "The empowerment process: Integrating theory and practice." Academy of management review, vol. 3, pp. 471-482, 1988.

[8] A. Bandura. "Self-efficacy mechanism in human agency." American Psychologist, vol. 37, no. 2, pp. 122-147, 1982.

[9] M. Garvin, H. Killen, J. Plane, D. Weintraub. "Primary school teachers' conceptions of computational thinking." Proceedings of the 50th ACM Technical Symposium on Computer Science Education. ACM pp. 899-905, 2019.

[10]ECEP Alliance. "Stakeholders involved in BPC." Retrievedfromhttps://ecepalliance.org/resources/stakeholders-involved-bpc, 2018.

[11] Code.org, CSTA, and ECEP. "2019 State of computer science education." Retrieved from https://advocacy.code.org/, 2019

FLAMES: A Socially Relevant Computing Summer Internship for High School Students

Amy Isvik
Department of Computer Science
North Carolina State University
Raleigh, NC, USA
aaisvik@ncsu.edu

Veronica Cateté
Department of Computer Science
North Carolina State University
Raleigh, NC, USA
vmcatete@ncsu.edu

Tiffany Barnes
Department of Computer Science
North Carolina State University
Raleigh, NC, USA
tmbarnes@ncsu.edu

***Abstract*—In this article, we examine a female-oriented, high school computing outreach program, FLAMES, consisting of an 8-week high school summer intern program run within a university computer science (CS) department. We focus on examining the effects of the program on students skills and affect towards computing. Much of the literature in CS outreach research examines summer camps, after-school programs, and other school-year events that often have a focus on only teaching students computing content. Our program is unique and socially relevant as students are trained to assist teachers with the development of Computational Thinking-Infused curricula for their classrooms. This paper presents the design of our program, an overview of the curriculum, and results including both student and teacher feedback. Results show that the program has benefited each of the parties involved, including its student participants, facilitators, and the teachers assisted by the participants. We share our lessons learned in order to help other CS departments develop similar broadening participation in computing programs.**

Keywords*—*Professional Development; STEM+C; Computational Thinking

I. Introduction

According to the National Center for Education Statistics, women received only 19.1% of all Computer Science Bachelor's degrees in the 2016-17 academic year [1]. Studies have indicated that women's sense of belonging has an important impact on their persistence in CS [2], and that having female role models and positive interactions with CS outside of the classroom are important strategies for promoting female participation in the discipline [3], [4].

The Future Leaders in Algorithms, Mathematics, and Engineering Sciences (FLAMES) program is a free high school outreach initiative hosted by our university focused on increasing diversity in computer science by broadening participation in computing to female high school students. Participants are not required to have prior programming experience. In 2019, the program was expanded to include an 8-week summer internship program serving 19 high school students, which ran through a research lab at the university.

This paper will provide a brief background and inform readers about the FLAMES internship. We will end by providing lessons learned for others looking to create a similar program for fostering female interest in computing.

978-1-7281-7172-2/20 $31.00 ©2020 IEEE

II. Background

A 2011 study illuminated promising practices for promoting gender equity in undergraduate research experiences, identifying several effective strategies for supporting women and encouraging them to continue in computer science and engineering [5]. The strategies included having a critical mass of female participants, providing role models and mentors, and discussing topics that relate to both men and women such as implicit bias as a way to indirectly introduce gender equity. Research also shows that women often place great value on social activism, which is a significant factor in the CS gender gap [6].

The use of socially relevant computing activities [7], experiences that make an impact in their communities and their world, can promote sustained engagement in CS and in STEM in general [4], [8]. Burge et al. report success in implementing a one-week residential summer camp for 25 high school girls focused around the design of a mobile application to be used by researchers to study animal behavior. The camp even included a trip to a local zoo for inspiration and understanding of the real world context for their mobile app. After participation in the camp, the participants were more confident in their computer science abilities and reported a better understanding of uses for computer science and what computer scientists do [9].

Similarly utilizing computing for social good, the Game2Learn model [10] was designed to leverage educational game development for retaining students in CS by having undergraduate students develop games to teach CS concepts using rapid prototyping. This project model leverages students' enthusiasm for games and social relevance as the finished products can be used to teach computer science.

Community-based service-learning is an educational approach which situates learning in a community service setting. We leverage this framework by having our students help local state teachers create projects for use in their classrooms, allowing our students to use their technical skills to benefit education in their communities; as women are more likely to chose activities that help people, showing our students that CS can be used to help people is important for broadening participation in computing [11].

We have implemented several of the aforementioned strategies in FLAMES. We made a focused effort to intentionally recruit female students. Participants were provided role models and mentors through university student facilitators, faculty interactions, and research lab rotations shadowing undergraduate research interns. We additionally followed recommendations to host conversations around implicit biases and ethics in computing as well as to create a community of students and role models which encourages young women to remain in CS. Additionally, our students develop rapid prototypes of computational thinking (CT)-infused projects that will be used by active K-12 teachers.

III. Context

A. Participant & Facilitator Data

We recruited primarily through high schools within the county and a few rural schools in nearby counties. Marketing was targeted to young women, however any student could apply. Students were allowed to share recruiting information with their friends and neighbors. As this program is designed with equity in mind, in addition to student essays, reviewers also looked at available role models and parental education. Though not required, all selected participants had taken at least one programming course in school. A breakdown of student demographic information is found in Table I.

TABLE I
FLAMES Participant Demographic Information

Total	Gender		2018-2019 Grade Level				Black or
	Female	Male	9th	10th	11th	12th	Hispanic
N=19	68%	32%	10%	21%	69%	0%	5%

There were two female facilitators who lead the summer internship (1: Hispanic PhD recipient, 2: White PhD student).

B. Implementation

The internship program served two main purposes: first to provide assistance to teachers in an Infusing Computing professional development (PD) and second to show prospective students what socially relevant computer science and research looks like. The internship ran from 9:00 AM - 4:00 PM each day with a 1 hour lunch break at noon. Depending on students needs, they could work morning, afternoon or both. In order to prepare interns for supporting the PD, we offered a 3-day leadership workshop and a 1-week coding course that covered each of the block-based programming activities taught during the PD. Both week 3 and week 8 of the internship coincided with an Infusing Computing PD [12]. For this PD, students provided coding support for K-12 teachers who were designing CT-infused projects for their subject area classrooms. The interns typically worked in pairs to help complete teacher projects or resolve issues. Students communicated with teachers through video calls, group messaging, and in-person.

The other four weeks of the internship focused on developing and enriching students' computing skills through web development and rotations through CS research labs. Students spent one week developing and updating websites for organizations on campus and two weeks embedding themselves within active research labs, shadowing student researchers. Each intern was able to choose two labs that they wanted to participate in for 5 days; their themes were: biological algorithms, critical infrastructures, health analytics, collaborative computing, intelligent tutoring systems, and educational games. Within these labs, some students helped with field study observations, software testing, conducted literature reviews, or classified data. Throughout the internship, graduate students would do impromptu visits to the interns to get help with research ideas, data wrangling, and pilot testing summer camp activities; they also spoke about ethics, implicit bias, and bias in machine learning.

Ending the internship, students presented their experiences, including what they had learned in their research rotations. Presentations were attended by the department faculty, graduate students, and undergraduate researchers as well as community members from the interns' schools. Students also attended the university research symposium, viewing the outcomes of the undergraduate researchers they previously shadowed.

IV. Evaluation & Feedback

We reflected on this experience, for future improvements, by examining student artifacts, interview data, and communications between interns and those they helped.

A. Student Perspective

Student perspective data comes from their final presentations, semi-structured interviews with 10 students (9 female, 1 male), and 3 students' weekly blogs written for school credit (2 female authors, 1 male).

On Skills Gained In addition to the eleven students who received school credit for the hours worked during the internship and the seven students who requested letters of recommendation for their college applications, each student walked away with skills and experiences that they could add to their resume and use in the future. Students gained professional skills such as client communication, time management, and collaboration. They also learned technical skills and gained experience working with programming languages and software tools like, Snap*!*, Python, Java, Julia, R, Unity3D, PyChart, Eclipse and git. After learning some data analytics in a research rotation, one female student shared, "I just found birth data online in my free time and was able to visualize the data to see that there was a drop in birth on weekends versus weekdays." Another student reflected in their blog, "This internship definitely helped me build and develop my skills in computer science as well as working with other people. I got to practice working in a professional environment, which was a relatively new experience for me."

On the Working Environment To foster a positive working environment, we were lenient in attendance and schedules. Interns had individualized schedules allowing them to attend external commitments. We took this into consideration when pairing students so that they could enjoy and meaningfully contribute to the internship. We believe that we were successful on this front. One student shared in their blog that "The work atmosphere here is very chill... and the rules are not too strict. Decisions are made cooperatively, as the researchers are always talking with each other about [research decisions], and frequently consult us if we have tested what they are talking about. Everyone works very hard though, and you can tell they are passionate about what they are working on. I really enjoy the work environment, as I feel very comfortable here and I feel like I can share my voice." By implementing a more relaxed work environment, we were also able to provide opportunities for students to learn teamwork and collaboration while having fun. During work lulls we often allowed students to play games requiring the use of decomposition, abstraction, and other skills beneficial to CS careers. Additionally, these informal activities helped to build rapport among students, leading to the creation of community in computing, vital to women's persistence in CS.

On an Expanded Understanding of CS One of the biggest takeaways students shared from participation in the internship was an expanded understanding of the ways in which computer science can be applied. One student remarked, "I thought computer science was just programming, but coming here I got to see how computer science can be applied to multiple different fields." Many students had taken at least one computing class and thought of computing as merely making different forms of technology, apps, programs or tools. The internship experience helped to fight the misconceptions that students held about computer science. As students put it, "[FLAMES] kind of crushed that stereotype that all you're doing is staring at a computer screen all day," "It's not just somebody who's sitting and constantly typing out code," and "There are so many things you can do with computer science that doesn't mean you're just in a room with a laptop. You're working with people from the national parks. You're catching genetic abnormalities." By realizing that computer science was more than a cubicle, they also learned about the role collaboration plays in the field. One student said, "Computer science, although you can do things on your own, it's a team effort and that's something I didn't think about before."

On Research Rotations Many students chose the research rotations as their favorite part of the internship as it enlightened them on the forms and domain applications that CS might take. This includes "learning about a project that has real world application." and "I'm no longer afraid to read research papers. I understand how abstracts and research papers work." The research rotations allowed students to interact with and learn from researchers with a variety of backgrounds. One student shared, "I had a limited view of CS, this really helped open up my perspective; [Undergrad1] is a business major and isn't limited by her major about being able to use Python and CS." These interactions with college students allowed the high school interns to ask questions and learn more about the college experience. On the value of conversations one student said, "[Undergrad2 and I] talked about college a lot. What college and computer science has been like for her. What's been good, what's been not good. I think especially creating those bonds with the undergraduates was helpful." "She also shared about her application process. I think just having insight into that was very helpful." We also heard changes in students' attitudes: "I learned a lot more about college and I think I feel better after talking with [the facilitators] that it's manageable if you try." [Student] further stated "Before I did this program I used to think [CS] would be extremely challenging. It is challenging, but it's doable if you have the interest." Another student went on to say, "Not until this internship had I really understood how [CS] looks in the real world and how you can apply it in different careers" and explained that this knowledge helped them to consider a career that uses CS.

On Helping Teachers Several students mentioned that working with teachers prompted them to apply for the internship. In an interview, one student stated, "It was cool knowing we made an impact for their classrooms because they can use the programs we made to teach people." In addition to the excitement of making helpful projects, students also spoke positively on their teacher interactions, "[the teachers] were all so excited to code and their passion was contagious... all their curiosity about computer science was refreshing to see". When asked about how it felt to help teachers, one student spoke about the experience of explaining the projects and programming concepts, saying "You have to be more detailed but also concise and simple so they know what you are talking about." Another student explained, "I'm really proud of the work that we've gotten done...It seems like we're really helping the teachers out a lot and they're very thankful. It still feels weird to be teaching teachers, but it's so nice when we finish and they praise us. It was also fun to see how the teachers acted as students." Likely as a result of these interactions, without prompting, students mentioned in both interviews and presentations that they saw "the importance of computing in education." One student stated, "I would have never even thought that an English teacher would use a [coding] project for their class, but they did and it was pretty cool," continuing "I really do believe that CS should be in every school for the future."

Overall, the internship proved valuable to students. They learned professional and technical skills, enjoyed helping others, increased their interest in computing, and gained a broader understanding of CS and the college experience. One student said, "[This experience] has shown me that computer science is used on a daily basis and has restored my interest in programming and developed my people skills."

B. Teacher Perspective

Forty-one off-site teachers requested the interns' help and all 10 local teachers were paired with an intern developer. In total, the interns helped create 45 projects for 43 teams. Interns made small code changes or created entire projects depending on the teacher's level of coding comfort.

In reviewing teacher reflection surveys and the #code-help chat channel used during PD, teachers showed avid appreciation, thanking students frequently for all their help. Teachers found the interns approachable and appreciated receiving individualized help. "The Zoom Kids are great!! Really helpful as I was creating my project. So willing to answer my questions and offer suggestions." One teacher noted "I think the feedback and implementation was shocking. Whatever was requested was done. I have never experienced anything like that before." One teacher shared "...I think my brain was just so tired, I could not think of a way to start! Once she got rolling, I could see where I wanted the programming to go." Overall the teachers were very receptive to the interns, "I enjoyed the opportunity to work with the HS students on our projects. They were incredibly knowledgeable and I would not have come up with the project that I did without them!! That collaboration piece was really unique and I appreciated the help!"

C. Researchers Perspective

A total of 6 professors participated in the research lab rotations. They were already hosting REU students and "were not opposed to the idea" of having an extra intern or two shadow their students. After having interns the researchers stated, "The interns were eager to work on whatever tasks we gave them, they did a good first pass at tagging data." Another mentioned, "I was conducting a classroom study and the interns were very helpful in collecting observations. I wouldn't have been able to collect that extra data on my own." One professor noted, "it would have been good to know their exact programming proficiency ahead of time. My first two knew JavaScript and Python, the second set of students had weaker programming skills and so my students had to come up with other tasks for them." Overall though, the professors and researchers agreed that they would want to host students again the following year.

V. Discussion & Lessons Learned

After reviewing all of the feedback, we believe the FLAMES internship was successful in encouraging students, especially young women to pursue further interests in computing. Students were given the opportunity to learn computing skills from college role models and mentors, to have casual conversations with researchers about computing careers, and were able to see their projects have an immediate impact on the community. We now share our lessons learned from implementing and evaluating FLAMES for others who may wish to replicate our program.

[1] When running a large K-12 computing PD with limited staff, knowledgeable HS students make great substitutes.

[2] Assisting teachers provided a good opportunity for students to work on community-focused projects that have a social impact, which plays a large part in recruiting female students.

[3] Working on projects for members of the community allows students to reach beyond their technical comfort zone to attempt problems new to them.

[4] You can run a female friendly program that includes males.

[5] Provide training and information up front to groups hosting students. Knowing interns prior experience and coding skills can help groups prepare activities for their arrival.

[6] Small details can leave a large impression on students. Providing certificates or professional presentation locations make ordinary student experiences feel special.

Additionally, to help feasibility for others, we believe that a shorter, event focused internship could be adapted from this model, including activities like research rotations, facilitating K-8 coding camps, and industry visits and tech talks.

VI. Conclusions & Future Work

Overall, participation in FLAMES proved valuable to students. They learned professional and technical skills, enjoyed helping others, and gained a broader understanding of computer science and the college experience. Furthermore, the interns were valuable to young researchers who were able to get assistance on their summer projects. Though the research rotation experience was far from flawless, it had a strong impact on the students and was the favorite experience of the internship for many students. The interns were also mission critical for the success of the PD, appreciated by both PD facilitators and teacher participants, who enjoyed the students' individualized support on their projects.

In the future, we would like to balance the research focused CS activities with more industry and professional oriented computing careers. We believe this could be achieved through sponsored site visits or invited presentations from industry employees. We intend to continue the FLAMES program refining our activities as we go.

References

[1] National Center for Educational Statistics. (2018, sep) Degrees in computer and information sciences conferred by postsecondary institutions, by level of degree and sex of student: 1970-71 through 2016-17.

[2] R. M. Powell, "Improving the persistence of first-year undergraduate women in computer science," *ACM SIGCSE Bulletin*, vol. 40, no. 1, pp. 518–522, 2008.

[3] J. Wang and S. Hejazi Moghadam, "Diversity barriers in k-12 computer science education: structural and social," in *Proc. of the 48th ACM SIGCSE Tech. Symp. on CS Ed.*, 2017, pp. 615–620.

[4] S. Chapman and R. Vivian, "Engaging the future of stem: A study of international best practice for promoting the participation of young people, particularly girls, in science, technology, engineering and maths (stem)," *Sydney: Chief Executive Women*, 2017.

[5] K. A. Kim, A. J. Fann, and K. O. Misa-Escalante, "Engaging women in computer science and engineering: Promising practices for promoting gender equity in undergraduate research experiences," *ACM Trans. on Comp. Ed. (TOCE)*, vol. 11, no. 2, pp. 1–19, 2011.

[6] L. J. Sax, et al., "Anatomy of an enduring gender gap: The evolution of women's participation in computer science," *The J. of Higher Education*, vol. 88, no. 2, pp. 258–293, 2017.

[7] M. Buckley, J. Nordlinger, and D. Subramanian, "Socially relevant computing," *ACM SIGCSE Bulletin*, vol. 40, no. 1, pp. 347–351, 2008.

[8] N. Z. Khan and A. Luxton-Reilly, "Is computing for social good the solution to closing the gender gap in computer science?" in *Proc. of the Australasian CS Week Multiconference*, 2016, pp. 1–5.

[9] J. E. Burge, G. C. Gannod, M. Doyle, and K. C. Davis, "Girls on the go: a cs summer camp to attract and inspire female high school students," in *Proc. of the 44th ACM SIGCSE Tech. Symp. on CS Ed.* NY, NY, USA: ACM, 2013, pp. 615–620.

[10] T. Barnes, H. Richter, E. Powell, A. Chaffin, and A. Godwin, "Game2learn: building cs1 learning games for retention," in *Proc. of the 12th SIGCSE conf. on Inno. & Tech. in CS Ed.*, 2007, pp. 121–125.

[11] A. R. Carberry, *Characterizing learning-through-service students in engineering by gender and academic year*. Tufts University, 2010.

[12] R. Jocius, et al., "Code, connect, create: The 3c professional development model to support computational thinking infusion," in *Proc. of the 51st ACM SIGCSE Tech. Symp. on CS Ed.* NY, NY, USA: ACM, 2020.

Using Black Music as a bridge to understanding introductory programming concepts

David James
Department of Computer and Information Sciences
Spelman College
Atlanta,GA
djames18@spelman.edu

Lelia Hampton
Department of Computer and Information Sciences
Spelman College
Atlanta,GA
lhampto4@scmail.spelman.edu

***Abstract*— Computer Science is a field that still has long strides to make before its workforce reflects the racial, ethnic and gender diversity found in the United States. To address this problem the authors developed culturally relevant class activities and homework problems that teach students to use loops, lists, functions and conditional logic, by remixing popular Black music in an introductory Python course. The activities were developed with the thought that students would be less intimidated by the content, if they saw their culture reflected in the course materials. Using an online survey, students were asked to compare their experience working on the problems that used Black music as a context, with their experience completing textbook problems on the same content. All of the survey respondents were Black female undergraduate students enrolled in a STEM major at a historically black college.**

Students reported that they were better able to identify with the examples and problems using Black Music as a context. Study participants also indicated that making enjoyable music motivated them to work harder than they would on textbook problems. Of the 33 study participants, 60% had no prior experience programming, and 63% of the students expressed an interest in taking further computer science coursework as an elective. The authors explain the sequence of assignments they used to help students understand introductory computer science concepts, and share lessons learned from using Black Music as a tool in the classroom.

Keywords—STEAM, CSxMusic, culturally responsive pedagogy

I. INTRODUCTION

There is a persistent lack of participation in computing, but especially among women, people of color, and women of color. In 2018, only 4% of Bachelor's degrees in computer science were awarded to black women [1]. In order to address participation and interest in computing, music has been used as a novel approach in computer science education to increase engagement and enhance persistence in computing. Most studies occur in K-12 settings [2][3][4][5], or out-of-school settings such as workshops or camps [6]. While some studies include participants higher education [7][8][9], few studies have taken place in higher education environments serving a population of African American women. Our study targets African American women in higher education through the use of hip hop music as a tool for culturally responsive pedagogy in computer science education. To address this gap in the literature we pose the following research question: How does remixing Black Music impact a student's learning experience in an introductory programming course?

II. METHODS

The study takes place in an introductory computer science course for non-majors at a four year historically black college. All of the study participants are Black Women who are STEM Majors at the college. The authors drew a pool of participants for the study by taking a convenience sample of students from two of the 5 sections of the introductory Python programming course. 33 of the 53 students enrolled in the two sections of the course responded to the surveys. The authors distributed an online survey at the end of the course, which asked students to compare the music-based problems they'd worked on with textbook problems involving looping and conditional logic. Items on the survey also asked how much experience they've had with programming, and if they had formal training with music before the course.

The authors used a mix of inductive and deductive coding to categorize responses to open ended questions in the survey. The first two themes, relating prior knowledge to new knowledge, and using culture to draw students to the material (connecting abstractions with lived realities) were drawn from Gay's[10] concept of a pedagogical bridge, within her theory of culturally responsive teaching. The third theme (computing as a tool to increase creativity and fun) sprang directly from the students reflections on their experience in the class.

III. PROCEDURE

The remix project was broken into four activities for the students: (1) We introduced study participants to the concept that black music can be constructed using algorithms, by walking them through an algorithm they could use to re-create a popular song. (2) The students were asked to create their own algorithm for a remix by sketching their plan to rearrange premade pieces of a popular song (called samples). (3) After students learned about for and while loops, we taught them how to place their samples in loops to code the remix algorithm they created. (4) The students chose their own song they would remix in two different ways, and used conditional logic to select which remix version they wanted to hear. The students were also given assignments to learn about looping and conditional logic straight from the text book, such as summing up odd or even numbers between a starting and ending point.

A. Making Algorithms to remix Black Music

Early in the course the instructor planted the idea that algorithms can be used to create Black Music. In the first class session is dedicated to recreating the song Otis by using an algorithm to rearrange parts of the song Try A Little Tenderness. After the lesson, the students are asked to make a remix of a popular song by flowcharting how its parts should be rearranged. The students were given a PowerPoint slide with buttons that triggered 8 samples of a popular song (Location by Khalid). The participants had to diagram the order of the samples in their remix and how many times each of the samples should be looped. The students were required to have at least four samples and at least two loops in their remixes. During the exercise are instructed to test and revise their remix algorithms. To test their remixes students had to execute their algorithm by hand, by clicking on the samples to play them in the order prescribed by the algorithm. If the remix didn't sound "good", they were asked to edit the algorithm and walk through it until the steps produced a desirable outcome.

B. Using Python to code the Remix Algorithm

After teaching the students how to use for and while loops they are introduced to the jythonMusic library [11].The study participants would use this library to play samples and loop them using the python programming language. The IDE included with the library, called JEM (Java Environment for Music) is designed to run jython code, which is python syntax (version 2.7) that can be used to leverage objects and methods written in java libraries. Using sample code the students learn how to store a sample (stored in a .wav music file) into an AudioSample object. Once this object is constructed its methods can be used to play, pause, stop, speed up and slow down a sample, which will be audible through the sound card/speakers of the student's computer.

C. Remixing their own Music

Once students became comfortable using the jythonMusic library, they were given an assignment to make at least two remixes of one song that they choose. The remix project required students to create a program that asks a user to choose a version of the remix they would like to hear (via the console window), play the appropriate remix until it ends, and return to ask if they'd like to hear another remix or quit. Each version of the remix they created had to be housed in a function. Before arranging their remixes, the participants had to be taught how to identify a sample, and determine whether that sample sounds good when placed in a loop. Audacity has a few tools (like loop play and the selection tool) that allow students to preview and loop their sample, before its saved to a file.

The students were prompted to identify at least two songs that they would like to work with and emphasized that they should use instrumental versions when possible. Instrumental versions of songs are easier to remix because samples of music without words are easier to loop. Some songs also may not have enough variation to sound like a new work once its samples are rearranged. Since the students will create at least two remixes from one song, there has to be a fair amount of variety with respect to the number of sounds in that song. The instructor advised the students to use song they've chosen as their sole source of samples for the remix. Blending two or more songs together requires the students to find songs that have compatible tempos, keys and rhythms, which is beyond the scope of an introductory computer science course. After completing the assignment students were asked for their thoughts on the music-based activities versus problems that required them to use loops in the textbook.

IV. Findings

In discussing the delivery of instruction to ethnically diverse students, Gay[10] emphasizes the importance of establishing cultural congruity in your instruction. Gay says you accomplish this by spending a great deal of time demonstrating through examples, stories and problems how course concepts operate in practice, through the experience and cultural lenses of your students. She calls the use of these culturally relevant examples "pedagogical bridges to connect prior knowledge to new knowledge, the known with the unknown, and abstractions with realities.", and highlights the positive impact it has on academic achievement.

In our survey students were asked to compare textbook problems that used loops (such as counting and summing even and odd numbers) to their remix project, which asks them to use for and while loops to rearrange a song they choose. The students were given about two weeks to complete the project. The authors also asked students whether they would like to see Black music used more or less frequently as a context for computer science instruction, and why they chose to answer the way that they did. Students were asked to state their major, number of years of experience with music, years of experience with programming and whether they would like to take further computer science course work. Most of the participants in the study had no prior programming experience and no previous training in music.

Although this class is the only computer science course required by their majors, over 60 percent of the study participants showed an interest in taking future computer science coursework. It's quite encouraging to see that students did not have to have a musical background to learn programming concepts through remixing. As an instructor, I did have to emphasize that students wouldn't be graded on the quality of the music they produced. Below in Table 1 the authors have provided a summary of responses from the Likert scale items in the web survey.

TABLE I. SUMMARY OF SURVEY RESPONSES

Programming Experience	Prior Music Training	Desire to take more classes in computing
20/33(60.6%) of students had no experience	21/33(63.6%) of students had no training	21/33 (63.6%) of students would certainly take more courses
10/33(29%) had less than one year of experience	2/33 (6.06%) had less than a year of training	5/33 said they may take more courses
Three students (9%) had more than one year of experience	9/33(27.27%) had 3+ years of training	7/33 students will not take more courses

We will present the findings from the open ended questions on the survey in three themes. Two of the themes are derived from Gay's concept of a pedagogical bridge, and one inductive theme sprang from the students responses. The two themes from Gay's work[10] are relating prior knowledge to new the use of culture as a magnet to the course material. The third theme which falls outside of the concept of the pedagogical bridge is called computing as a tool to increase creativity and fun.

A. *Theme 1:Pedagogical Bridges - Relating prior knowledge to new knowledge*

One finding we have discovered that is in line with Gay's idea of a pedagogical bridge is that the music helped students to better understand programming concepts. Understanding how to use loops, and trace the flow of their program, made it easier for them to understand how to modify their code for a better outcome. Students gave the following responses when asked if they would like to see more problems in the future that use Black music as a context.

> "I would like to use more problems that use black music as context in computer science because I identify as Black and I enjoy music. I think it is a great learning tool to use music that (I like) to create a remix. I do not see a purpose in using music or other tools that I cannot relate to from personal experience. We learn better when we use concepts and tools that WE enjoy using (for instance black music was used to help black students learn a new topic of interest)."

> "I like the idea of using music because it is something that is more personal and easy to connect to than just a prompt saying to add numbers or do a task. It allows for creativity and motivates me to actually understand what i am doing so that i get a product i like and am proud of.."

B. *Theme 2: The use of culture to draw students to the course material (connecting abstractions with lived realities)*

Another helpful finding of the study is that our students are constantly connected to Black Music, through Spotify, Apple Music, YouTube and traditional radio. Since music is a part of their daily experience, they are already aware of the sound of a good remix. Students worked on their project with a picture of the polished sound that they'd often heard, and it pushed them to work on the project longer than they would have, if the project did not have a context that was familiar and important to them. Students submitted the following responses when asked whether they cared about the quality of the remix, and if that impacted the amount of time spent on the project.

> "Yes, when listening to song remixes on the radio they are still smooth and seamless. So, when completing my project I want to have that same outcome. Wanting to have that specific outcome did make the time spent on the project even longer."

> "Well the remix had to sound right, so that meant that I had to put in more time, opposed to me just adding random numbers together. (comparing to problems from the text)"

> "In order to get my remix to flow like a natural song, I worked for hours to ensure that it was work that I was proud of."

Using Black music as a cultural tie to the material in this class also prompted students to share their code and remixes with friends, due to their familiarity and love of black music.

> "I would like more black music because it takes computer science outside of basic computing and makes it fun. This project is something I was able to show my producer uncle and he thought it was so cool"

> "One of my favorite parts of this class was the fact that it involved such a strong music base. I was kind of scared when starting this class because I have no previous computer science background but the fact that it contained such a strong music base made me really fall in love with it. I told some of my friends about the process we were going through and how excited I was about it and they thought it was interesting as well."

> "I think there should be more use of black music in the context of a computer science class because black music uses different concepts of computer science (remixes, loops, lists, etc.) I thought that it was interesting that black music was so relatable and a great example of how even though computer science is a largely white field and industry, the concepts of computer science can all be found in many different genres of black music."

The infusion of black music into the course made the material more approachable, by helping students to see themselves reflected in the material. This was especially important since the course is one that is taken largely by non computing majors, many of which (48%) wait until they are upperclassmen to enroll. Some participants said that they perceive computer science to be an intimidating discipline dominated by people who don't look like them.

C. *Theme 3: Computing as a tool to increase creativity and fun*

Many of the students also remarked that they had fun working on this project, and that it helped them to be creative in ways that they hadn't imagined before enrolling in the class.

Some of the students also expanded their view of what computer scientists do as a result.

> "The remix project was one of my favorite projects because I got to choose a song that I really like and work with it to create something. Although it was challenging at times because some beats didn't sound right or make a smooth transitions, I found that was the part I liked the most. I got to be creative and I understood that it was ok if it did not sound perfect."

> "I really enjoyed the music remix project. It gave me a chance to be creative and unique while simultaneously learning about programming."

> "The project was more interesting to me. I was engaged because it dealt with something that involved music. I love listening to music so it was fun learning how to create my own remix to my favorite song and write a code to allow it to play. The (textbook) assignments that we have done do not engage me as much. They seem to be …irrelevant to my life."

V. Lessons Learned

Culturally responsive theories of pedagogy bring home the importance of understanding students' culture, and underscores the value of expertise that students already have. Within the context of the classroom, it's important to understand the current music your students like and weave that culture throughout examples in your courses. Students know exactly what music excites them, so you can ask what their favorite song and artists are at the beginning of the semester, and create some samples from those songs. Also, take the time to teach students how to make samples from their own favorite songs, which allows students to work with the most current songs that move them. At the start of this process it is helpful to have samples that are already cut and placed in the right directories for sample code to work. This cuts out pesky errors at the outset when students are just starting out and need quick results to stay motivated. I have had students lose interest, after getting repeated errors from source code or music samples being placed in the wrong directory.

It's also important to emphasize to students that they are not being judged by the quality of their music production, but they are being judged on how well they are able to understand how to use conditional logic, loops and functions. Some students in the study got so caught up tweaking the sounds that they forgot to finish a working prototype that satisfies the requirements.

References

[1] Computing Research Association, "CRA Taulbee Survey," Comput. Ressearch News, vol. 31, no. 5, 2019.

[2] R. Eglash, M. Krishnamoorthy, J. Sanchez, and A. Woodbridge, "Fractal Simulations of African Design in Pre-College Computing Education," Trans. Comput. Educ., vol. 11, no. 3, pp. 17:1--17:14, Oct. 2011.

[3] J. Freeman et al., "Engaging Underrepresented Groups in High School Introductory Computing Through Computational Remixing with EarSketch," in Proceedings of the 45th ACM Technical Symposium on Computer Science Education, 2014, pp. 85–90.

[4] R. B. Shapiro, A. Kelly, M. Ahrens, B. Johnson, H. Politi, and R. Fiebrink, "Tangible Distributed Computer Music for Youth," Comput. Music J., vol. 41, no. 2, pp. 52–68, May 2017.

[5] A. L. Meyers, M. C. Cole, E. Korth, and S. Pluta, "Musicomputation: Teaching Computer Science to Teenage Musicians," in Proceedings of the Seventh ACM Conference on Creativity and Cognition, 2009, pp. 29–38.

[6] Y. Kafai, K. Searle, C. Martinez, and B. Brayboy, "Ethnocomputing with Electronic Textiles: Culturally Responsive Open Design to Broaden Participation in Computing in American Indian Youth and Communities," in Proceedings of the 45th ACM Technical Symposium on Computer Science Education, 2014, pp. 241–246.

[7] S. Siva, T. Im, T. McKlin, J. Freeman, and B. Magerko, "Using Music to Engage Students in an Introductory Undergraduate Programming Course for Non-Majors," in Proceedings of the 49th ACM Technical Symposium on Computer Science Education, 2018, pp. 975–980.

[8] A. Misra, D. Blank, and D. Kumar, "A Music Context for Teaching Introductory Computing," in Proceedings of the 14th Annual ACM SIGCSE Conference on Innovation and Technology in Computer Science Education, 2009, pp. 248–252.

[9] D. Fields, V. Vasudevan, and Y. B. Kafai, "The programmers' collective: fostering participatory culture by making music videos in a high school Scratch coding workshop," Interact. Learn. Environ., vol. 23, no. 5, pp. 613–633, 2015.

[10] G. Gay, "Preparing for Culturally Responsive Teaching," J. Teach. Educ., vol. 53, no. 2, pp. 106–116, 2002.

[11] B. Manaris and A. Brown, "Making Music with Computers |Creative Programming in Python." [Online]. Available: https://jythonmusic.me. [Accessed: 10-Jan-2019].

Computer Science Principles for Teachers of Deaf Students

Richard E. Ladner
Paul G. Allen School
University of Washington
Seattle, WA, USA
ladner@cs.washington.edu

Andreas Stefik
Dept. of Computer Science
University of Nevada, Las Vegas
Las Vegas, NV, USA
stefik@unlv.edu

Jill Naumann
Model Secondary School for the Deaf
Washington DC, USA
jill.naumann@gallaudet.edu

Erin Peach
Code.org
Seattle, WA, USA
erin@code.org

***Abstract*—A major goal of AP Computer Science Principles (CSP) is equity, that is, that all students should have the opportunity to learn computer science at a basic level. In this experience report, we explore how well the Code.org version of AP CSP meets the needs of Deaf students. We report on a professional development workshop for 14 teachers that teach at schools for the Deaf or in Deaf programs in mainstream schools. These schools and programs use the bilingual approach to teaching with instruction in American Sign Language (ASL) and other resources (e.g., textbooks, workbooks, videos, websites, computer apps, exams) in English. Synthesizing the experiences and advice of the teachers and workshop staff, we offer lessons learned for CS teachers in schools for the Deaf and Deaf programs in mainstream schools, mainstream CS teachers who may have one or a few Deaf students in their classes, and AP CSP content providers.**

Index Terms*—Computer Science Principles, Deaf, English Language Learners, Bilingual, Professional Development

I. Introduction

Students who are Deaf [1] in the US commonly have hearing parents and are the only Deaf person in their family. They often learn American Sign Language (ASL) from peers or at school. Consequently, ASL becomes their principal language and English their secondary. In some sense, these students are English Language Learners (ELLs) and some of the approaches to teaching these students is similar to approaches to teaching ELLs [1]. According to the National Center for Education Statistics (NCES Table 204.27) [2], almost 5 million (about 10%) of students enrolled in public schools in the United States (US) in 2016 are ELLs.

The approach to teaching Deaf students at state residential schools for the Deaf and many Deaf programs in mainstream schools is bilingual, with instruction in ASL and with all other resources (textbooks, workbooks, videos, websites, computer apps, exams) in English. Unlike the situation for typical hearing ELLs, who are on a path to learning spoken and written English and being fully bilingual, Deaf students may never master spoken English and may be weak in written English. Nonetheless, the vast majority of these students are intellectually capable of mastering computer science and should be given the opportunity to do so.

In this experience report, we describe a professional development workshop for 14 teachers of Deaf students at state residential schools for the Deaf and Deaf programs at mainstream schools. All these teachers, including 8 who are Deaf themselves, use a bilingual approach to Deaf education. The workshop was conducted in ASL with the help of ASL interpreters for hearing attendees who did not know ASL. The purpose of the workshop was to prepare these teachers to teach the Code.org curriculum for AP Computer Science Principles (CSP) in their respective schools. A major outcome of the workshop is a set of lessons learned, from both the workshop staff and teachers, for the various stakeholders in Deaf education and PreK-12 computer science education.

The following sections include related work on Deaf students and bilingual education. From there, we discuss workshop staff and teacher participants, the workshop program, highlights, and lessons learned for a variety of stakeholders. These stakeholders include teachers in Deaf classrooms, teachers with one Deaf student in their classes, and AP CSP content providers.

II. Related Work

There is very little literature on the preparation of teachers to teach computer science to students with disabilities at the PreK-12 level. At SIGCSE 2019, Stefik *et al.* reported on a professional development workshop for teachers of blind and visually impaired students [3]. Following that workshop, the first two authors created a professional development workshop for teachers at schools for the Deaf and Deaf programs at mainstream schools. In their prior work, there was much concern about replacement of visual content of computer science curricula with non-visual content. In this report, the concerns are quite different and are more about integrating computer science into the bilingual approach to Deaf education.

A. Deaf Students

Deaf students typically fall under the Individuals with Disabilities Education Act (IDEA) (First authorized in 1975 as the Education of All Handicapped Children Act) or Section 504

This work by AccessCSForAll was supported by the National Science Foundation under Grants #CNS-1738252 and #CNS-1738259.

[1]The capital "D" in Deaf is used to indicate that the students referred to in this paper use American Sign Language as their primary language and are considered part of the Deaf Community.

978-1-7281-7172-2/20$31.00 ©2020 IEEE

of the Rehabilitation Act of 1973. According to the National Center for Education Statistics (NCES Table 204.30) [4], in 2017-18, there were about 7 million PreK-12 students with disabilities served under IDEA. This is about 13.7% of all PreK-12 students. As many as 1.5 million more students may be covered under Section 504. Within the IDEA group, about 75,000 students were identified as having a "hearing impairment" which can range from total deafness to moderate hearing loss.

According to NCES (Table 204.60) [5], in 2017, only about 10% of these "hearing impaired" students attended schools for the Deaf of any kind, and 88.3% attended mainstream schools, with some in Deaf programs. The remaining students were in other educational settings, such as home-schooled. In the US, because education is run at the state level and below, there is high variability in the educational opportunities PreK-12 students receive. There is even more variation among Deaf students because of the varying educational philosophies (oral versus bilingual) and the willingness of parents to send their children away from home to residential schools. The oral philosophy of Deaf education focuses on hearing enhancement technology, speech-reading, and speech, and discourages the use of sign language.

B. Bilingual Education

Bilingual Deaf education has a long history going back to the founding of schools for the Deaf in the early 1800s. Strassman *et al.* stated: "for those interventions that have been studied, d/Deaf students' achievement is positively affected by educational practices similar to those recommended for ELLs [1]." Nine sound principles for ELL pedagogy are delineated by Li [6]. Although not all these principles apply to Deaf students, several of them appear to be what our teachers report using with their students.

It may be tempting to think of using a student's first language as a "crutch" in an ELL pedagogy. The work of Sparks *et al.* suggest strength in an ELL's first language leads to eventual strength in the ELL's acquired language [7]. Rather than a crutch, the first language is a launching point. A similar result was found in Deaf students by Scott and Hoffmeister that ASL is a launching point to learn concepts in English [8].

There is a series of two papers authored by A.G.S. Raj *et al.* related to computer science taught in India using Tamil-English bilingual college students [9], [10]. The papers reported on two studies where students were taught computer science lessons in two conditions, English alone and in a combination of Tamil and English. In both studies, the amount of learning in the two conditions were about the same. However, in the case of Tamil + English approach, students were more engaged in the classroom and felt better about their learning. In our workshop, teachers did not report on an all-English approach to teaching computer science. All our teachers reported using a bilingual approach in their classes.

III. Workshop Staff and Teachers

The workshop staff consisted of the four authors of this report. The first two are experienced researchers and practitioners in K-12 computer science education, the third, who is Deaf, is an experienced AP CSP teacher at a school for the Deaf, and the fourth is an employee of Code.org, an endorsed content provider for AP CSP with expertise in accessibility. The first and third authors are bilingual in ASL and English.

We recruited teachers who use the bilingual approach from residential schools for the Deaf, day schools for the Deaf, and Deaf programs in mainstream schools. There were 14 teacher participants in the workshop from 11 different states. All 14 were ASL fluent including 8 who were Deaf. All but three were active teachers in state schools for the Deaf. One was a statewide coordinator for Deaf students in their state; one was a teacher in a Deaf program in a mainstream high school; and one was a middle school teacher in a private K-8 school for the Deaf. Only one was experienced in teaching computer science and another five had experience teaching technology subjects such as coding, robotics, web design, and computer aided design (CAD). The remaining 8 teachers did not have CS teaching experience. Table 1 describes participants in more detail.

IV. Workshop Program

The workshop followed the general approach of the Code.org professional development workshops for teachers. The College Board recognizes Code.org as an endorsed curriculum provider for AP Computer Science Principles. We focused on the Code.org AP Computer Science Principles (2019-2020) curriculum.

Code.org professional development makes heavy use of teacher modeling in a process they refer to as Teacher-Learner-Observer (TLO), in which a pair of teachers prepare a lesson from the Code.org AP CSP curriculum and teach it to the other teachers in the workshop, who act as students [11]. Workshop facilitators and staff act as observers who engage workshop participants in reflection after each lesson. In this case, the lesson was given in ASL with any supplementary materials in English, just like what would happen in a bilingual school for the Deaf.

In total, eight lessons were taught, a model lesson by the staff member who taught at a residential school for the Deaf, and seven more by the teachers. All the teachers created highly visual slides as part of their lessons. All teachers prepared by using Code.org lesson plans, resources, and tools to implement an experiential activity. These activities led to discussions of the computer science concepts used in the activity and introductions to the technical language used in practice. Teachers were asked to be creative in making their lessons as accessible as possible for their students. They were allowed to modify a Code.org lesson to suit the students' needs. Several hours were allotted during the workshop to prepare their lessons. Each lesson was 40 minutes followed by 20 minutes of reflective discussion between the workshop participants who taught the lesson and those acting as students

TABLE I
SUMMARY OF ATTENDEES OF THE WORKSHOP

Job Description	School Setting	CS Teaching Experience
Technology Teacher	State School for the Deaf	Coding, CAD, Robotics
Computer Science Teacher	State School for the Deaf	Computer Science
Math Teacher	State School for the Deaf	none
Math Teacher	State School for the Deaf	none
Math Teacher	State School for the Deaf	none
English Teacher	State School for the Deaf	none
Statewide Coordinator for Deaf students	Multiple Mainstream Schools	none
Technology Teacher	State School for the Deaf	Coding, Web design
English and History Teacher	Mainstream School with Deaf program	Only as a student teacher
Language Development Teacher	State School for the Deaf	none
Math Teacher	State School for the Deaf	none
Math and English	PreK-8 Private School for the Deaf	none
Substitute Teacher	State School for the Deaf	Coding
Biology and Earth Science Teacher	State School for the Deaf	Robotics

separately first, then all together. The 8 lessons covered in the workshop using the TLO model covered algorithms, number systems, network protocols, data compression, and encryption.

In addition to the TLO sessions there were additional sessions most of which involved the teachers in activities: unplugged, using tools, programming, exam preparation, a panel of deaf students, and a discussion of teachers' future plans.

V. Workshop Highlights

The workshop was highly accessible to all teachers and staff. Two certified interpreters were available throughout the workshop to translate from ASL to English and *vice versa*. All the TLO sessions were enthusiastically presented by the teacher pairs, while the remaining teachers kept to their student roles. Almost all the teachers were unfamiliar with the content of their lessons, but were enthusiastic to learn new material and tools. Some teachers worked into the night to prepare their lessons. In several cases, the teachers consulted with the workshop staff to make sure they understood a new concept or tool.

Because one of the staff was an experienced AP CSP teacher of Deaf students, they were able to answer many questions that came up in the sessions about the Explore and Create tasks. They also had experience modifying the Code.org AP CSP curriculum to make it more accessible, which helped ground the discussion about how to make the material more accessible to Deaf students. Another staff member was an expert on programming languages.

The panel of three Deaf students had very interesting backgrounds. All three, two male and one female, were the only Deaf person in their families. Two of the three had very little exposure to Deaf people until adulthood. Now, both are learning ASL and integrating more into the Deaf community. The third had a Deaf friend in the neighborhood growing up so had more exposure to Deaf people and was fluent in ASL. The students were from three different universities, but all participating in the same summer research program studying various problems in human-computer interaction (HCI) at the site of the workshop. One, a PhD student, was a mentor in the program and the other two, both seniors, were participants. The teachers asked many questions of the students trying to understand their motivations for entering the computing field. All three were engaged in technology from a relatively early age, indicating that early exposure and success in technology may be an important factor in their choice of field of study.

On the final day of the workshop, the teachers were asked what their plans were and this varied. Several said they will now take on the role of the "computer science advocate" at their school. All but three of the teachers were from state schools for the Deaf that go from PreK-12. Several of them mentioned starting with the Code.org CS Discoveries curriculum for students in 6th-10th grade, then moving to the AP CSP curriculum. Several mentioned establishing a summer computer camp to increase interest in a future AP CSP offering. One teacher summed up the experience of many of the teachers in saying:

> I was reluctant. But really happy after all. I feel part of a family. I can now see the big picture. All this can be done without a lot of money. I will talk to the principal about starting a CS and robotics program at my school.

VI. Lessons Learned

There were several lessons learned that impact teachers in Deaf classrooms, teachers with one Deaf student in their class, and AP CSP content providers.

A. *Lessons for Teachers in Deaf Classrooms*

The lessons learned for teachers in Deaf classrooms is based on the experiences of the one staff member who has actually taught AP Computer Science Principles for three years and the experiences of all 14 teachers who taught various subjects in all-Deaf bilingual classrooms. As mentioned earlier, in this setting, the language of instruction is ASL, while most of the academic resources are in English. Some basic advice is that students should sit in a circle so they can all see each other to keep lines of visual communication open when using ASL. Hands-on activities were reported as more effective than lecturing or using captioned video. This is quite compatible with a variety of preK-12 curricula from various providers.

Teachers should not feel compelled to follow exactly the Code.org AP CSP curriculum, especially when it applies to the amount of time suggested for each activity. Because reading speed and comprehension are often different with Deaf students, activities may take longer than the time allotted. Furthermore, preparation time can take longer in order to make modifications to the curriculum for Deaf students. Examples of modifications include creating a more visual slide deck for the lesson and creating meaningful warm-up activities for the Deaf students in preparing for the lesson (e.g., describing a virtual game of battleship to introduce all students to the rules before a lesson).

Although captions on videos are important for access, they are often hard to follow because students need to split attention between captions and content. It is easy to miss some captions because the content has captured a student's attention, or *vice versa*. Videos in ASL may be beneficial.

ASL does not have a standards committee, nor do most human languages. Thus, there are no standard signs used for many concepts, including computing concepts. Indeed, there are even regional signs for the word "computer" used around the United States. This is not necessarily a problem because all the regional signs for "computer" have one translation in English. There was some debate among our teachers as to whether a computer concept should even have sign or, alternatively, just be finger spelled.

B. Lessons for Teachers with one Deaf Student

Most Deaf students are in mainstream schools. Even if they are in a mainstream school with a Deaf program, it is highly likely that they would be the only Deaf student in the computer science class they take. This student will typically have an Individualized Education Program (IEP) or Section 504 Plan that calls for either a sign language interpreter or real-time captionist. The sign language interpreter translates what is being spoken in English to ASL or something called Pidgin Signed English (PSE). PSE is close to ASL except signs are done in English order. A real-time captionist is a highly trained person who translates spoken English to text, word for word. It is important to note that sign language interpretation and real-time captioning are not perfect, so there will be misunderstandings.

There are some Deaf students who use hearing technology (hearing aid or cochlear implant) to hear what is being said. These "assistive listening devices" may be aided by speech reading (often called lip reading). In any case, sight-lines are important to these students. Deaf students should be close to a teacher (to speech read or hear the teacher), interpreter (to see signs), or caption screen (to see text of what is spoken). The teacher should be close to the slides, interpreter, and captionist, so as to minimize the time to switch attention.

C. Lessons for Content Providers

Previous advice to content providers is first do an accessibility audit of your AP CSP curriculum [3]. Teachers in the workshop emphasized that all videos in the curriculum should be captioned and that English explanations should be straightforward and easy to follow. Visual and non-textual ways of explaining content can be very useful. When possible, it is recommended to provide visual and illustrative content in formats which can be incorporated into teachers' classrooms. They also mentioned that it is helpful to think of Deaf students as English Language Learners (ELLs) who number in the millions.

Providing videos in ASL directly could meet the visual communication needs for Deaf students and assist teachers in introducing concepts to students. However, we see this as more an ideal, as there are significant challenges. First, considerable work would be needed to address the concerns raised by the 14 teachers in this workshop regarding regional consistency of signs and establishing a consensus around finger spelling or creating signs for technical concepts. Second, given the cost in hiring interpreters, teams that do not know ASL could require significantly more resources to create the videos, as opposed to captions, which can be added easily and cheaply.

References

[1] B. K. Strassman, K. Marashian, and Z. Memon, "Teaching academic language to d/deaf students: Does research offer evidence for practice?" *Gallaudet University Press*, vol. 163, no. 5, pp. 501–533, 2019.

[2] "NCES Table 204.27," Retrieved from: https://nces.ed.gov/programs/digest/d18/tables/dt18_204.27.asp.

[3] A. Stefik, R. E. Ladner, W. Allee, and S. Mealin, "Computer Science Principles for Teachers of Blind and Visually Impaired Students," in *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, ser. SIGCSE '19. New York, NY, USA: ACM, 2019, pp. 766–772. [Online]. Available: http://doi.acm.org/10.1145/3287324.3287453

[4] "NCES Table 204.30," Retrieved from: https://nces.ed.gov/programs/digest/d18/tables/dt18_204.30.asp.

[5] "NCES Table 204.60," Retrieved from: https://nces.ed.gov/programs/digest/d18/tables/dt18_204.60.asp.

[6] J. Li, "Principles of effective english language learner pedagogy," New York, NY: College Board. Retrieved from Educational Resources Information Center website: https://files.eric.ed.gov/fulltext/ED562799.pdf, 2012.

[7] R. L. Sparks, J. Patton, L. Ganschow, and N. Humbach, "Do L1 Reading Achievement and L1 Print Exposure Contribute to the Prediction of L2 Proficiency?" *Language Learning*, vol. 62, no. 2, pp. 473–505, 2012. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9922.2012.00694.x

[8] J. A. Scott and R. J. Hoffmeister, "American Sign Language and Academic English: Factors Influencing the Reading of Bilingual Secondary School Deaf and Hard of Hearing Students," *The Journal of Deaf Studies and Deaf Education*, vol. 22, no. 1, pp. 59–71, 12 2016. [Online]. Available: https://doi.org/10.1093/deafed/enw065

[9] A. G. Soosai Raj, K. Ketsuriyonk, J. M. Patel, and R. Halverson, "Does Native Language Play a Role in Learning a Programming Language?" in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, ser. SIGCSE '18. New York, NY, USA: ACM, 2018, pp. 417–422. [Online]. Available: http://doi.acm.org/10.1145/3159450.3159531

[10] A. G. Soosai Raj, E. Zhang, S. Mukherjee, J. Williams, R. Halverson, and J. M. Patel, "Effect of Native Language on Student Learning and Classroom Interaction in an Operating Systems Course," in *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education*, ser. ITiCSE '19. New York, NY, USA: ACM, 2019, pp. 499–505. [Online]. Available: http://doi.acm.org/10.1145/3304221.3319787

[11] "Code.org AP CSP Curriculum," Retrieved from: https://studio.code.org/courses/csp-2019.

Successful Interventions to Eliminate Achievement Gaps in STEM Courses

Larrabee, Tracy
larrabee@ucsc.edu
UC Santa Cruz

Norouzi, Narges
nanorouz@ucsc.edu
UC Santa Cruz

Robinson, Carmen
crobins3@ucsc.edu
UC Santa Cruz

Quynn, Jenny
jquynn@ucsc.edu
UC Santa Cruz

***Abstract*—At our institution equity gaps persist between student subgroup populations in STEM courses, mirroring a nationally recognized trend in higher education. This research applies backward design to explore the size of those gaps and reasons for differences in achievement between 1) female versus male, 2) first generation versus non-first generation, 3) LatinX versus non-LatinX, and 4) EOP versus non-EOP student groups. During her career, the first author of this paper designed and applied a comprehensive teaching approach to her large, undergraduate, Computer Science theory course. Careful analysis reveals three main categories of pedagogical practice used during lecture: role modeling, demonstrating productive failure, and illuminating stereotype threat. Five quarters of experimentation, revision, and application of these practices produce promising results for reducing equity gaps. Course design and learning theories from the educational literature are explored and provide the framework the authors use to explore and explain findings.**

***Keywords*—Computer science education, Equity gap, Gateway courses, STEM majors, Intervention, Role modeling, Productive failure.**

I. Introduction

Disparity or differences in performance between student subgroup populations, such as differences between genders or differences between races [1], allows for predicting which students entering university are more likely to be successful in a certain course, successfully declare a STEM major [2], and graduate with a STEM degree. Disparity, or the gap between student performance by subgroup is evidence that crucial knowledge and critical thinking skills are not equitably distributed among students and are reserved for, or limited to, students whose backgrounds and experiences continue historical patterns [3]. Disparity allows for predicting which students will lead the nation when it comes to thinking technically and creatively, designing solutions that will save our species, and other species, and preserve life on our planet [4].

Believing that it is possible to know which students will make the greatest contributions to STEM fields limits what is possible for students at a time when the nation needs to expand possibilities and build inclusive environments where students can exercise problem solving skills and tackle the most historic and pressing challenges of their time [5]. Predicting who among us will be our future STEM leaders divides communities and society along technical lines and discourages Discipline-Based Education Research (DBER) to spread STEM content and higher-order problem solving skills [6].

DBER offers a framework for considering disparity in STEM education by applying inquiry to create solutions that will close performance gaps, revealing solutions for inclusive and effective teaching practices that will ultimately impact the everyday decisions of people across the nation [7] and around the world [8]. Institutional data often replicates historical patterns confirming that STEM knowledge and skill are practiced by certain students. And institutional data can be used to redefine the nature of the work and program quality by the institutional data are evidence of the effectiveness of the invitation to study STEM, and that programs are creating louder, bolder, clearer messages of inclusion and student-centered teaching.

Along with many others, the authors of this paper desire to support learning, achievement, and equity within their courses and across degree programs, and to reduce indicators of disparity. To do this, they have consulted the educational literature, identified and tested our own DBER learning theories, participated in campus teaching community workshops, and consulted with others about their teaching methods and experiences. We try a variety of things, keeping our eyes on student performance by subgroup within our courses at our institution, the University of California, Santa Cruz. Our hope is to understand how students achieve by subgroup, particularly in our large, STEM gateway courses that have been identified as barriers to persistence for undergraduate students [9].

Recently, and with cautious optimism, we identified a course where student background could not be used to predict student performance by subgroup. This paper applies a backward design approach [10] to explore elements of the course that may explain reduction in achievement gaps. Guided by literature and grounded in theory on student-centered teaching practices [11] and growth mindset [12], the authors explain course design, teaching, and assessment practices. This paper is not intended to be prescriptive. The authors do not claim to have a recipe for all-inclusive teaching or that eliminating equity gaps is as easy as following a recipe. This paper is not a formula for success, but rather an opportunity for the authors to explore and explain a teaching practice in the context of equity gaps.

The term persistence, has been used in the educational literature to explain student success [13] and specifically in the study of STEM education [14]. However, the term persistence, which sounds like resilience, suggests a quality of the learner. In writing this paper, the authors consider the implications of

978-1-5386-5541-2/18/$31.00 ©2020 IEEE

using student qualities to describe outcomes in the face of disparity indicators and choose instead to unpack the learning experiences of students and instructors and use of data to improve student engagement [15], motivation, and learning, and to support all students to achieve. This paper intends to offer information to other instructors and degree programs that are working to develop a new analytical unit of study, student experience or satisfaction, as a more valid predictor of student success.

II. Course Outline

The focus course for this paper is "Applied Discrete Mathematics" that concentrates on mathematics for computer science. In addition to the mathematical core, there is substantial emphasis on application. For example, when discussing modular arithmetic, cryptology comes up, and the importance of proofs by induction in algorithms and asymptotics is emphasized. The course covers sets, logic, proofs, combinatorics, functions, and relations, but the emphasis throughout the course is on mathematical rigor and proof. This class is a traditional large-lecture class with ten weeks of homework and quizzes followed by a final exam.

The course moves quickly, with a semester's worth of topics packed into ten weeks, but the start of the course involves making sure that all the students, who have very different preparations, have the same basic foundation in sets and logic. In the first weeks, there are frequent allusions to deeper explorations of interesting material and equally frequent opportunities for students to gauge their mastery. For example, when the students are asked to provide the combinatorial argument for Pascal's identity (which can be found online), they are required to try it themselves before accessing the many wonderful online explanations. When the students hand in their solutions, the instructor and TAs cannot know which students looked up the solutions without attempting the problem first.

For every lecture there are one or two "Questions of the Day" (which the students call QotDs). For this students are not only given the problems, but they are told that if they can handle various parts of the problem without resorting to looking up the answer, they are showing mastery of the material. The instructor talks to students about the importance of private self-evaluation. The QotD answers are handed in with the weekly homework, but students do not hand in their self-evaluations. Sometimes a QotD will be used as a short pair-and-share activity in class, where students speak with each other in small groups, finishing the problems later, outside of class. The weekly quizzes often visit QotD, or other homework problems.

III. Methodology

We have examined different interventions to close the equity gap in CS gateway courses. The main author of this study, recently, after five quarters of steady improvement and constant experimentation with teaching methods, was able to close the gap between the grades of her underrepresented minority and first-generation college students and the rest of the class. In the latest approach, the author used a three-pronged approach described in the following sections.

A. *Role Modeling*

The first intervention identified is diversity within a teaching team approach. The teaching team is identified as the professor or instructor, four Teaching Assistants (TAs) and four Modified Supplemental Instructors (MSIs). During the past five quarters that this course was offered, half of the teaching team was female and the teaching team was diverse. From the literature, a unified, collaborative, and diversified teaching environment supports student engagement, sense of belonging, and achievement [16].

B. *Productive Failure*

Aligned with growth mindset [12], the instructor used lecture to incorporate the notion of failure as the appropriate path to learning, incorporating failure into problem solving as typical. The instructor normalized failing with statements like "Engineering majors are hard; it's good to fail the first time you attempt a problem." and "People who fail at a problem the first time tend to retain things better than those who luck into the right answer" [17].

In practice, TAs did not take points off on homework for arriving at the wrong answer. The homework policy is based on effort and students understand that they are expected to try and that parallel homework problems will show up on the weekly quiz that is graded. Students have the responsibility for learning the content through problem solving. To help students do this, students are supported by the teaching team, making help more accessible. A video of lecture is posted for students as well as links to Khan Academy and other sources for outside help on the course website. The instructor is also available during office hours and monitors online forums where students ask and answer questions. In addition to instructor's availability, TAs and tutors hold regular office hours and/or individual and group tutoring sessions.

C. *Modeling Self-Compassion*

Steele and Aaronson coined the term "stereotype threat" in 1995 to mean "being at risk of confirming, as self-characteristic, a negative stereotype about one's group" [18]. Stereotype threat is an issue for underrepresented students as it can cause grade sensitivity. The danger is that students may fail an exam and instead of considering becoming more engaged with the course such as putting in more study time, they believe the failure is confirmation that they don't belong and become at risk of withdrawing.

The final tactic was to explicitly discuss the stereotype threat. An African American MSI tutor in one Section of the course — who was an extremely high achieving students selected to provide supplemental tutoring to others — told the instructor that it was like having a light bulb go on for him. Until the instructor addressed the issue in class, he felt as if he did not belong in a STEM major, but after stereotype threat was discussed, he quickly realized it wasn't that he was unsuited for engineering, but that the material is hard for everyone. In addition to the instructor's in-class efforts to raise awareness about the concept of stereotype threat, the School of Engineering at our institution has had other successes in bringing disadvantaged populations closer to parity. The Multicultural Engineering Program (MEP), which serves approximately 291 of the school's 4,234 declared undergraduate majors, has also closed the gap significantly.

IV. Data and Results

Institutional data identifies STEM gateway courses that demonstrate at least one of four equity gaps meaning that when students in a STEM course are divided into two cohorts, the average grade of one cohort is statistically significantly lower than the other cohort. The four equity gaps are represented by cohorts 1) female vs. male, 2) first-generation vs. non-first-generation, 3) LatinX vs. non-LatinX, and 4) EOP vs. non-EOP (At our institution, an EOP student is one who has been identified as having educational disadvantages via family income, first-generation status, attended historically underperforming schools, are currently in the military, were raised in a foster family, or are undocumented students). Many students are represented in all four Equity measures (such as a female, Latina, first generation, former foster-child). At our institution, large STEM lecture courses tend to demonstrate all four of these equity gaps. Tables below show historical course demographics by quarter for all cohorts under study. The data represented here have been collected from the "Applied Discrete Mathematics" course from Fall 2014 to Summer 2018.

TABLE I
Table 1. Percentage of different genders by quarter

Gender	*Fall*	*Spring*	*Summer*	*Winter*
F	19.6%	21.12%	20.66%	20.64%
M	80.4%	77.68%	79.34%	77.74%
U		21.12%		20.64%

TABLE II
Table 2. Percentage of First Generation status students by quarter

First Gen	*Fall*	*Spring*	*Summer*	*Winter*
N	66.58%	70.13%	70.40%	72.93%
Y	33.42%	29.87%	29.60%	27.07%

TABLE III
Table 3. Reported Student Ethnicity by quarter

Ethnicity	*Fall*	*Spring*	*Summer*	*Winter*
Asian	2.45%	1.21%	0.0%	1.13%
LatinX	19.66%	16.12%	23.21%	14.61%
International	7.79%	10.09%	14.29%	8.79%
Two or more	6.16%	5.54%	0.0%	7.52%
Unknown/Unspecified	1.63%	1.85%	0.0%	2.70%
Caucasian	28.8%	27.13%	32.14%	26.88%

TABLE IV
Table 4. Percentage of EOP-status students by quarter

EOP	*Fall*	*Spring*	*Summer*	*Winter*
N	68.74%	74.86%	70.40%	73.22%
Y	31.26%	25.14%	29.60%	26.78%

In order to compare the effect of the methodology described earlier, we have compared the GPA of each cohort under study in the "Applied Discrete Mathematics" course with two other STEM courses (a mathematics class and a computer science class). In the graphs below, we illustrated the Hispanic/LatinX versus Caucasian Equity gap. A similar pattern has been observed when comparing female versus male, first-generation versus non-first-generation, and EOP versus non-EOP equity gaps.

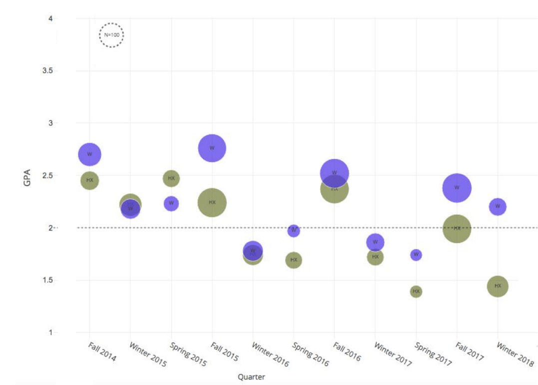


Fig. 1. GPA by Ethnicity: Latinx vs. Caucasian in a Mathematics class

Fig. 2. GPA by Ethnicity: Latinx vs. Caucasian in a Computer Science class

As illustrated in Figure 3, after incorporating the set of interventions in the Applied Discrete Mathematics course, the course presents none of the four Equity gaps. One of the previously marked Equity gaps is shown in Figure 3.

V. Discussion

Addressing disparity or differences in student achievement between student subgroups requires the appropriate data, apply institutional support, and a willingness to acknowledge

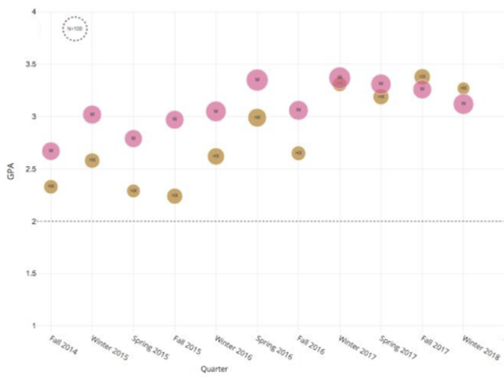


Fig. 3. GPA by Ethnicity: Latinx vs. Caucasian in a Mathematics class

gaps exist. Having looked at disparity indicators for different gateway courses over several quarters, it was only recently there was the opportunity to apply backward design to explain success.

Looking for disparity indicators within a course or gaps in achievement by subgroup should be a process that takes place over time, using data from several quarters and from the same course and instructor. The authors of this study intend to continue to follow disparity patterns for this course and explore the design of a disparity index. This index would capture more general levels of student achievement using mean average and standard deviation of student scores, and allow for instructors to share indicators along with their pedagogical theories and practices as a way to explain student achievement. This will work for STEM instructors and programs interested in examining gaps, eyes wide open. The data in this paper, and accompanying analysis, represent a beginning point for meaningful, course, program, and institutional discussions related to teaching practices and course design, and not only how to account for disparity, but how to talk about gaps based on evidence. One trend is notable – the higher the overall average score in the course, the smaller the achievement gaps between subgroups of students. This finding is consistent with student achievement data from other engineering courses. The authors of this study intend to expand on this project and investigate additional data trends that relate to teaching for inclusion and designing equitable assessment practices.

VI. Acknowledgments

The authors credit the valuable support from two on-campus tutoring programs, as well as support from the Center for Innovations in Teaching and Learning Center, which provided pedagogical reinforcement to address stereotype threat and to incorporate more active learning techniques into lecture.

References

[1] A. Flores, “Examining disparities in mathematics education: Achievement gap or opportunity gap?.” *The High School Journal*, vol. 91, 2007.

[2] W.-C. J. Mau, “Characteristics of us students that pursued a stem major and factors that predicted their persistence in degree completion.” *Universal Journal of Educational Research*, vol. 4.6, 2016.

[3] S. Freeman, “Active learning increases student performance in science, engineering, and mathematics.” *Proceedings of the National Academy of Sciences*, 2014.

[4] M. Clark, “Academic pathways study: Processes and realities.” *ASEE Annual Conference and Exposition*, 2008.

[5] S. Singer and K. Smith, “Discipline-based education research: Understanding and improving learning in undergraduate science and engineering.” *National Academies Press*, 2012.

[6] ——, “Discipline-based education research: Understanding and improving learning in undergraduate science and engineering.” *Journal of Engineering Education*, 2013.

[7] U. C. J. E. Committee, “Stem education: Preparing for the jobs of the future.” 2012.

[8] J. Engler and E. Alden, “The work ahead: Machines, skills, and us leadership in the twenty-first century.” *Council on Foreign Relations*, 2018.

[9] M. H. Glenda Crosling and L. Thomas, “Improving student retention in higher education: Improving teaching and learning.” *Australian Universities’ Review*.

[10] G. Wiggins and J. McTighe, “What is backward design.” *Understanding by design 2*, 2001.

[11] D. Kember and K.-P. Kwan, “Lecturers’ approaches to teaching and their relationship to conceptions of good teaching.” *Instructional science*, 2000.

[12] C. Dweck, “Mindset: The new psychology of success.” *Random House Digital*, 2008.

[13] J. Braxton, “Reworking the student departure puzzle.” *Vanderbilt University Press*, 2000.

[14] A. Maltese and R. Tai, “Pipeline persistence: Examining the association of educational experiences with earned degrees in stem among us students.” *Science Education*, 2011.

[15] E. Kahu, “Framing student engagement in higher education.” *Studies in higher education*, 2013.

[16] G. Slavich and P. Zimbardo, “Transformational teaching: Theoretical underpinnings, basic principles, and core methods.” *Educational Psychology Review*, 2012.

[17] A. Eva, “Why we should embrace mistakes in school. the greater good science center at the university of california, berkeley.” 2017.

[18] C. Steele and J. Aronson, “Stereotype threat and the intellectual test performance of african americans.” *Journal of personality and social psychology*, 1995.

Lowering the Barrier for Undergraduates to Learn about Computational Research through a Course-Based Conference Experience

Amy R. Lazarte
Puppet
Portland, Oregon
amy.lazarte@puppet.com

Anna Ritz
Biology Department, Reed College
Portland, Oregon
aritz@reed.edu

***Abstract*—Computer science research is largely communicated through conferences, and these in-person meetings offer a potentially powerful means to engage undergraduates in cutting-edge research. However, attending a conference as an undergraduate is an opportunity reserved for very few students, typically those who are doing relevant research with a faculty member at the time of the meeting. In an effort to give a broader set of students access to a scientific meeting, we describe a pilot study where thirteen students attended an ACM conference as part of an interdisciplinary course. While these numbers are admittedly small, students reported larger average gains in learning about oral and poster presentations compared to a large background population of students who participated in course-based research. In a follow-up survey two and a half years later, the cohort reported that they learned more on average about scientific careers and professional networking compared to other students whose conference attendance was not linked to a course. We find that conference attendance is a promising way to engage a broader swath of students in computer science and interdisciplinary topics.**

***Keywords*—undergraduate education, conferences, interdisciplinary courses, broadening STEM participation**

I. Introduction

Conferences and workshops are the cornerstone of computer science research dissemination, and undergraduate students have the potential to benefit from conference attendance in numerous ways. Students may gain a broad sense of active research areas in computing, observe how real research is communicated, and have a chance to meet researchers at all career stages (from graduate students to leaders in the field to industry representatives). Undergraduates who have attended scientific conferences have reported increased confidence and an increased sense of belonging [1]–[5]. Further, students gain a better understanding of research and the profession [2]–[4]. Research has shown that technical conference attendance can be beneficial even for early-career computer science undergraduates [2].

This work was supported by the National Science Foundation (NSF-CISE #1643361 and NSF-DBI #1750981).

978-1-7281-7172-2/20$31.00 ©2020 IEEE

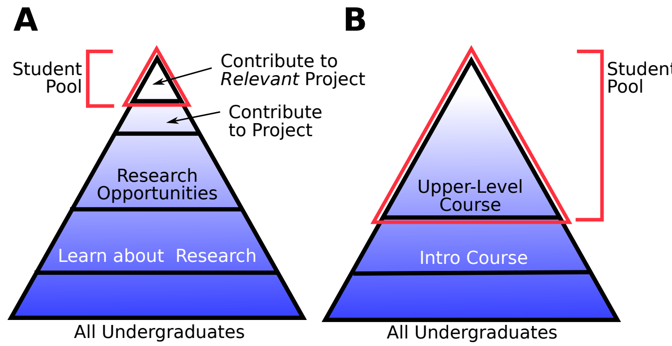


Fig. 1. Paths to undergraduate conference attendance. **(A)** This opportunity is typically reserved for students who have conducted research. **(B)** This report proposes course-based participation.

Despite the large gains that can come with conference attendance, only a handful of undergraduates ever get this opportunity. Undergraduates who attend conferences typically have worked on research projects that are presented at the venue, and presenting work has been shown to be valuable for undergraduates [4]–[6]. However, there are numerous barriers to engaging undergraduates in research [7], [8]. Many undergraduates are unaware that academic research is a possibility, and may not think to ask for opportunities. While funded research opportunities exist, they are often competitive, and students may not be able to participate due to financial or family obligations. Of the students that find research opportunities, they usually need to meaningfully contribute to a project that is relevant to a scientific meeting. Finally, the timing of conferences can make undergraduate attendance difficult. As a result, only a small number of the students who navigate this process end up attending conferences (Figure 1A).

Researchers in science education have acknowledged the barriers that students face in securing research opportunities [7], [8], which are closely tied to barriers for students attending conferences. In an effort to broaden participation in undergraduate research, Classroom-Based Undergraduate Research Experiences (CUREs) bring research opportunities into undergraduate courses [9]. The Genomics Education Partnership (GEP) is a multi-institutional example from biology where undergraduates help annotate fly and other eukaryote chromosomes [8]. GEP students reported learning and professional gains similar to those reports by summer undergraduate researchers [8].

Classroom-based opportunities have reduced the barrier to learning about scientific research, and we wanted to similarly reduce the barrier for conference attendance by integrating it into a course. Inspired by the benefits of CUREs, we have integrated conference attendance as a component of an upper-level course at a primarily undergraduate institution. In 2016, Dr. Ritz conducted a pilot study to bring thirteen undergraduates to an ACM conference in Seattle, WA, USA. The study was designed to assess how conference attendance affected student perceptions about scientific research compared to other student experiences that (a) did not involve conference attendance and (b) were not part of a course. While the numbers from student surveys are not large enough to make concrete claims, this experience report describes the assessments and trends that we have observed thus far.

II. Methods & Implementation

Reed College is a private primarily undergraduate institution serving about 1,400 students in Portland, Oregon, USA. Dr. Ritz, a computer scientist by training, teaches computational biology courses within Reed's Biology Department.

A. Course, Conference, & Assignments

Dr. Ritz integrated conference travel into an upper-level elective *Computational Systems Biology* course (Bio331), where students learn about biological networks and the graph algorithms that elucidate network features to address open biological questions. This course requires one semester of an introductory Biology course and one of two other prerequisite courses: either a programming-heavy *Introduction to Computational Biology* course or *Introduction to Computer Science*.

The 2016 pilot study was conducted in the first offering of Bio331, so the course was designed from the start with a conference experience in mind. Bio331 students attended the Association for Computing Machinery's Conference on Bioinformatics, Computational Biology, and Health Informatics (ACM-BCB [10]). ACM-BCB presents computer science contributions to biology/biomedical fields, and its breadth in application is of interest for students from a variety of STEM majors. ACM-BCB was held in Seattle, Washington, USA in 2016, a 3.5-hour drive from Reed College.

The Bio331 assignments that pertained to ACM-BCB travel were staggered over three weeks, and the students conducted a multi-week independent project on a topic of their choice at the end of the semester (Table I). Importantly, students were given complete choice regarding the talks they attended at the conference, allowing them to explore topics that were not necessarily related to Bio331. Example assignments are freely available at https://www.reed.edu/biology/courses/bio331/conference-resources.html.

TABLE I
EXAMPLE ASSIGNMENTS RELATED TO CONFERENCE ATTENDANCE

Before the Conference	Complete pre-course survey Read abstracts for relevant tracks Conference attendance logistics Prepare to field questions from attendees
During the Conference	Write short summaries of 3 talks Write short summaries of 2 posters
After the Conference	Complete post-course survey Write a detailed summary of one paper Write a reflection essay
Independent Project	Give an oral presentation Write a mini-paper in conference template

B. Assessment

1) Pre- and post-course surveys: We assessed the conference experience using the Classroom Undergraduate Research Experience (CURE) survey[1] [11]. The pre-course survey determines student demographics, attitudes about science, and experience with course elements, and the post-course survey estimates student learning gains in course elements and changes in attitudes about science. Student responses are compared to a much larger background dataset of student responses from other CUREs. We administered the pre-course survey a few days before the conference and the post-course survey upon returning from the conference to evaluate the impact of conference attendance rather than the impact of the entire course (Table I).

2) Long-term surveys: In May of 2019, we followed up with any student who had traveled to a conference that was supported by Dr. Ritz. The 2019 survey covered demographic information, perceived learning gains, influence of the conference on career choice, and barriers for attending. This survey is freely available at https://www.reed.edu/biology/courses/bio331/conference-resources.html.

III. Results and Discussion

Seven students were enrolled in Bio331 in the fall of 2016. Dr. Ritz recruited six more Reed students who had previously taken *Introduction to Computational Biology* to participate in the conference. We consider this group of thirteen students to be the **BCB Cohort**, which included two sophomores, two juniors, seven seniors, and two recent graduates. Five (38%) of the BCB Cohort were women and five (38%) were members of an underrepresented group. Strikingly, over 50% of the BCB Cohort were interdisciplinary majors with Biology and over 20% were computer science or mathematics majors. All registered Bio331 students completed the course after returning from the conference.

A. CURE Survey Assessments

The CURE pre-course and post-course surveys were administered by an independent survey system, and we received an analysis of results [11]. Eleven students in the BCB

[1]The CURE and other surveys were conducted with IRB approval by Reed College (#2016-S26, #2017-S23 & #2018-S24).

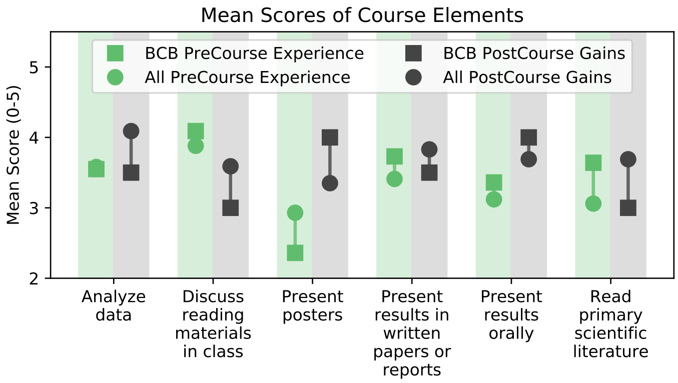


Fig. 2. Perceived experience and learning gains of BCB Cohort compared to CURE survey background population. Score elements for BCB Cohort (squares) compared to background (circles). Green: student experience from pre-course survey (Reed $n = 11$; All $n = 6,195$). Gray: perceived gains from post-course survey (Reed $n = 5$, All $n = 4,876$).

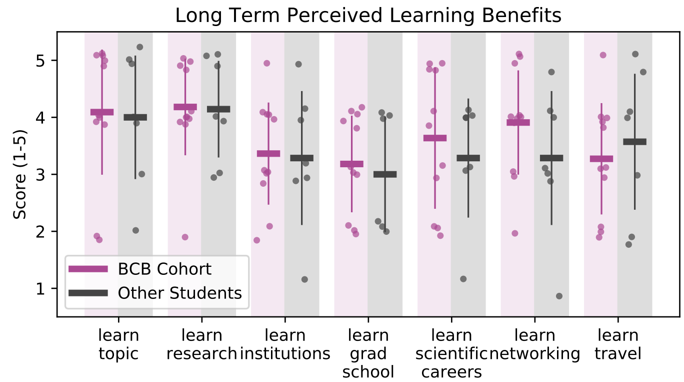


Fig. 3. Perceived learning benefits for the BCB Cohort (magenta, $n = 11$) vs. other students who attended conferences (gray, $n = 7$) evaluated two and a half years after ACM-BCB '16. Mean and standard deviation shown on a scale from 1-5; a randomized jitter was applied to the points for visibility.

Cohort took the pre-course survey, and only five students took the post-course survey. We do not aim to find significant correlations in our data due to this pilot study's small numbers, though the survey analysis compared to a much larger background of students who participated in CUREs.

We considered six elements from the CURE surveys that were related to the conference experience. On average, the BCB Cohort reported less experience in preparing posters but more experience in reading primary literature compared to the background population (Figure 2 green). In the post-course survey, the BCB Cohort reported a larger average score for presenting posters and oral results and a smaller average score for the other elements (Figure 2 gray). The pre-course experience and post-course gains are dependent, since students who had experience reading literature may report smaller gains in that element compared to students who had no experience reading literature. Given this consideration, the largest gains in the BCB Cohort compared to the background population were related to presenting work.

B. Long-Term Survey

In May of 2019, we followed up with the thirteen students from the BCB Cohort and twelve other undergraduates who had attended a conference as part of Dr. Ritz's research. This background set of students was more representative than the CURE survey students, since here all students attended a conference, and all but one student was a Reed undergraduate. Most students in the background population attended computational biology conferences such as ACM-BCB, but a few also also attended cryptography and cell biology meetings. Seven students in the background population (58%) were women. We note that all students in the background set had conducted research that was presented by themselves or others at the conferences; thus they may have even larger perceived benefits according to previous studies [4], [6].

Eleven students from the BCB Cohort and seven students from the background population responded to the 2019 survey. Students in the BCB Cohort felt, on average, less prepared to attend a conference than the background population[2] (3.18 ± 0.72 vs. 3.42 ± 1.18). This is not surprising, since all of the students in the background population were presenting research. The BCB Cohort had increased confidence in preparation for attending a future conference (4.09 ± 0.66), but the average score was still lower than the background population (4.43 ± 0.49). Interestingly, six BCB Cohort students (54.5%) reported that they became *more interested* in the conference topic and career opportunities (the other students reported that the experience *did not change* their future interests). In the background population, only three of the seven students (42.8%) became *more interested* in the conference topic and career opportunities. This hints that conference attendance in a course may help students clarify their career paths more than students presenting work at the meeting, since those presenting research are already engaged in the field.

We compared the BCB Cohort to the background in their response to seven learning benefits related to the original goals of the study: *How much did you feel you learned about…*

1) The conference topic?
2) Academic research?
3) Other types of institutions?
4) Graduate school?
5) Scientific careers?
6) Professional networking?
7) Professional travel?

Small numbers prohibit a statistical analysis of responses, but there is a slight increase in average BCB Cohort score in learning about scientific careers and learning about professional networking (Figure 3).

We also surveyed the hardships that students encountered during the conference: five BCB Cohort students and three background population students reported hardships such as missed classes, bad timing with other events, and difficulty working out logistics. On average, these hardships did not have a large impact on either group (BCB Cohort 1.55 ± 0.68 and background 1.6 ± 0.80). All participants who responded to the survey found the conference topic interesting and stated that they would attend another conference if they had the opportunity.

[2]Values in this subsection are reported as (mean $\pm$ s.d.) on a 1-5 scale.

IV. Discussion

We have described our first steps towards assessing the influence of a course-based conference experience to help broaden engagement of undergraduates in STEM disciplines. Classroom-based experiences have the benefit of engaging a larger set of students, and integrating conference attendance into a course is a clear way to provide the experience for more students in an unbiased manner. Since our pilot study, others have written about how to support undergraduates at conferences [12]. A recent study found that formally preparing for a biology conference helped students reduce anxiety about professional interactions as well as gain a sense of belonging [3].

We focused on a technical conference at the intersection of computer science and biology/biomedicine. Many computing conferences encourage undergraduate attendance, including SIGCSE, the Grace Hopper Celebration of Women in Computing, and the Richard Tapia Celebration of Diversity in Computing. These meetings, while beneficial for students, do not serve the same audience as technical conferences. We encourage faculty to consider bringing students to conferences in their area of expertise - while many of the topics may be beyond the students' knowledge, they will gain a broader sense of the faculty's research area. Further, conferences that span interdisciplinary topics may expose undergraduates to different fields of STEM, potentially broadening participation in certain subfields such as computational biology.

There are substantial costs for integrating a conference into a course, especially if the conference is not located in the same city as the institution. The 2016 pilot study was supported by an NSF grant for undergraduate conference travel (#1643361). Students who presented research at conferences were able to apply for college and department funding, and were supported by other grant mechanisms. In our experience, conference organizers are excited to have undergraduates attend and have offered discounts for conference registration. In order to make this a sustainable activity, we are considering less-expensive venues where students can still see technical research, meet graduate students and faculty, and learn about professional travel and networking. Some options may be attending smaller workshops and symposia run by graduate students, or traveling to a nearby research institution for part of their seminar series. Biology courses often have labs with substantial reagent or field trip costs; if conference attendance was considered similar to these activities, faculty may be able to receive departmental support.

While the CURE surveys were useful to establish initial assessments in the pilot study, many of the elements from the CURE survey were not relevant to a conference experience, but rather reflected an overall course experience. For example, course elements and learning gains related to assignments, tests, group work, and labs were not relevant for conference attendance. Reed students also have research experiences as part of courses (including a required year-long senior thesis), which conflates the CURE surveys. Further, as of 2018, the independent survey system is no longer available for collating and analyzing the results [11]. We continue to refine a survey that aims to assess conference activities within a course.

While our initial results show promising trends, further assessments with more students are required to draw conclusions about course-based conference attendance. We are continuing to integrate the conference experience in Bio331, and ten students from the Fall 2019 class attended IEEE BIBM in San Diego, CA. We plan to continue the longitudinal study for this and future cohorts of Bio331 students. Recent NSF funding has also helped establish an ACM-BCB travel award for undergraduates from different schools, and the first cohort of eight students attended the 2019 conference in Niagara Falls, NY. This effort will help shed light on the impact of conference attendance through course participation compared to a travel award.

Acknowledgment

Special thanks to all the students who have attended conferences and helped make this research possible.

References

[1] J. M. Francioni, "A conference's impact on undergraduate female students," *ACM SIGCSE Bulletin*, vol. 34, no. 2, pp. 66–69, 2002.

[2] H. M. Wright and N. B. Tamer, "Can sending first and second year computing students to technical conferences help retention?" in *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*. ACM, 2019, pp. 56–62.

[3] E. A. Flaherty, R. E. Urbanek, D. M. Wood *et al.*, "A framework for mentoring students attending their first professional conference," *Natural Sciences Education*, vol. 47, no. 1, 2018.

[4] H. W. Helm and K. G. Bailey, "Perceived benefits of presenting undergraduate research at a professional conference." *North American Journal of Psychology*, vol. 15, no. 3, 2013.

[5] A.-B. Hunter, S. L. Laursen, and E. Seymour, "Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development," *Science education*, vol. 91, no. 1, pp. 36–74, 2007.

[6] P. A. Mabrouk, "Survey study investigating the significance of conference participation to undergraduate research students," *Journal of Chemical Education*, vol. 86, no. 11, p. 1335, 2009.

[7] E. Seymour, A.-B. Hunter, S. L. Laursen, and T. DeAntoni, "Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study," *Science education*, vol. 88, no. 4, pp. 493–534, 2004.

[8] D. Lopatto, C. Alvarez, D. Barnard *et al.*, "Genomics education partnership," *Science*, vol. 322, no. 5902, pp. 684–685, 2008.

[9] L. C. Auchincloss, S. L. Laursen, J. L. Branchaw *et al.*, "Assessment of course-based undergraduate research experiences: a meeting report," *CBE Life Sci Educ*, vol. 13, no. 1, pp. 29–40, 2014.

[10] "ACM Conference on Bioinformatics, Computational Biology, and Health Informatics (ACM-BCB)," http://acm-bcb.org/index.php, [Online; accessed 1-October-2019].

[11] "Classroom Undergraduate Research Experiences (CURE) Survey," https://www.grinnell.edu/academics/resources/ctla/assessment/cure-survey, [Online; accessed 1-October-2019].

[12] J. Davis and C. Alvarado, "Supporting undergraduates to make the most of conferences," *ACM Inroads*, vol. 8, no. 3, pp. 32–35, 2017.

Faculty in Residence: Improving Preparedness of Underrepresented Students in Computing

Alvaro Monge
Comp. Eng. and Comp. Science
California State University
Long Beach, CA, USA
alvaro.monge@csulb.edu

Jaye Espy
353, LLC
Washington, D.C., USA
jayeespy@gmail.com

Lynne Grewe
Computer Science
California State Univ. East Bay
Hayward, CA, USA
lynne.grewe@csueastbay.edu

Susan Wang
Computer Science
Mills College
Oakland, CA, USA
wang@mills.edu

***Abstract*— Google's Faculty in Residence (FIR) Program brings together computing faculty from universities serving students underrepresented in the computing industry. Three cohorts of faculty have participated in FIR from 2017 through 2019, for a total of 73 faculty from universities that are either designated as a Minority Serving Institution or that have a significant part of its student population underrepresented in computing. In the month-long, immersive summer program, participating faculty learn about software engineering best practices from an industry perspective, the recruitment, application, and interview process, engage in hands-on project development, and are exposed to the work culture at Google. One theme of the program is the importance of project-based learning and each faculty was tasked with designing and developing a project that they would then assign in their classes. While there was complete flexibility in the design of the project, the expectation was to adopt project-based learning that would support diverse and inclusive classrooms. Another important component of FIR is the recruitment, application and interview process used by Google and companies like it. This part of the program provides faculty with specific practices that they can implement in their classes to improve students' preparedness in applying and interviewing for technical internships and positions. This report summarizes the program, describes the experiences of the authors in the program, and offers recommendations for others to adopt.**

Keywords*— Faculty in Residence, broadening participation, project -based learning, underrepresented students

I. Introduction

Google's Faculty in Residence (FIR) Program brings together computing faculty from universities serving students underrepresented in computing degrees and careers. Three cohorts of faculty have participated in FIR from 2017 through 2019, for a total of 73 faculty from universities that are either designated as a Minority Serving Institution (MSI) or that have a significant part of its student population underrepresented in computing. In the month-long, immersive summer program, participating faculty learn about software engineering best practices from an industry perspective, the recruitment, application, and interview process, engage in hands-on project development, and are exposed to the work culture at Google.

II. Background

Some of the prior industry-academia collaborations relate to industry sponsored research, industry recruitment of students, and, at some universities, industry advisory boards that can provide valuable insight on a department's curriculum. In certain computing disciplines, such as artificial intelligence, there are significant increases in the level of research interaction between professors and companies, which take the form of extended joint appointments [6]. There is a need for novel, deeper and longer lasting interactions between industry and academia that include cultivating enterprise-driven culture within universities and strong industry informed curriculum design [8]. The FIR program is an effort that seeks to improve the preparation of all students for technical careers, with particular focus on underrepresented students. Another effort is the Googler in Residence (GIR) program that assigns a Google engineer to spend a semester teaching at a Minority Serving Institution (MSI). Both programs, FIR and GIR, had been designed and were in the implementation phase when in 2017, a special session at the SIGCSE Technical Symposium discussed the impact of such programs to support underrepresented students [2]. The special session organizers recognized the need to create and scale efforts like these programs that prepare students for technical careers. The FIR program's model to introduce faculty to industry practices has a wide impact as these faculty reach thousands of students. Like the cohort models that have succeeded in increasing graduation rates of underrepresented students in computer science [7], the FIR program also uses a cohort model to guide faculty towards a common goal and to build an educator community that is improving the preparedness of these students. It is doing so by presenting and training faculty in professional practices and tools used in industry, which can address the knowledge deficiencies found in graduating students [9, 11, 4]. Radermacher and Walia [9], identified and classified "...knowledge deficiencies found in graduating computer science students for the purpose of better preparing students for their future careers in academia or industry". They present the knowledge gaps in several categories with the top deficiencies being written and oral communication, project management, software tools, and testing. More recent publications report on a persisting academia-industry gap faced by recent computer science graduates [11] and how students are having to fill this gap on their own after an internship experience revealed to them that their Computer Science program was not preparing them as expected [4]. Valstar identified that it was "lack of faculty awareness, real vs fake projects, and resource limitations" that leads to the persisting gap [11]. The first two of these causes are

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

much of the focus in the FIR program as it seeks to improve the preparedness of students at MSIs. The program improves faculty awareness around technical and professional skills such as problem solving, unit testing, code reviews, collaborative work, and use of professional tools. In addition, we believe the FIR program's emphasis on project-based learning also seeks to reduce the academia-industry gap that is partially due to "real vs fake projects".

III. Google FIR Overview

A. *Immersion in Industry Work Culture*

From the first day of the FIR program, the participating faculty cohort are immersed in the Google culture starting with the excitement of the orientation when each new hire gets a work laptop and a Noogler hat. This immersion in Google's engineering culture continues throughout the length of the program, which includes participating in the first week in several of the onboarding and hands-on training activities required of new hires (whether interns or full employees), joining other Googlers on their team meeting, attending TGIF meetings, and yes, riding the GBikes, and enjoying the free snacks in the micro-kitchens and free food from the many cafeterias and food trucks.

B. *Project-Based Learning Focus*

Project-based learning is described as a cooperative, student-centered approach to teaching that emphasizes the development of skills through practice, sustained inquiry and facilitated learning through the management of a project or product [1, 5]. A key component of the FIR program is for each faculty to design and develop one or more projects to be used in their classes that (a) captures some of the main learning objectives of the course, (b) addresses a real-world problem interdisciplinary in nature, (c) is guided by the instructor and yet has flexibility for personalization, (d) has students collaborate with one another, and (e) supports diverse and inclusive classrooms. The range of projects designed, developed and implemented by the FIR cohorts has been wide, from a cross disciplinary project aimed at first-year students to solving real-world problems in a data structures course to mobile app development projects to business and entrepreneurship projects. In particular, the projects developed and implemented by the authors of this report include a Contact List project in a Data Structures and Algorithms course where students form teams to implement a contact list via hashing with specifications on goals and outcomes at the same time giving students flexibility to add features and extensions; a Scaffolded Application for a Database course distributed via GitHub Classroom, where students are provided with user interfaces and they develop the backend database work which is unit tested along the way; a cross curriculum CS project development experience that features Google Interviews and learning by example [3] as well as practical hands on work.

Some of the project implementations included subsequent project-related monitoring of student feedback and assessment of outcomes. For example, for the cross-curriculum project, students reported a positive shift in their project development skills and expressed high motivational interest in the related Google interviews and the real world learn by experience examples.

C. *Software Industry Best-Practices*

Some educators are aware of the importance of such practices as unit testing and of source code version control tools. It is, however, from an academic's perspective. Our experience at FIR sharpened our awareness and expanded it to include the importance of code reviews. Learning that developers write more lines of code to test than they write lines of code that ends up in production, makes you take notice and start planning how to incorporate such skills in your classes.

The faculty participating in FIR incorporated many of these industry best-practices into their projects, such as version control via GitHub or Bitbucket, code review among project partners, unit testing, integration testing, and testing in general. Continuing to practice these skills throughout the curriculum is important in learning and in further advancing knowledge of these skills.

D. *Internship/Job Search Skills*

Another important component of the FIR program is providing faculty with information on the recruitment, application and interview process used by Google and companies like it. This part of the program supplies faculty with specific practices that they can implement in their classes to improve students' preparedness in applying and interviewing for technical internships and positions. Practices such as resume building, constructing an online profile via LinkedIn and GitHub, whiteboarding, and mock interviewing have been widely adopted by FIR faculty in their individual institutions, often offered through workshops, computer club activities, and one-on-one work with the students. One of the highlights of participating in FIR is the optional opportunity each faculty has to experience a whiteboard technical interview. The personal knowledge gained in this hands-on experience serves to highlight how we share the importance of practicing for technical interviews and training students on key steps to follow during these interviews. One of the most important steps is for candidates to verbally communicate their problem solving approach on the problem to the interviewer. Such verbal communication of the thought processes one uses in solving a problem is rarely practiced in CS classes, yet, it's a critical skill to develop if students are to succeed in technical interviews.

E. *Mentorship & Learning Experiences*

A distinct feature of the FIR program is the mentorship provided by Google engineers to FIR faculty. Each faculty is matched with and mentored by an experienced Google engineer who guides and provides industry perspectives on the design and development of faculty's projects. The mentor also shares their insights on computer science curriculum, expectations of new college hires, and the Google work culture. Faculty and mentor meet throughout the program and sometimes the mentorship continues beyond FIR into the classrooms. Faculty in the program have the benefit of a visit at their university by the Google FIR Team and mentor to meet with and answer questions from students. It is powerful and motivating for students to hear directly from Google engineers that what they learn in school, such as version control, code review, and testing, are important and relevant best-practices used every day in industry.

F. Building an Educator Community

One of the successes of the FIR program is the building of a community of educators who are passionate about having their students succeed and thrive in the tech industry. The FIR program is a unique experience bringing together faculty at different levels in their academic careers from universities spread throughout the US – some designated as Historically Black Colleges and Universities (HBCU), some designated as Hispanic Serving Institutions (HSI), others as women's colleges; some granting PhD degrees, others offer only Masters degrees, and while some came from community colleges. There are as many differences in our backgrounds as shared similarities in our professional work, especially when it comes to describing our students. We serve at institutions that have a significant percentage of students underrepresented in higher education [10] and even more so in the computing industry. Many of our students are first-generation, come from low-income families, work long hours to pay for their education, commute to campus, some have families to care for and support financially, and some struggle to make ends meet. Yet, they persevere and sacrifice to earn a higher education. Our students have strong family values, cultural richness and assets that create dynamic learning environments in our classrooms. As we discovered these shared experiences about our students, a bond of community started to form. It is this spawning of an educator community that has stayed with us many months since having completed the FIR program. Like the successes that cohort-based education efforts have with underrepresented students [7], the FIR program's long-lasting success will likely be attributed in part to the supportive educator community created in those four weeks in Mountain View California.

IV. Support of MSIs

To achieve some of the outcomes to address direct support for MSIs, Google instituted a formal partnership agreement with the United Negro College Fund (UNCF) to support Historically Black Colleges and Universities (HBCU) and also partners with the Computer Alliance of Hispanic-Serving Institutions (CAHSI) and Hispanic Serving Institutions (HSI). These relationships attempt to directly impact three specific levels – students, faculty and institution (inclusive of the community at-large). At each level, the partnership will deploy strategies that maximize outcomes and impacts towards the main goals of significantly improving the production of MSI graduates in the computer science and computer science-related ("CS") fields; and, maximizing the yield of African American and HBCU CS as well as Hispanic and HSI CS graduates entering the tech-workforce. These organizations and Google recognize that the significant challenges in the STEM-CS education pipeline and the lack of diversity in the tech-workforce require the development and implementation of a collaborative, partnership-driven and scalable workforce development model in order to increase the yield and preparation of African American and HBCU as well as Hispanic and HSI CS graduates. In addition, a major goal of the partnership aims to transform HBCU and HSI campuses as CS education and training platforms that engage surrounding communities and local K12 education agencies to broaden the impact in a sustainable manner. The strategic approach for the partnership is framed by three pillars:

- Student Engagement, Readiness and Preparation
- Faculty Engagement & Professional Development
- Institutional/Community Capacity Building

The HBCU Innovation Summit founded by UNCF is one shining example of these partnerships. Started in 2013, the HBCU Innovation Summit brings students and faculty to Sillicon Valley for four days to hear from and learn from tech companies – 14 companies in 2018, including Google, eBay, Pixar, Twitter, Adobe, etc. The summit includes workshops, company tours, a career fair, and interviews [12, 13].

In addition, UNCF is responsible for the development of an HBCU CS Center of Excellence which aligns with the specific UNCF/Google Partnership, and will support innovation in computer science education and tech skills development across HBCU campuses; and empower African American students to succeed in college and careers in the tech industry.

V. Reflection

Cultural and family assets of diverse students create dynamic learning environments that need to be nurtured to keep students engaged despite their many non-academic commitments. While many students have grit, they often lack a growth mindset and may question their belonging in computer science. We need to instill in them this growth mindset by creating learning activities that are culturally sensitive, provide continuous feedback, and allow flexibility to complete them, while preparing them with the professional skills sought by tech companies. Addressing the growth mindset via project-based learning has garnered positive feedback as project-based learning is student-centered, with opportunities for them to work on personally meaningful components.

In general the added practices such as resume building, constructing an online profile via LinkedIn and GitHub, whiteboarding, and mock interviewing have been successful and made positive impacts in getting students prepared and building their confidence as they get ready to enter the tech industry. We identified obstacles such as not having the luxury of any (or limited) whiteboards in which to conduct tech interview trainings or have students practice. Still, we adapted and understood the importance of verbally communicating the thought processes and problem solving approaches candidates must do in a technical interview.

Some of the challenges shared by faculty regarding project implementation include team-work management skills, time management skills, guidelines for code review, further testing, getting buy-in from others at their home institution, and finding the time to incorporate industry practices in an already packed CS curriculum.

VI. Conclusion

In order to attract a diverse and inclusive workplace, it is important that tech companies provide access to skill-boosting development and resources so students from MSIs have wider opportunities and are better-prepared candidates. The FIR program offers faculty a unique and up-close engagement with industry and an opportunity to align curriculum with high-quality, industry-sponsored standards, learn more about the recruitment process, engage in project-based learning and be exposed to the work culture at Google.

There are numerous strategies that we recommend tech companies, such as Google, implement to continue to achieve positive outcomes and growth, including some of the following:

- Establish programs like FIR to increase faculty awareness of industry practices
- Identify more faculty of color to participate in the FIR programs
- Create quicker design career pathways and preparedness into industry
- Provide shared principles to fill the student skills gap while graduating more students who are workforce ready
- Create synergies and/or hubs across MSIs as a consortium to engage other MSIs that are not as strong

ACKNOWLEDGMENT

We are grateful to Google for creating the Faculty in Residence Program and to the Google Engineering Education team that has made it a success and continues to improve it.

REFERENCES

[1] Buck Institute for Education. "What is PBL?" https://www.pblworks.org/what-is-pbl [Online; Retrieved 10-24-2019]

[2] L. Burge, M. Mejias, K. Galloway, K. Gosha, and J. Muhammad. 2017. "Holistic development of underrepresented students through academic: industry partnerships," in Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE '17). Association for Computing Machinery, New York, NY, USA, 681–682. DOI:https://doi.org/10.1145/3017680.3017808

[3] L. Grewe and C. Hu. 2019. "Assisting with Frustration in Learning via Machine Learning and Computer Vision", in Proceedings of the ACM Turing Celebration Conference, China. DOI: https://doi.org/10.1145/3321408.3322864.

[4] A. Kapoor and C. Gardner-McCune. 2019. "Understanding CS undergraduate students' professional development through the lens of internship experiences," in Proceedings of the 50th ACM Technical Symposium on Computer Science Education (SIGCSE '19). ACM, New York, NY, USA, 852-858. DOI: https://doi.org/10.1145/3287324.3287408

[5] T. Markham. "Project Based Learning," in Teacher Librarian, 39(2), 38-42. 2011.

[6] G. Morrisett, S. Patel, J. Rexford and B. Zorn. "Evolving academia/industry relations in computing research: interim report". 2019. https://www.cccblog.org/wp-content/uploads/2019/03/Industry-Interim-Report-w-footnotes.pdf [Online; Retrieved 10-24-2019.

[7] S. Narayanan, K. Cunningham, S. Arteaga, W.J. Welch, L. Maxwell, Z. Chawinga, and B. Su. "Upward Mobility for Underrepresented Students: A Model for a Cohort-Based Bachelor's Degree in Computer Science," in Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE '18). Association for Computing Machinery, New York, NY, USA, 705–710. 2018.

[8] I. Polycarpou, P. Andreou, C. Laxer, S. Kurkovsky, "Academic-industry collaborations: effective measures for successful engagement," in ITiCSE 17, Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education, 2017.

[9] A. Radermacher and G. Walia. 2013. "Gaps between industry expectations and the abilities of graduates," in Proceeding of the 44th ACM technical symposium on Computer science education (SIGCSE '13). ACM, New York, NY, USA, 525-530. DOI: https://doi.org/10.1145/2445196.2445351

[10] U.S. Department of Education, Office of Planning, Evaluation and Policy Development and Office of the Under Secretary. "Advancing diversity and inclusion in higher education." Washington, D.C., 2016. http://www2.ed.gov/rschstat/research/pubs/advancing-diversity-inclusion.pdf [Online; retrieved 10-24-2019.]

[11] S. Valstar. 2019. "Closing the academia-industry gap in undergraduate CS," in Proceedings of the 2019 ACM Conference on International Computing Education Research (ICER '19). ACM, New York, NY, USA, 357-358. DOI: https://doi.org/10.1145/3291279.3339440

[12] UNCF HBCU Innovation Sumit. https://www.uncf.org/programs/hbcu-innovation-summit. [Online; visited 10-24-2019]

[13] UNCF's Innovation Summit in Silicon Valley is changing the STEM game. https://theundefeated.com/features/uncf-innovation-summit-in-silicon-valley-is-changing-the-stem-game [Online; visited 10-24-2019]

A Framework for Designing Contextualized Computing Curriculum

Ursula Wolz
RiverSound Solutions/Lang College
Montclair, NJ/New York, NY
ursula.wolz@gmail.com

Gail Carmichael
Shopify
Ottawa, Canada
gail.carmichael@shopify.com

Anne Marie Webber
Goffstown High School
Goffstown, NH
annemarie.webber@sau19.org

***Abstract*—Contextualized computing is a two-decades-old approach to providing foundations in computer science. The intent has always been to promote a diversity of approaches and to cast a wide net through which to bring under-represented groups into the field. Much of the curriculum design is ad hoc. This experience paper presents a disciplined model for curriculum design that provides a structure and methodology for integrating computing with another discipline. A framework for analysis is presented that abstracts the curriculum development process. It is grounded in 50 years of scholarship on instructional design. It extends established practice to concurrently develop goals, objectives, activities, and assessments across at least two domains. The methodology is applied in two non-traditional domains: an industry-based work-integrated learning program at a 'software as a service' company, and in an alternative high school mathematics class for students at risk. This approach is unique in its emphasis on promoting a principled framework for curriculum design. It extends traditional instructional design by applying methodologies of agile development to identify, execute, and assess instructional computing.**

***Keywords*—contextualized computing, interdisciplinary computing, computing curriculum design, high school computer science**

I. A Framework for Contextualized Computing

The broadening participation movement has fostered a variety of approaches to teaching computer science. Contextualized computing, described by Xu et. al in 2008 [1], is an approach that directly supports diversity.

Context may be brought into a computing-specific course, or computing may be integrated into another context altogether. An early example of contextualized computing was an effort to teach programming to digital artists [2]. Many other examples have been reported (such as [3], [4], [5], [6], [7]), typically with the intention of extending the reach of interdisciplinary computing [8], [9] or attracting a more diverse group of people to the field. Contextualized computing is a promising solution for the lack of quality computing instruction available [10]; indeed, as coding appears increasingly in high school graduation requirements, contextualized computing may be the only practical way to insert computer science into a curriculum without removing something else.

A problem arises when courses are taught outside the well-established computer science community. This report describes a framework used in two contexts: high school alternative math, and industrial training. The framework provides a structure through which curriculum designers can attend to the intersections of the identified computing concepts and learning goals of the context.

II. A Concurrent Curriculum Design Framework

We present a framework to guide instructional design for contextualized computing curriculum. It can be used to integrate computing concepts with a targeted context to provide transparency in goals, expectations, and outcomes for both the contextual area and computing.

The framework is visualized via the diagram in Figure 1. The red circle (labeled A) encompasses computing concepts and skills in a single area of computer science, such as software engineering or data structures. The two greens circles represent skills and technologies from the contextual domain we want to integrate with. The larger green circle (labeled C) represents skills and technologies that are used more broadly over time. For example, in a work-integrated learning setting, it might capture all the skills that employees across a company use. In a high school setting it might address identified graduation requirements in the contextual discipline. The smaller dark green circle (labeled B) is a subset of the light green circle. It represents the skills that are required immediately in the contextual discipline. In the work-integrated learning setting, the dark green circle might be the skills that a student needs to have to succeed on a team they are joining imminently. In a high school course it is identified by state or national standards. The largest blue circle (labeled D) encompasses the broader skills, knowledge, and attitudes of computing. Not all of these are necessarily directly applicable to the specific context we are integrating with, but they contribute to breadth in the field of computing.

There are intersections between the area of computer science in the red circle and the context-specific skills (labelled 1), the context-specific skills used broadly over time (labelled 2), and the broader skills, knowledge, and attitudes of computing (labelled 3). The best opportunities to integrate computer science skills with the desired context exist in the first two intersections (labelled 1 and 2), while the third intersection

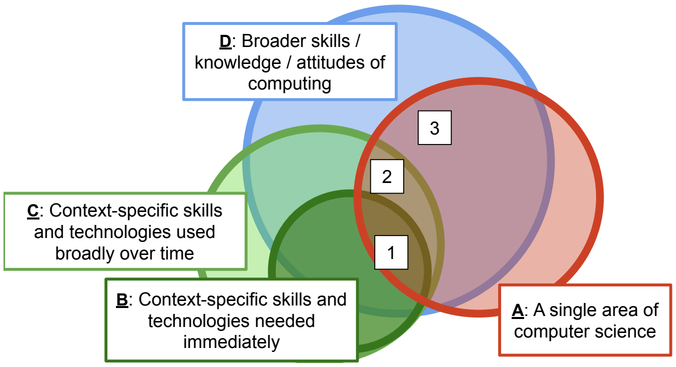


Fig. 1. Concurrent curriculum design framework.

(labelled 3) provides an opportunity to strengthen abilities in computing and indirectly contribute to success.

A. Procedure for Curriculum Development

Contextualized computing requires a dual design process in that instructional goals for both computing and the contextual subject area must be developed. As early as 1949 Tyler [11] proposed a framework for developing large curriculum projects by addressing the following questions:

1) What is the educational purpose?
2) What experiences are available to meet that purpose?
3) In what manner can these experiences be organized?
4) How can it be determined that the purposes were attained?

Instructional Systems is the field of study that provides theory and practice for instructional design, typically of a single content area. One well-recognized design procedure is that of Gagne, Briggs and Wanger [12]. A process model developed by Dick & Caray [13] defines stages of analysis from instructional goals to student outcomes. Within the contextualized computing framework this requires addressing instructional goals, learning objectives, student activities, student assessment (such as testing), and instructional assessment (evaluation of the course).

B. An Iterative Concurrent Process

Starting with the traditional process model, our framework supports an agile iterative cycle. The initial task is to define a *desired context*. In Section III we report on three: natural language, development at a particular software company, and high school alternative mathematics. Defining the context is followed by identifying the *area of computer science* we wish to integrate, which may be (or correlate to) an academic course.

Integration informs the five steps enumerated above as they are applied to the diagram in Figure 1. Defining the instructional goals of a learning experience means deciding broadly what our learners should be able to do by the end of the experience. At this stage we can identify concepts from the area of computer science that relate to the desired context skills (intersections 1 and 2 in the diagram). We can also look at the broader skills in computer science that relate to the course and would benefit performance in the context indirectly (intersection 3). Then we can consider ways to connect the concepts from the area of computer science with the practice of the desired context, or vice versa. The same considerations apply when breaking the instructional goals down into more detailed, specific learning objectives.

When designing student activities, we have an opportunity to look even more closely at the overlaps between the area of computer science and the desired context. A simple approach might be to re-skin a traditional activity found in an academic course with surface features from the desired context. Or we might design an activity to support learners in making explicit connections between the skills and knowledge from the area of computer science and those used in the context. For even deeper integration, we can have our learners solve a problem in the context using the course's skills and knowledge. We also have an opportunity to have our learners perform similarly to how participants in the integrated context would; for example, we might ask learners to pair program in a learning experience the same way they would on a team in an industry setting.

III. Examples of Designing for Two Different Contexts

We now illustrate examples of applying the framework using two dramatically different contexts: an industry-based work-integrated learning course connecting systems programming to the workplace context, and a high school alternative math class in which the final exam was a collaborative programming project.

We emphasize that this is an experience report rather than a formal quantitative research study on the efficacy of our methodology. We are reporting this at RESPECT as a vehicle for inviting others into using our approach to further enhance and codify the framework.

A. Systems Programming in an Industrial, Work-Integrated Learning Context

Shopify, a leading global commerce company, partners with two local universities to offer a curriculum-aligned work-integrated learning program [14]. The program aims to close the gap between what is learned in a computing degree and the skills required of an industry software developer. Students participate in learning activities at Shopify and rotate through a number of team placements throughout their computer science degrees. One author led the design and launch of the first version of the program.

We ran an experimental course designed to connect a campus-based academic systems programming course with the context of software development practice at Shopify. In this example, the 'red circle' of Figure 1 represents the systems programming course, while the 'green circles' represent the particular skills used on teams in the company.

1) Instructional Goal : The instructional goals were to: (1) enhance the learning occurring at the partner university's systems programming course with relevant practical skills;

(2) illustrate how the concepts taught in the academic course applied to the work done at the company; (3) Provide a less structured learning experience where students could help each other to research more open-ended tasks that instructors don't generally have the 'answers' for.

The goals land in the intersections labeled 2 and 3 in Figure 1 in that we targeted skills and concepts from the academic course that were relevant to the tools and languages used for software development at the company, but not necessarily those that students would need immediately during their next team placements.

2) Learning Objectives: The course's learning objectives were as follows:

1) Use the same operating system as the on-campus course in a new, practical context.
2) Use a command-line interface in an applied setting.
3) Practice writing C code for input/output on a real device.
4) Work with hardware designed within the company.
5) Investigate how memory management works in a high-level programming language used often in the company.

3) Student Activities: Students met for one hour per week at Shopify during the same semester they took the on-campus systems programming course. At Shopify, they were given open-ended problems centered on working with Raspberry Pis, interacting with hardware designed in-house at the industry host, and researching the Ruby interpreter source code. They were asked to acquire and write simple programs in C for peripherals for the Pis, participate in a workshop exploring how to work with the Bluetooth interface of the in-house hardware, and write a report on what they learned about memory management in the Ruby interpreter.

4) Student Assessment: Assessment for this course was informal: students were expected to attend each weekly hour, and to complete their report in a timely manner. They were excused for good cause. Unsatisfactory participate was noted in their next performance review.

5) Instructional Assessment: Instructional assessment was determined by biweekly student discussions with formally assigned program mentors as well as an anonymous feedback form at the end of the semester. We also received detailed and thoughtful suggestions directly from some students. This offering was one of the first in the program.

Results of the experimental course were mixed. Observations showed that students met all the desired objectives. However, they spent too long working with the Pis and peripherals, causing them to spend more time in the intersection labeled 3 in Figure 1 than was ideal. Spending more time on skills directly applicable to their next team placements (intersection 1) and connecting more directly to skills that other teams use (intersection 2) would have improved student satisfaction.

B. The Alternative Mathematics Classroom

We used our framework to design curriculum for an alternative mathematics class for at-risk high school students. These students will not qualify to enroll in computing courses, and our challenge was to integrate foundational programming skills into their mathematics experience. The school supported a radical projects experience in which students built a physical museum exhibit. The alternative math class contributed a physical quilt.

Turtlestitch (turtlestitch.org), a version of Snap! that emphasizes Turtle Geometry, provided the context for introducing computing. In our framework, the 'red circle' (labelled A) course content is coding in Snap!, the small context 'green circle' (labeled B) is geometry and algebra skills, the large context 'green circle' (labeled C) is common core mathematical practice that articulated directly with 'blue circle' (labeled D) big computing.

1) Instructional Goal : The instructional goal was to engage the alternative math student in mathematics and coding to reinforce that formal math was useful, and more to the point, that they could master it. The secondary goal was to empower them as coders and provide basic skills in information technology. The practical goal was to create a collaborative quilt. The completed quilt was their 'final exam.'

2) Learning Objectives: Learning objectives came from three sources: (1) Common Core mathematical practice, (2) selected Common Core high school standards in algebra and geometry, (3) CSTA CS Standards. Objectives included (1) Algebra HSA.Q.A.1 Reason Quantitatively and Use Units, (2) HS Geometry G-CO:12 Construct Geometric Figures, and (3) G-MG:1&3 Apply geometric concepts in modeling situations. Because this a math class, CSTA standards were mapped to the primary Common Core math practice standards.

3) Student Activities: The learning module was called 'Problem Solving Unit – Operation Quilt.' Students were shown basic turtle stitches (how to make a square). Algorithms were introduced as Snap! scripts. Discussions occurred that mixed geometry and coding, such as what the term 'algorithm' meant in computing and mathematics. Geometry definitions in relation to turning through a circle (e.g. core trigonometry) were introduced by having students use turtle movements to draw standard polygons, construct a circle (using a control structure), understand how variables can impact scaling, and how to construct re-usable components by defining their own blocks. Students were asked to discover on their own or as a group how to draw any polygon, and how to approximate a circle. They were challenged to identify the parameters for unique design. Once students had mastered essential geometry and coding skills, each designed and implemented at least two images for a 'seasons' themed quilt shown in Figure 2.

4) Student Assessment: Assessment was tied directly to the production of blocks on the quilt. They were also required to write short reflective essays on the experience. Students were hesitant at first, thinking they were bad at math, and since Turtlestitch was being taught in a math class they must be bad at it, too. When they learned that giving up wasn't an option, they persevered through all of the coding they were tasked with, and then some. Everyone passed.

Students rose to this task and accomplished it with excellence. They excelled at helping each other with their coding, troubleshooting, and embroidering. When setbacks occurred,

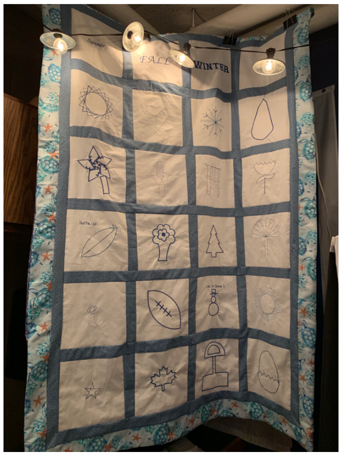


Fig. 2. Final exam quilt from the alternative math class

such as designs that were too large, they eagerly embraced and adopted advanced concepts such as the use of variables to support scaling.

5) Instructional Assessment: The careful consideration for the intersection of math and coding skills allowed us to meet both the formal objectives of the required standards as well as the subtext of producing math- and tech-confident individuals. Given the opportunity to reflect on the experience, they articulated that problem solving is hard, and often frustrating, but that persevering to a tangible outcome is satisfying. The school administration was satisfied as well: the students all met their math requirement for graduation.

IV. Recommendations

Based on our experience, we recommend the following steps when applying our framework, with the most important considerations appearing first:

1) Identify the computing domain and context.
2) Integrate the specific skills students need now in the desired context (intersection 1 in the diagram) first.
3) Integrate with broader skills within the specific context but that students don't necessarily need immediately (intersection 2) next.
4) Integrate with the even broader set of skills, knowledge, and attitudes that contribute to being a stronger computer scientist (intersection 3) last.

Ensure the course and the context do not feel like separate, disconnected tracks. When possible, allow students to experience the practical implications of theory within the context before learning about the theory. Reduce the amount of time between experiencing the practice in the context and learning about the theory behind the practice. Apply the following rules iteratively:

- If a requirement in a course can be fulfilled by an experience in the context, avoid making students cover the requirement twice, instead focusing on connections to the theory or giving credit toward the course.
- Support students in actively reflecting on connections between the academic computing material and the context.
- Consider which 'direction' would work best: are you building a computer science course that integrates context, or are you integrating computing into an academic or industrial learning context?
- Consider whether you are designing a new course, adapting an existing course (such as Alternative Math), or providing a dual learning experience (such as the industrial experience).

V. Summary and Future Work

A framework for contextualized computer science curriculum is dependent upon addressing the natural intersections between the computing learning goals and the contextual learning goals. The framework provided here, based on sound principles of instructional design provides a framework for transparency in course development. We invite you to join us in this enterprise by visiting the (redacted) website of one of our authors.

References

[1] D. Xu, D. Blank, and D. Kumar, "Games, robots and robot games: Complementary contexts for introductory computing education," in *Proceedings of Third International Conference on Game Development in Computer Science Education (GDCSE'08)*, 2008.

[2] J. Maeda, *Design by numbers*. MIT Press, 1999.

[3] J. D. Bayliss and S. Strout, "Games as a "flavor" of cs1," in *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education*, SIGCSE '06, (New York, NY, USA), pp. 500–504, ACM, 2006.

[4] R. E. Beck, J. Burg, J. M. Heines, and B. Manaris, "Computing and music: A spectrum of sound," in *Proceedings of the 42Nd ACM Technical Symposium on Computer Science Education*, SIGCSE '11, (New York, NY, USA), pp. 7–8, ACM, 2011.

[5] M. Guzdial, *Introduction to computing and programming with Python: A Multimedia Approach*. Prentice-Hall, 2004.

[6] U. Wolz, C. Ault, and T. M. Nakra, "Teaching game design through cross-disciplinary content and individualized student deliverables," *Journal of Game Development*, vol. 2, no. 2, 2007.

[7] D. Xu, U. Wolz, D. Kumar, and I. Greenburg, "Updating introductory computer science with creative computation," in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, SIGCSE '18, (New York, NY, USA), pp. 167–172, ACM, 2018.

[8] L. N. Cassel and U. Wolz, "Interdisciplinary computing, successes and challenges (abstract only)," in *Proceeding of the 44th ACM Technical Symposium on Computer Science Education*, SIGCSE '13, (New York, NY, USA), pp. 738–738, ACM, 2013.

[9] U. Wolz and L. B. Cassel, "The role of interdisciplinary computing in higher education, research and industry," in *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, SIGCSE '12, (New York, NY, USA), pp. 7–8, ACM, 2012.

[10] E. S. Roberts, "Meeting the challenges of rising enrollments," *ACM Inroads*, vol. 2, pp. 4–6, Aug. 2011.

[11] R. Tyler, *Basic Principles of Curriculum and Instruction*. University of Chicago Press, 1949.

[12] R. M. Gagne, L. J. Briggs, and W. W. Wager, *Principles of Instructional Design*. Harcourt Brace College, 1992.

[13] W. Dick and L. Carey, *The Systematic Design of Instruction*. Scott Foresman & Co, 1990.

[14] G. Carmichael, C. Jordan, A. Ross, and A. Evans Adnani, "Curriculum-aligned work-integrated learning: A new kind of industry-academic degree partnership," in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, SIGCSE '18, (New York, NY, USA), pp. 586–591, ACM, 2018.

Through the Looking Glass: Computer Science Education and the Unintended Consequences of Broadening Participation Policy Efforts

Rebecca Zarch
SageFox Consulting Group
Amherst, USA
rzarch@sagefoxgroup.com

Sarah Dunton
ECEP Alliance
Holyoke, USA
sdunton@mghpcc.org

Joshua Childs
University of Austin
Austin, USA
joshuachilds@austin.utexas.edu

Anne Leftwich
University of Indiana
Bloomington USA
aleftwic@indiana.edu

***Abstract*—This experience report provides insights into the unintended consequences of five states efforts to make computer science education policy changes in an effort to broaden participation in computing (BPC). At the 2019 Expanding Computing Education Pathways (ECEP) meeting, several member-states were invited to share about the unintended consequences of computer science education policy reform in their states. Due to the nature of policy making and implementation, marginalized communities including students, practitioners, and under resourced schools are most impacted by education policy reform efforts. As computer science education gains traction as an education policy priority in states and districts, it is important to learn the lessons of past education policy failures and successes, specifically how these policies could trigger unintended consequences that will impact the broadening of participation within K-12 computer science education. The examples put forth by the states include unintended consequences of policies such as making CS count as a graduation requirement, defining computer science, developing CS standards, and teacher certification. These experienced unintended consequences may be relevant to other states seeking to make CS policy changes. This paper concludes with a reflection on the ECEP model as a tool for mitigating these unintended consequences as part of the BPC efforts.**

***Keywords*—broadening participation; policy; experience report**

I. Introduction

The Expanding Computing Education Pathways (ECEP) is an alliance network of states focused on equity in computer (CS) education. Funded by the National Science Foundation since 2012, ECEP has grown from an initiative serving 2 states, to a network of state teams, local stakeholders, and national partners collaborating on systemic CS educational reform. Based on these collaborative efforts, we identified a model for state change. The model was intended to serve as a framework for advancing BPC goals within a state. State leaders build strategic, data driven, efforts furthering CS educational reform utilizing the model as a framework. The ECEP model for state change utilizes 5 key concepts: (1) Identify a diverse set of stakeholders, (2) Understand the landscape, (3) Organize stakeholders, (4) Seek funding, and (5) Develop an infrastructure and process to monitor BPC progress. The model is intended to scaffold state education reform and advocacy efforts while maintaining a BPC focus

Any policy effort designed to make wide scale change is complex and may result in unintended consequences (e.g., Lubienski, 2005). This seems even more prevalent in CS education policy reform efforts, potentially due to the multifaceted and novel nature of the work (Ericson, Adrion, Fall, & Guzdial, 2016). CS education advocates are attempting to build pathways to CS education for what the National Science Foundation has described as the missing 70%. This missing 70% refers to the percent of women, African Americans/Blacks, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, Native Pacific Islanders, and persons from economically disadvantaged backgrounds, and persons with disabilities who are not currently enrolling in and being retained in K-20 CS education (Kurose, 2017) ECEP states often have similar focus areas within the model yielding lessons learned about making systemic change within their states.

Often, American education policy is created by stakeholders who are not responsible for implementing the broad policy changes that usually go beyond their original intent (e.g., Madsen, 2002). Legislation that is aimed at addressing one issue in society may have effects or unintended consequences elsewhere that dampen or even reverse the gains the policy sought to acquire in the first place. These unintended consequences of policy (both positive and negative) have been found at all levels of educational policy: federal, state, and local (Brady, Duffy, Hazelkorn, & Bucholz, 2014). Unintended consequences are the result of policies created at every level of the educational system, leading to practices, actions, beliefs that were inadvertent and caused more unforeseen issues. For example, zero tolerance policies were implemented over the past thirty years in an effort to curb the perceived increase in violence and discipline infractions in schools. This zero tolerance policies have shown to have had a negative impact on Black girls (Lindsey, 2018), lead to the proliferation of the school-to-prison pipeline (Love, 2016), and have not made our schools any safer (Martinez, 2009).

Frequently, stakeholders charged with proposing, writing, or passing the policy or law do not consider what the unintended consequences of a policy may be, even though the power of unintended consequences has been well documented (Ganapati & Frank, 2008). However, working through all the possible outcomes of a given policy or law can be an impossible task for stakeholders who usually operate within constrained timeframes, pressure from relevant constituents, the influence of money, or not being able to fund a proposed policy or law (Hyatt & Filler, 2011). Due to the nature of policy making and

Funding from the NSF under award numbers 1228355 and 1822011

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

implementation, marginalized communities and students, practitioners, and under resourced schools are most impacted by unintended consequences in education (Stechter et al, 2001). As CS education gains traction as an education priority, it is important to learn the lessons of past policy failures and successes, specifically how these policies relate to unintended consequences that will impact the broadening of participation CS education.

In September 2019 ECEP members gathered for an annual summit in which state teams had the opportunity to share the unintended consequences of local CS education policy efforts. This report highlights a collection of state stories that serve as a cautionary tale for other state leadership teams currently engaged in CS education reform efforts. These stories are designed to create a roadmap by defining the policy, highlighting what happened when the policy was implemented, what lessons were learned when obstacles appeared in the implementation phase, and how leaders may have mitigated these problems prior to the policy being adopted.

II. Lessons Learned

A. California

California and its CSforCA campaign has long been advocating for CS to "count" toward college eligibility in its higher education system. Research has demonstrated that when CS "counts" toward high school graduation and college eligibility, students are more incentivized to take it and prioritize CS in their already demanding high school schedules. When the CalState university system announced a proposal to increase the quantitative reasoning requirement from three to four years, and accept CS toward the additional quantitative reasoning requirement, it seemed like a "win" for our multi-stakeholder coalition.

However, as the CSforCA coalition's equity advocate partners discussed the possible unintended consequences, we learned that the proposed change could disproportionately decrease eligibility for African American, Latinx, and low-income students, who currently lack access to advanced level CS courses in their high schools. Moreover, since these students have historically struggled to meet university admissions standards because they often attend under-resourced schools that don't offer access to these courses, this change is seen as further disadvantaging students in an existing unequal system of education. The CSforCA coalition is working closely with equity advocates to develop an implementation timeline that would increase expectations and opportunities for all students, while ensuring a solid infrastructure is in place to so that all students have equal access to high quality and advanced level instruction, while also having the scaffolding in place to be successful in a college-preparatory pathway.

We learned that equity in CS must mean being an advocate for equity in education overall. It is necessary for CS education advocates to explore unintended consequences of well-intentioned policy proposals and recognize that we are operating in an existing unequal system of education. It is our collective responsibility to use CS education as an opportunity to disrupt these inequalities, rather than contribute to them.

B. Utah

Prior to 2013, Utah had a Computer Technology graduation requirement, which could only be fulfilled by a basic computer literacy course. When Exploring Computer Science (ECS) was introduced as an alternative method for completing this graduation requirement, the number of Utah high school students enrolled in CS courses grew dramatically. In 2016, the Utah Board of Education responded to this success by replacing the "Computer Technology" graduation requirement with an updated "Digital Studies" graduation requirement. Six courses were accepted for this graduation requirement, including ECS three other CS courses, and two business courses. On paper, this policy change appeared to be a win, with more advanced CS offerings that might appeal to students with some programming backgrounds.

In practice, Utah has seen a drop in CS enrollments since this policy change has been enacted. Allowing for more CS courses to fulfill this graduation requirement has not led to more CS section offerings at local schools, perhaps because most Utah schools do not have more than one CS teacher. Furthermore, the more advanced CS courses often require a higher level of CS endorsement. The school's one CS teacher may not yet be endorsed to teach anything beyond ECS. In contrast, the business teachers who used to teach "Computer Technology" were already endorsed to teach the two more advanced business courses. The Utah ECEP team has heard anecdotal stories of students who have expressed an interest in enrolling in CS classes being registered in business classes instead, with only those students with vocal parents as advocates being enrolled in CS classes. To identify struggling schools and the underlying causes for lower CS enrollments, the Utah ECEP team is conducting a report on enrollment trends by schools and districts. We are also working on a CS for Utah campaign to help administrators, guidance counselors, teachers, parents and students better understand the value of CS for all students.

C. Georgia

In 2015, the GA governor created a task force on computing education that resulted in the expansion of high school course offerings and the creation of a position dedicated to CS at the DOE. In addition, the State Board of Ed approved certain courses to count for graduation credit (science, math, and foreign language). Since then, attention around the state has been focused on CS teacher professional development. Private, non-profit, and government organizations, working in concert under the umbrella of CS4GA, offered a plethora of diverse CS professional development (PD) opportunities. In 2016, the Georgia Professional Standards Commission required that CS be taught by a teacher with an approved credential (an add-on certification for in-service teachers or an endorsement). The CS teachers, many of whom lacked this credential, protested and the credential requirement date was pushed back two consecutive years and is now being enacted in 2019. Due to poor communications and test burdens, the state lost some CS teachers when they left CS for their prior field of instruction. Many CS teachers that were near retirement described being unmotivated to take the required CS test to obtain the credential. Recently the professional standards commission agreed to allow teachers with other certifications (Business, Math, Engineering, Science) to teach the Middle School Courses until the legislation is fully enacted in 2025 and districts had enough time to train their teachers.

Support for CS continued to grow with legislative commitments to teacher training, equipment purchases, and curriculum development. In 2019, Senate Bill 108 was passed nearly unanimously to require all high schools and middle schools to offer CS by 2025. This bill was accompanied by an appropriation of $750,000, with 85% dedicated to teacher training. These requirements brought out the question “What counts as CS?.” The State Council which is made up of 30% industry, 30% higher ed, as well as government and K-12 representatives, lacked consensus over what counted as CS. For example, the programming courses were voted in by an easy majority, but cyber security, IT support, Web Design, and Networking were a mixed result. Despite having defined what CS is as a state when we created our K-8 standards, our definitions of what constitutes CS remains amorphous. Without a clear definition, it is difficult to identify what needs to be covered in a certification process. CS is more than programming, as once was the case, and includes foundational knowledge, awareness, and skills like digital citizenship and computational thinking. Expanding the understanding of what constitutes CS is currently underway in Georgia.

D. Indiana

One example of an unintended consequence in Indiana of CS education policy and implementation is the passage of the 2018, Senate Bill 172. The bill included one policy that by 2021, all high schools will be required to offer at least 1 CS class. Rural school districts in particular report difficulties associated with offering CS at the high school level with their limited teaching staff. By 2018-2019, approximately 50% of public high schools had students who completed a CS course and only 14 counties still had no students that completed a CS course during that school year. Although we are seeing an upward trend, smaller school districts have expressed the difficulties in offering so many required diverse courses, and have attempted to come up with solutions to address this problem through online courses and shared career center courses. The Executive Director of The Indiana Small and Rural Schools Association stated that “We acknowledge that larger school districts can offer more diverse course offerings...The logistics of transporting either students or teachers...will take time and extra support. It is tough to add an advanced course in one district without adding enough students to fill the course from both systems” (Lagoni, 2017).

Although the Indiana Department of Education has been working to support school districts to achieve these instantiations, there is still little known about how this policy will be enforced. Many partners throughout Indiana are working hard to support rural and small schools. Through summit meetings, we have been able to host sessions directly related to providing PD support for K-8 teachers and focusing on supporting rural schools. Also, due to landscape reporting, we have been able to identify which districts do not have any students who have completed a CS course yet. Therefore, we have been able to target those specific school districts and work with them to offer CS.

E. Virginia

In 2016, Virginia law mandated CS standards for all students be integrated into K-8 classrooms, and also created mandatory standards for four standalone elective courses at the middle and high school level. Prior to the clarity provided by the General Assembly through the funding allocation, CodeVA was largely viewed by the Virginia Board of Education (VDOE) as a vendor, rather than a partner. The initial independence of CodeVA afforded Virginia with some very significant advantages. CodeVA’s independent advocacy led to all of Virginia’s early adoption of CS policy and legislation. However, the lack of a defined relationship and partnership wasted time. For example, although the VDOE adopted Virginia’s CS standards in November of 2017, it was not until early summer 2019 that the VDOE assigned course codes to those classes, allowing school divisions to officially offer the classes.

Heading into summer 2019, CodeVA offered its free, state-funded summer professional development institutes with heavily enrolled sessions. Yet there was unexpectedly low PD attendance for high school level courses. Many of the classes had been cancelled by their school divisions at the last minute. The issue turned out to be related to Carl D. Perkins Career and Technical Education grant funding restrictions. The VDOE had issued CS elective course codes, but had not assigned CTE Virginia's Educational Resource System Online codes. Thus, division grant compliance officers flagged these classes as problematic, and due to the problematic flagging, divisions simply cancelled the courses. In many cases, these classes still could have been offered by the school division had they known to contact CodeVA for advice on alternative course codes. The same CTE course that many Virginia divisions had used since CodeVA began its work would have satisfied the Perkins funding requirements until the following year when the VDOE could have worked out the problem. The VDOE is now working on planning to assist in clarifying and in developing implementation plans for divisions.

III. Discussion

Engaging a diverse group of stakeholders is an essential component of making educational policy change at the state level in an effort to minimize the unintended consequences on students, teachers, district leaders, and industry. The ECEP framework can be used by any state to mitigate the potential for unintended consequences, especially as they relate to BPC:

1) Build a diverse leadership structure.. Having a leadership team that represents a diverse set of voices ensures that all students, teachers, district leadership, and other stakeholders in computing education are considered when advocating for policy reform. If specific stakeholders are not at the decision making table advocating for their systems and specific needs, policy can create unnecessary burdens, deepening the inequities in CS. ECEP recommends that states include stakeholders from departments of education, government offices, business and industry, K-12, higher education, community groups, national CS education and advocacy groups, non-profit organizations, informal education, students and parents. Demographic diversity should be a priority in leadership development to ensure a focus on BPC. For example, Georgia's case study showcased the importance of having more voices involved making decisions that could have predicted the unintended consequence of requiring current teachers to obtain certification.

2) Understand the data landscape. Using available state and national data to create a landscape report is critical for informing decision making and policy design. Policy development based on strong data allows for strategic planning, potentially alleviating the possibility for unintended consequences down the road. For example, Indiana used student enrollment data to focus efforts on rural schools that needed more training and support.

3) Organizing stakeholders. Developing and promoting a shared purpose and message of BPC when championing change efforts provides an opportunity to reach out to other vested communities such as literacy, math, informal education, and/or non-profits. By broadening the equity message, BPC efforts gain support while protecting against ripple effects that may negatively affect other communities and aligned initiatives. In Virginia's example, if VDOE had involved CodeVA in earlier conversations as a partner, there could have been a continutation or increase, of, CS growth

4) Work towards sustainability. Seek funding to develop an infrastructure that allows for BPC to remain at the heart of any CS educational process. A strong, well-funded infrastructure can help multiple groups align goals, organize technical assistance and PD with an equity focus and monitor the landscape, allowing efforts to adjust and adapt when appropriate. In Utah's example, it showed the importance of building a structure to support schools and teachers in being able to equitably extend beyond Exploring Computer Science.

5) Focus on data. A good data infrastructure allows for continuous monitoring of the landscape to ensure the BPC goals are being met, without any group being unintentionally left out or behind. Collecting outcome data is crucial to ensure that efforts are addressing inequities, not exacerbating existing discrepancies in access, enrollment, and retention in computing. As shared in many of these case studies, unintended consequences often impact the missing 70% that we critically need in CS. Therefore, it is important that continuous monitoring of our BPC goals are at the forefront.

Finally, just as states report that communication and collaboration are essential to all elements of the ECEP model, it is critical that these stories are shared. ECEP participants highly value the opportunity to learn from other members in the community. By sharing these stories state teams are able to reflect on their own work, draw upon strategies tried in other states, and learn from missteps. This cycle allows the BPC community to grow and reflect, with the goal of seeing more students from the missing 70% building confidence in CS and pursuing CS classes, degrees, and potentially careers.

Acknowledgment

Julie Flappan, Director of the Computer Science Equity Project at UCLA's Center X (CA), Helen Hu, Professor of Computer Science, Westminster College (UT), Bryan Cox, Computer Science Specialist, Georgia Department of Education (GA), Chris Dovi, Executive Director, CodeVA (VA)

Produced with support from The National Science Foundation Award numbers 1228355 and 1822011.

References

[1] M.P. Brady, M.L. Duffy, M. Hazelkorn, and J.L. Bucholz, "Policy and systems change: Planning for unintended consequences. The Clearing House: A Journal of Educational Strategies, Issues and Ideas," 87(3), 102-109, 2014.

[2] S. Ganapati, and H. Frank, "Good intentions, unintended consequences: Impact of Adker consent decree on Miami-Dade County's subsidized housing," Urban Affairs Review, 44(1), 57-84, 2008.

[3] K.J. Hyatt, and J. Filler, "LRE re-examined: Misinterpretations and unintended consequences," International journal of inclusive education, 15(9), 1031-1045, 2011.

[4] J. Kurose, "Dear Colleague Letter: Pursuing Meaningful Actions in Support of Broadening Participation in Computing," (BPC) (NSF 17-110) Retrieved from https://www.nsf.gov/pubs/2017/nsf17110/nsf17110.pdf, 2017.

[5] C. Lagoni, "The Results Don't Always Match The Model" Retrieved on September 17, 2019 from https://www.indianasmallandrural.org/the-results-dont-always-match-the-model, 2017.

[6] T.B. Lindsey, "Ain't nobody got time for that: Anti-Black girl violence in the era of #SayHerName," Urban Education, 53(2), 162-175, 2018.

[7] B.L. Love, "Anti-Black state violence, classroom edition: The spirit murdering of Black children," Journal of Curriculum and Pedagogy, 13(1), 22-25, 2016.

[8] S. Martinez, "A system gone berserk: How are zero-tolerance policies really affecting schools? Preventing school failure: alternative education for children and youth," 53(3), 153-15, 2009.

[9] C. Lubinski, "Public schools in marketized environments: Shifting incentives and unintended consequences of competition-based educational reforms," American Journal of Education, 111(4), 464-486, 2005.

[10] B. Ericson, R. Adrion, R. Fall, and M. Guzdial, "State-based progress towards computer science for all," ACM InRoads, 7(4), 59(2), 57-60, 2016.

[11] J. Madsen, "Educational reform at the state level: The politics and problems of implementation," Routledge, 2002.

[12] B. Stecher, G. Bohrnstedt, M. Kirst, J. McRobbie, and T. Williams, "Class-size reduction in California: A story of hope, promise, and unintended consequences," Phi Delta Kappan, 82(9), 670-674, 2001.

Reflections on Launching a Networked Improvement Community with Computer Science Educators

Carol L. Fletcher
Texas Advanced Computing Center
The University of Texas at Austin
Austin, TX
cfletcher@tacc.utexas.edu

Ryan Torbey
Texas Advanced Computing Center
The University of Texas at Austin
Austin, TX
rtorbey@tacc.utexas.edu

Joshua Childs
Educational Policy and Planning
The University of Texas at Austin
Austin, Texas
joshuachilds@austin.utexas.edu

Rebecca Zarch
SageFox Consulting Group
Amherst, MA
rzarch@sagefoxgroup.com

***Abstract*—This experience report details the lessons learned while launching a Networked Improvement Community (NIC) with 23 teachers in Texas as part of the NSF-funded Accelerating Women's Success and Mastery in Computer Science (AWSM in CS) project. Conceived to address the persistent gender inequities in computer science (CS) education, the NIC was designed to bring together researchers and practitioners to collaboratively develop and implement solutions with the goal of increasing female participation in CS courses. This experience report explores the lessons learned, such as the importance of building a sense of community, trust, and collaboration, before jumping into problem solving as a NIC. Additionally, the report addresses considerations for sustaining the NIC virtually given the logistical constraints placed on teacher collaboration during the school year.**

***Keywords*—CS for All, RPP, NIC**

I. Introduction

Accelerating Women's Success and Mastery in Computer Science (AWSM in CS) is a project focused on improving the enrollment and experience of young women in secondary computer science classes in Texas. While the bulk of this experience report will examine the lessons learned in launching the AWSM in CS (pronounced "Awesome in CS") project's Networked Improvement Community (NIC), it is important to understand the context of the overarching goal of the project, addressing the persistent disparities in computer science course enrollment between male and female students in Texas, in order to fully appreciate our approach.

The project was conceived as a response to the trends in enrollment in high school CS courses seen since 2011. The lack of female representation in high school computing has been well documented with females seen as a subset of students who are traditionally underrepresented in CS along with students of color, students from low socio-economic backgrounds, students with disabilities, and students from rural communities [1,2]. Since our research team began tracking CS enrollment in 2011, notable improvement has been documented in several of these traditionally under-represented subpopulations. As noted in Figure 1, overall enrollment in high school CS courses has more than doubled since 2011 (124% increase) [3]. Even more encouraging is that the enrollment of underrepresented minorities (URM), defined in this study as Black and Hispanic students, has increased by 154% and the enrollment of economically disadvantaged students (EcoDis), defined here as eligible for free or reduced lunch, has increased by 156%. Upon first glance, it would appear that improvements in female representation have also been promising, with a doubling of female enrollment (104% increase).

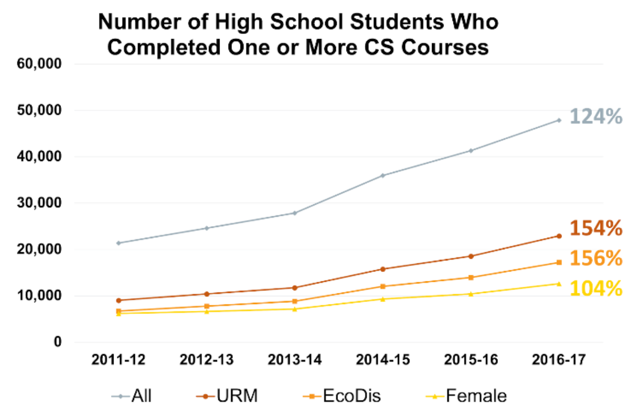


Fig. 1. Number of high school students who completed one or more CS courses

A deeper examination of these data in the context of overall improvement, however, shows that as a percent of the overall enrollment of students in high school CS, young women have seen a decline since 2011, going from 29% in 2011-12 to 26% in 2016-17. In short, the gap is widening between young men and young women in CS in Texas. In fact, when we examine traditionally underrepresented subpopulation's enrollment in CS courses compared to their representation in the high school student population, we find that the gap is most acute for young women (Figure 2) [3].

To address this persistent underrepresentation, The University of Texas at Austin, in collaboration with Austin Independent School District and 10 other Texas school districts, launched the AWSM in CS project in 2018 with funding through the Computer Science for All Researcher Practitioner Partnerships (CSforAll:RPP) program of NSF (Award #1837602). This project was planned as a Networked Improvement Community (NIC) consisting of 23 secondary CS teachers all committed to recruiting, supporting, and retaining more young women in their CS courses. A NIC is one approach to engaging the diverse parties of an RPP. This experience report will highlight some of the strategies deployed to design and support the NIC, some lessons learned in launching our NIC, and, based on the initial launch, considerations for sustaining the NIC.

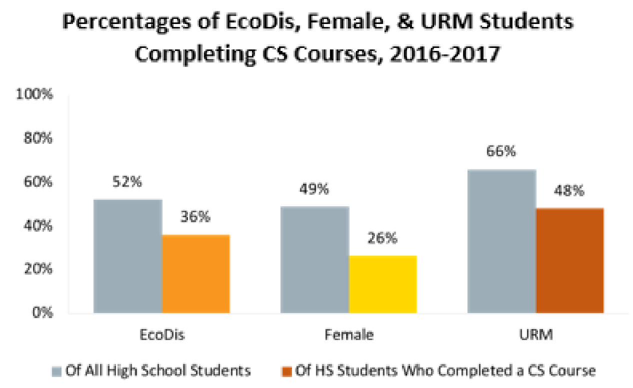


Fig. 2. CS course completetion percentages of underrepresented groups

II. Improvement Science as a tool for addressing BPC

In Texas, educators have long been engaged in efforts to improve teaching methods and student outcomes around high school computing courses. As mentioned earlier, CS course completion for underrepresented students has increased over the past five years. However, more investment and engagement is necessary to have this improvement trend impact young women in CS education. In recent years, organizations like the National Science Foundation (NSF) and CSforAll have promoted the tools and frameworks of improvement science to advance efforts to broaden participation. From its onset, improvement science has been defined as seeking to discern what works for addressing a complex problem, for whom, and under what set of specific conditions [4]. Improvement science in education has focused on addressing gaps between the aspirations of educational systems and their capacity to deliver high-quality education to all students [5].

A key framework and tool within improvement science is the plan-do-study-act (PDSA) cycle. PDSAs serve as a process for rapid cycles of learning from practice, a way to maximize learning, and a method for introducing a change to a complex system [6, 7]. PDSAs include four steps: planning a small test of change; doing or implementing a practice that matches what was planned; studying by monitoring or measuring what was implemented; and finally acting by refining and adjusting to what happened in the previous phases of the PDSA cycle to improve in the next iteration. An important part of the PDSA cycle process is to learn from the data. This involves comparing what was anticipated or predicted to what actually happened and took place. Improvement science uses PDSAs to frame, discipline, and document the learning that happens in organizations [6]. It provides educators an opportunity to implement new ideas, processes, and practices, refine them based on identified needs, and then use the results of implementation to make changes and commit resources and expertise to where it best fits.

NICs serve as a one example of the potential of improvement science in education [4]. NICs were created to address problems of practice by linking diverse kinds of expertise from research, educational design and practice in a process that can lead to improved student and educator outcomes [8, 9]. Russell et al. (2016) situate NICs as operating as scientific learning communities around four key dimensions: 1) they are focused on a well-specified aim; 2) they are guided by a deep understanding of the problem, the system that produces it, and a shared working theory of how to improve it; 3) work is disciplined and oriented by the rigor of improvement science, and 4) NICs are coordinated to accelerate the development, testing, and refinement of interventions, their rapid diffusion out into the field, and their effective integration into varied educational contexts. Beyond just identifying problems, NICs leverage the expertise of both researchers and practitioners to engage in activities that purposely arrive at a collective and deep understanding of the problem to be solved [5]. Spreading and scaling improvements in NICs requires several functions that are facilitated by a “hub”. These functions include improvement coaching, network initiation and development, data analytics, innovation design, knowledge management and collaborative technology to support collaborative action as well as spread knowledge, and that the network’s capacity to reach its aim increases over the time of implementation [5].

III. AWSM in CS as a Networked Improvement Community

A. *Guiding Research Questions*

Several research questions guide the work of the AWSM in CS RPP, but this experience report will focus on addressing one question in particular:

What does the backbone organization learn about supporting practitioner change from participating as a hub or convener for the NIC?

This paper addresses some of the initial lessons learned by the backbone organizers from the NIC initiation and launch. We also discuss how these lessons learned will guide our work in sustaining the NIC through virtual meetings during the school year.

B. *Structure of NIC*

AWSM in CS is a three-year project that combines in-person summer institutes with a combination of virtual and in-person meetings during the school year to support and sustain the NIC. AWSM in CS kicked off with a 5-day institute in June 2019.The 5-day summer institute was intended to facilitate teachers’ root cause analysis of the problem, jumpstart planning of individual PDSA cycles, and build lasting relationships among participants. The research team partnered with professional development specialists from the National Center for Women & Information Technology (NCWIT) to provide training specifically focused on supporting female participation in computer science.

Sustaining a NIC consisting of teachers from multiple schools and districts is a significant challenge to a backbone organization. Unlike other professionals, teachers lack the ability to meet with their colleagues from outside of their school during the workday, either in-person or virtually, due to the structure of the school day. This problem is compounded for CS teachers, who are often the only CS teacher in their school (this is the case for 9 of the 11 schools represented in AWSM in CS). As such, it is vital that support during the school year be designed around the realities of the teacher workday. To maintain engagement throughout the school year, we chose to use monthly virtual meetings, conducted after school and facilitated through Zoom, as a vehicle for teachers to share the progress on their PDSAs and receive feedback from peers. NIC participants also committed to attending one in-person meeting each spring and fall.

IV. Lessons Learned in Launching our NIC

Several key themes emerged from the feedback from NIC participants in the summer institute. We believe these themes and the discussion surrounding them would be helpful to anyone planning to start a NIC.

A. Building Authentic Community

In reflecting on the launch of our NIC, the first lesson learned was the importance of building authentic community. The value of community cannot be underestimated when teachers are pushing themselves to learn something new and reflecting on their personal role in systemic inequities in CS. Nearly 80% of the teachers have more than 6 years of teaching experience, but less than 6 years of experience teaching CS. The teachers in our cohort needed the support of others to thrive. Just because you have people in the same space, doesn't mean that you have a community. Each teacher brings something different to the table. The group is diverse in terms of which courses they have taught, what endorsements they hold, and discipline in which they teach. You have to be purposeful in your design to build the types of collegial, trusting, collaborative, and reflective experiences, particularly when teachers are dealing with challenging and sensitive topics.

B. Co-Designing PD

One of the tenets of RPPs is to empower all of the participating partners. Prior to the institute most teachers had limited experience generating or using research (see Table 1). As novice researchers, and with the constraints of teacher work environments, empowering teachers as active partners can be challenging in the initial design phase. In AWSM in CS, this meant giving teachers control over the specific interventions they chose to select for their PDSA cycle, respecting and elevating the experience they bring to the table. This also meant utilizing feedback from teachers each day to modify the next day's agenda in response to their suggestions and needs. This feedback loop and the ability of teachers to customize their own PDSAs based on their personal interests or school contexts, built trust, buy-in and a sense of shared community that is often absent in traditional PD. One participant commented on a post-institute survey "The presenters mingled with teachers and got to know us. Each task we worked on pointed back to what we're doing next school year. Each step built on the previous until we finally had our plans."

C. Data Walk

One of our most popular activities of the summer institute was the data walk. This activity highlighted for us that even though teachers may be interested in a topic of equity, such as the lack of female participation in computer science, they may not be knowledgeable of the related statistics. Teachers' major focus is on their classrooms, with secondary focuses potentially on their schools and districts. In our data walk activity, we hung a variety charts around the room that highlighted different representations of the lack of female participation in CS. Many of the charts were at the regional, state or national level. As teachers walked around in small groups, they were able to simultaneously form a picture of the current state of equity in relation to female CS participation while also having meaningful conversations with their peers about potential causes for the lack of female representation in high school, college, and the workforce that laid the foundation for their root cause analysis. The data walk informed their root cause analysis and helped them to go beyond an exclusive focus on their own personal or anecdotal experiences when considering the root causes of underrepresentation.

TABLE I. EXPERIENCES USING RESEARCH

Since starting work at your school/district, how often have you done the following	**Never**	**Occasionally**	**Often**	**All of the time**	**Count**
Used research to mobilize support for important issues?	26%	44%	22%	9%	23
Used research to get others to agree with a point of view?	22%	65%	4%	9%	23
Selectively used research because it would support a decision?	26%	57%	13%	4%	23
Used research to discredit a policy or program?	52%	48%	0%	0%	23

D. Self-reflection

The systemic inequities in education are often uncomfortable for teachers to address. Examining the role that a teacher's personal actions may play in perpetuating inequities is an even more uncomfortable conversation. AWSM in CS was designed to create a welcoming and safe space to self-reflect. It is an immensely difficult task to assess one's own actions and how they may positively or negatively impact female participation in CS. One participant commented on a post-institute survey "It was a good opportunity to meet with other CS teachers and talk about our classes, which I never get to do. It brought up some things I had been doing poorly, and some things to be aware of." This depth of self-reflection is important to foster during the launch of a NIC, particularly one that focuses on PDSA cycles.

E. Time to Collaborate with Colleagues

Balancing the need to share research and information with teachers along with the time it takes for them to meaningfully process and consider how that research can impact their practice is a difficult task for RPP leaders. We purposefully designed the summer institute so that large chunks of time were devoted to true collaboration, giving teachers time to digest new material and think deeply about how it might impact their practice. NIC participants repeatedly cited this collaboration time as one of the most valuable aspects of the summer institute.

F. Building Trust by Honoring Teachers' Time and Expertise

Asking teachers to participate in a NIC means honoring their time and expertise by including them as co-designers, compensating their participation, and offering a high-quality experience in the project. The summer institute was the first engagement opportunity and the positive experience (see table 2) has laid the foundation for the next two years of the NIC.

TABLE II. TEACHERS' PERCEPTIONS OF THE INSTITUTE

Scale: Strongly agree (5); Agree (4); Neutral(3); Disagree (2); Strongly disagree (1)	Average
The goals of the AWSM in CS project are clear.	4.8
The orientation was supported by effective/appropriate use of technology.	4.8
The content of the orientation was relevant to my responsibilities	4.7
Expectations were thoroughly explained	4.7
The facilitator was knowledgeable and helpful.	4.7
The facilitator was well prepared.	4.7
This professional development opportunity will extend my knowledge, skills, and teaching performance	4.6
The orientation goals and objectives were clearly specified.	4.6
Time was used efficiently and effectively.	4.6
Sufficient time was provided for guided practice and tasks	4.5
The orientation activities were carefully planned and well organized.	4.5
The pre-meeting assignments were appropriate	4.4

V. Considerations for Sustaining our NIC

Intensive, in-person NIC meetings are valuable for laying the foundation for the work but not feasible for multi-district partnerships that must be sustained during the school year. Our challenge is to ensure that the positive aspects of the summer institute are reflected in the support provided during the school year. This support includes virtual monthly meetings along with one day in-person convenings each semester. As we move forward, the following considerations explore the more difficult work of continuing the NIC throughout the school year.

A. Supporting Teacher Agency

A large part of the philosophy of the RPP model is the empowerment of the practitioner. As we move into the school year, teachers are designing their own research-based interventions to test in their classrooms and schools. Our virtual calls include teachers sharing out updates on their PDSA cycles. At the time of this writing, we have had two rounds of calls with a total of six teachers who have shared their updates and gathered feedback from their peers and the project team. The ownership teachers have over their own interventions and iterations is an important part of sustaining the NIC as it moves into the school year. Milestones, such as the share out sessions on calls, allow for us to simultaneously nudge teachers into action while still allowing them ownership over their work. Supporting teacher agency is a core component of ensuring success as we move forward.

B. Continuing Engagement While Respecting Busy Schedules

Participating in a weeklong training during the summer is a lot different from a teacher perspective than engaging in a multi-year project. During the school year, teachers face an increased demand on their time. We have to achieve a delicate balance of respecting the time of teachers, while also putting structures in place that promote continued engagement. On the communication front, we have started a five-bullet weekly newsletter that allows us to both disseminate important information about the program as well as provide addition resources and food for thought for all teachers.

C. Creating Value

Finally, in order to sustain the NIC moving forward, we need to be focused on creating value for those involved. Part of our duty as the hub organization is to provide teachers with the skills and resources they need in order to best accomplish our shared goal of increasing the participation of females in middle and high school CS courses. With this in mind, we use the weekly emails and the monthly calls to connect teachers to relevant resources, such as short videos they can use in the classroom. In planning our first in-person meeting of the school year, we deliberately chose to bring in a guest speaker to address intersectionality, something we did not cover during the summer training but is highly relevant to the work we are doing. Moving forward, we aim to sustain our NIC by continuing to shape it into a valuable activity for those involved.

VI. Conclusion

Intensive NICs have a lot to offer the field of computer science education. The problems of equity in CS education are complex, and addressing them will take a concerted effort from all levels of our education system. Teachers, with their busy schedules and competing priorities, are often given marginalized roles to play in the efforts to enact transformational change. The backbone organization for AWSM in CS has learned valuable lessons about how to effectively initiate and sustain a NIC that both values the expertise of teachers and acknowledges the systemic constraints that educators face.

References

[1] Google Inc., and Gallup Inc. "Diversity Gaps in Computer Science: Exploring the Underrepresentation of Girls, Blacks and Hispanics." 2016.

[2] National Center for Women and Information Technology. "Women and Information Technology: By the Numbers." 2018.

[3] C.L. Fletcher, J. R. Warner, L. S. Garbrecht, and C. Ramsey. "Lessons Learned from Developing a Framework for Evaluating the Impact of Computer Science Teacher Professional Development on Csforall Outcomes." In American Educational Research Association Annual Meeting. New York, NY, 2018.

[4] D.M. Berwick, "The science of improvement" *Jama* 299, no. 10, 2008, 1182-1184.

[5] P.G. LeMahieu, A. Grunow, L. Baker, L.E. Nordstrum, and L.M. Gomez, "Networked improvement communities: The discipline of improvement science meets the power of networks." *Quality Assurance in Education* 25, no. 1, 2017, 5-15

[6] M. Hannan, J.L. Russell, S. Takahashi, and S. Park, "Using improvement science to better support beginning teachers: The case of the building a teaching effectiveness network." *Journal of Teaher Education* 66, no. 5, 2015, 595-508.

[7] C. Lewis. "What is improvement science? Do we need it in education?" *Educational Researcher* 44, no.1, 2015, 54-61

[8] A.S. Bryke, L.M. Gomez, and A. Grunow, "Getting ideas into action: Building networked improvement communities in education." *Frontiers in Sociology of Education*, 2011, 127-162.

[9] J.R. Dolle, L.M. Gomez, J.L. Russell, and A.S. Bryk, "More than a network: Building a professional community for educational improvement." *National Society for the Study of Education Yearbook* 112, no 2, 2013, 443-463.

[10] Code.org Advocacy Coalition, Computer Science Teachers Association, and Expanding Computing Education Pathways. "2019 State of Computer Science Education." 2019

Rural RPPs: Going from The Middle of Nowhere to Getting Somewhere

Shelly Hollis
Center for Cyber Education
Mississippi State University
Starkville, MS
shelly.hollis@rcu.msstate.edu

Marcus Golden
Mathematics, Computer and Information Science Department
Mississippi Valley State University
Itta Bena, MS
marcus.golden@mvsu.edu

***Abstract*— We have an RPP grant, but do we have a Research Practitioner Partnership? We have found ourselves asking that question over the past year as we have struggled to accomplish project goals and objectives. In this paper, we aim to help others learn from our experience the importance of understanding the difference in working with an RPP under construction and an RPP fully formed, share a summary of our story, and offer some advice based on our situation and plans moving forward.**

***Keywords*— RPP, partnerships, barriers, communication, rural**

I. Introduction

Beginning in the fall of 2016, the Mississippi Department of Education (MDE), in partnership with the Mississippi State University (MSU) Research and Curriculum Unit (RCU), launched a computer science content pilot called Computer Science for Mississippi (CS4MS). The call to participate has been extended each succeeding year to every district in the state and has expanded to include computer science (CS) content and courses from kindergarten through high school. These courses and teacher trainings have been offered to districts at no cost and included travel reimbursement and continuing education credits for teachers. Any teacher holding a valid license in Mississippi has been offered the training, and no special CS endorsements have been required. In Figure 1, the districts participating in the CS4MS pilot are marked in blue and non-participating districts in gray. As Figure 1 shows, there is a gap in participation among the schools in the Delta region of the state. Districts in the yellow highlighted area are not only rural, but also serve some of the poorest of Mississippi's population. Our project, ***Collaborative Research: Identifying Participation Barriers to Computer Science Education in Rural Mississippi***, focuses on this area. The major goal of this project is to form a research practitioner partnership (RPP) which investigates issues and perceptions that may exist as barriers to CS education. However, simply pulling together a team of practitioners does not automatically form an RPP.

II. Problems of (Our) Practices

A. Team Selection Errors

The first stated goal of the project is to form an RPP. Our method to accomplish this was to ask each district contact to strategically select participants from various roles (administrator, counselor, teacher) in order to give us a diversity of voices on the team. We knew we would need to provide some information as to why CS was important, why we were forming this group, what we hoped to accomplish, and how we wanted to work together. As researchers, sitting around the table at the university planning our first meeting agenda, we thought we had the perfect plan to, in just 4 hours, educate and excite this group of people to champion our ideas back in their own districts.

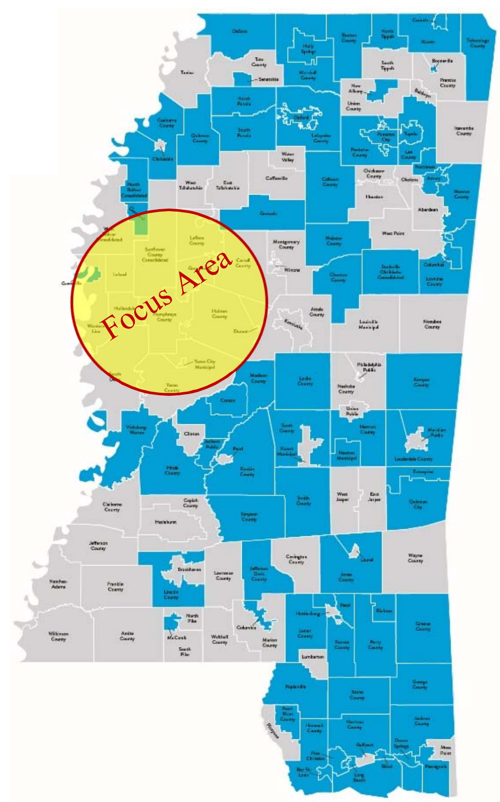


Fig. 1: Map of CS4MS Pilot Districts

B. Project Recruitment Errors

To illustrate where this began to go wrong, we need to share our strategy for getting districts to agree to participate in the project initially. We sent emails to the superintendents with the

This work was supported by the National Science foundation under Grant #1837407.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

subject line "Mississippi State University Grant Partnership." We explained in the email that we would like to partner with the districts under a National Science Foundation funding opportunity to investigate the barriers to CS education in their geographic area. When we got no response to emails, we followed up with phone calls. When we finally got through to someone it was often not the superintendent, but someone willing to listen and present the project to the superintendent on our behalf. We believe what was communicated or heard was "National Science Foundation," "funding," "free local professional development" and "free activities for students." This was sufficient to gain the coveted signed letter of commitment for proposal submission, and we blissfully proceeded under the impression that the superintendent had been properly briefed, would remember our important project between submission and actual funding time, and would gather the best people in the district to participate on our team.

C. *Team Communication Errors*

What follows is the reality we faced. When we received news that we had been awarded the project, we began to reach out to districts to identify RPP team members. We had to explain the project again because no one recalled the initial conversations; then, we had to repeatedly follow up (almost to the point of harassment) to get the names and email addresses of the district-selected individuals. When we began contacting the individuals, we found many of them had no idea about the project. Their name had simply been submitted by their administrator and no information had been given to them.

We also quickly found out that districts were not eager to allow people to leave campus for an entire day four times during the year to participate in this project. Therefore, we scaled back our face-to-face meeting requirements to two ½ day meetings with online meetings scheduled in between. We set the date for our first face-to-face meeting and began excitedly preparing binders for each participant containing a copy of the winning proposal, documents explaining the concept of an RPP, and blank calendar pages for next two years.

D. *Team Meeting Errors*

The November afternoon of our first RPP meeting arrived and our participants entered the room immediately eyeing the cookie tray and coffee table while flipping through the three-inch binder with deer-in-headlights looks. After introductions, we jumped right in, asking them to share their perceptions of CS while we made posters on the wall with their thoughts. We eagerly walked them through a "Purpose to Practice" activity[1] complete with colorful worksheet as a team-building exercise, feeling quite proud that we fit (forced) this RPP-building tool into our packed agenda. We took a short break and then started talking about the many activities we would need to conduct in their districts to begin exploring the initial research questions around barriers.

This is where the first hints of "we do not have the right people in the room" began to surface. First, we realized based on the sign-in sheet that while the districts selected participants in various roles, the actual attendees turned out to be primarily classroom teachers. Second, participants did not feel qualified or at liberty to plan or schedule events outside their immediate area of responsibility. For example, we talked about conducting a survey of all 4th graders in a district; however, there were no district-level representatives present, and the school-level participants were high school teachers who felt they did not have connections to the elementary school and were not sure how to make that happen.

Another similar issue arose when we talked about focus groups in a specific school which had no representation on the team. Even though there was a district-level person present, they did not feel at liberty to approve that activity or seem to know how to contact the school principal to get permission and discuss dates. We left that day feeling like the people present were interested in what they learned, voiced understanding and agreement with the need for CS education but were not exactly sure how they could really help.

We held a follow-up online meeting in January with the purpose of reviewing the IRB requirements of working with students through surveys and focus groups in preparation for getting those activities scheduled. Due to the very low attendance, five people out of 32, we resorted to individual calls with schools in each district, explaining the process multiple times, and never actually talking to the teacher who would facilitate the distribution and collection of permission forms and administer the online survey. We held our second face-to-face meeting in February with thirteen, less than half, in attendance and no representative at all from one entire district. Again, we struggled with having the right people in the room with the authority and/or knowledge of how to get permission to conduct activities in schools other than their own.

Ultimately, we were only able to survey 144 students (out of approximately 6,000 planned) across five districts; conduct focus groups with administrators, counselors, teachers, students, and parents in four districts; and provide coding activities in three schools within only one district.

III. What Have We Learned?

A. *Form the team based on the actions/outcomes needed.*

Ultimately, the biggest lesson we have learned is that we did not begin the project with an RPP. We began with a group of people who were pulled together based on inadequate information, "voluntold" participation, and no shared interests in the project goals. The blame for this falls squarely on us as the project initiators and our own lack of understanding of what an RPP really is and how it functions. Penuel and Gallagher explain in their book titled *Creating Research-Practice Partnerships in Education* that what we developed in the beginning was "researchers seeking schools and districts as sites for studies" [1]. Our research goals were driving the arrangement. We came in with a thorough background and understanding of why this project was needed, along with a set of activities planned to gather the data we needed. Our practitioners came in with little to no understanding of the project, its background, or what was expected of them.

---

1 http://www.liberatingstructures.com/33-purpose-to-practice-p2p/

When we were first considering who should be a part of our RPP (what roles within a district we wanted represented), we thought about it from the standpoint of getting different viewpoints on the research questions proposed in our project description. We were thinking of the RPP as a participant in the research, not as a partner. We needed to ask what roles within a district could best help with the work of the project and not who could inform the work. We needed practitioners who could schedule and facilitate the necessary activities within the district that would help us gather data to answer our research questions.

If you are going to ask the school district to select team members, be precise about whom they should select for the project by providing a list of expectations for team members; explain what type of activities they will need to facilitate within the district and what level of authority they need to have to adequately contribute to the team. Question district selections that appear to be the convenient choice rather than the best choice; selections should be made based on the individual's authority, ability, and interest in doing the work.

B. *Understand where you are in team/RPP development.*

We would have yielded better outcomes in year one if we had not tried to force the working concepts of an RPP on our newly formed group. If we had simply thought of the initial team as a taskforce, we could have accomplished more activities and collected additional data to start year two. Instead, we are starting over and building a new team to complete the activities of this final year. We will move forward, clearly defining what each participant is expected to do to help gather the needed data through the planned activities. Afterwards, we will ask them to assist us in analyzing the data to identify barriers and understand perceptions of CS education. This active participation in data gathering and analysis will help lead the group in developing solutions and activities to address what the data reveals, better positioning each team to begin CS education implementation planning for their districts.

C. *Invest in the time up front to educate and prepare potential partners.*

If you start your project by asking for a list of names, realize you probably do not have an RPP yet, but you are building champions from the ground up. Spend time cultivating them.

As we reflect on year one, what we needed was more time spent on building relationships up front. A fully functioning RPP takes *time*: time to build, time to develop trust, time to accomplish work, time to produce results. It is difficult to build trusting, mutualistic relationships in two four-hour meetings among people who, on a daily basis, have a different set of responsibilities.

As we begin year two, we are traveling to each district to meet with the superintendent or highest district-level contact possible to explain the project and its background, discuss what activities are required to gather the appropriate data, ask who would be the best people in the district to help accomplish those goals, and then be at liberty to begin developing a CS implementation plan. We are working to create a CS champion at the top within each district. These face-to-face meetings at the beginning (even before funding, if possible) are critical to the efficiency, health, and success of the project.

Because the team representing each district is comprised of participants from different roles and physical locations, we are also working individually with each district team this year to help them build a sense of community, be aware of their role within the team, and understand the purpose of the project as it relates specifically to their school or district. We realized during year one that we actually have teams within the team (or mini-RPPs at each district) and believe that it is important for those smaller groups to feel connected in order to accomplish the tasks of the project and allow them to better represent their district within the larger, five-group RPP. Ultimately, this will help create a stronger RPP to address future issues around CS education in that area of our state.

IV. New Strategies

As we have shared these struggles with others in the CS education space, someone recommended we frame the problems by considering the assessment indicators given in *Assessing Research-Practice Partnerships: Five Dimensions of Effectiveness* [2] by Hendrick and others. As stated in their work, these five dimensions are:

- Dimension One: Building trust and cultivating partnership relationships.
- Dimension Two: Conducting rigorous research to inform action.
- Dimension Three: Supporting the partner practice organization in achieving its goals.
- Dimension Four: Producing knowledge that can inform educational improvement efforts more broadly.
- Dimension Five: Building the capacity of participating researchers, practitioners, practice organizations, and research organizations to engage in partnership work.

A. *Dimension One.*

While it continues to be challenging to develop strong interpersonal relationships with colleagues several hours away and with whom we only interact around the work of this project, we have seen progress in Dimension One through meeting with each district individually both face-to-face and through online sessions. These meetings have helped us to connect with the practitioners in a more personal and relative way, as we learn about the numerous other responsibilities placed on them and limitations they face within their working environment. We have been able to express an understanding of their enormous workload while communicating the importance their knowledge and participation has in the success of this project. This has increased the participants' sense of commitment to the work and led to their feeling more valued and appreciated in their efforts to add to their heavy workload.

B. *Dimensions Two.*

As this small-strand project is primarily a time of building relationships and understanding problems of practice, we have not done much in the way of rigorous research as referenced in

Dimension Two. Our primary research efforts have centered around conducting online surveys and in-person focus groups with various district populations, including students, administrators, counselors, teachers, and parents. The RPP members have been an integral part in getting these data collection activities set up. They have become more involved in the process as they have had to complete online training to safely work with human subjects as required by our Institutional Review Board. Based on feedback from the RPP, we have adjusted our data collection methods across the five participating districts so that we can at least identify responses by district. This way each district can have a better understanding of barriers specific to their area while also understanding where they are in the larger study population.

C. *Dimension Three and Four.*

These meetings have also helped with Dimensions Three and Four, as we have gained a better understanding of each district's goals for general educational improvement and for increasing CS education specifically. We have been able to create a more customized picture of how CS education can help each individual district meet their overall educational goals, which generally gets them more excited about potential outcomes and more committed to the process and activities.

D. *Dimension Five.*

As we continue to work together on this project and plan for a larger study, we will see an increased capacity for all RPP members to engage in partnership work, as described in Dimension Five. As researchers, we are already seeing the need to view the districts as partners to investigate with and not simply as locations to study. We are seeing the practitioners recognize that we can assist them in understanding more about their students and problems of practice by working together and that the evidence produced through this work can inform and influence the district's educational goals.

V. Conclusion

As we move into year two of our project, we continue to seek answers to research questions surrounding barriers to CS education in rural Mississippi, but we now understand that we are building an RPP prepared to implement solutions to overcome those barriers and to anticipate future problems of practice that impact broadening participation. We plan to work with this group to write a medium-sized NSF CS4All proposal to submit in the spring. Through the data gathered during this current project, we believe we can develop shared goals, respecting the priorities of each district and making a long-term commitment to work together to identify problems of practice around the implementation of CS education in a way that overcomes the identified barriers, causing a shift in perceptions of CS.

Acknowledgment

Key collaborators in this work include Melissa Luckett, Heather McCormick, and Heather Craig.

References

[1] W. Penuel, D. Gallagher, "Creating research-practice partnerships in education" Massachusetts: Harvard Education Press, 2017.

[2] E. Henrick, P. Cobb, W. Penuel, K. Jackson, and T. Clark, "Assessing research-practice partnerships: five dimensions of effectivemenss," New York: William T. Grant Foundation, 2017.

PANELS

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Portland, Oregon & Online Virtual Conference
March 11, 2020

Role of Academia to Create Re-entry Pathways in Computing

Elodie Billionniere (Moderator)
School of Eng. & Tech.
Miami Dade College
Miami, FL, USA
ebillion@mdc.edu

Farzana Rahman
Department of EECS
Syracuse University
Syracuse, NY, USA
fraham02@syr.edu

Quincy Brown
Innovation & Strategy
AnitaB.org
Upper Malboro, MD, USA
quincybrown@gmail.com

Hyunjin Seo
Center for Digital Inclusion
University of Kansas
Lawrence, KS, USA
hseo@ku.edu

***Abstract*— Although most higher education institutions cater their programs to traditional college students, high school graduates or those in their early 20s, the adult-student population makes up most degree-seekers in the United States (U.S.). Adult-student population, known as non-traditional students, includes students who are returning to postsecondary institutions after dropping out, working adults, formerly incarcerated individuals as well as professionals who want to turn life experience into college credit. With the influx of non-traditional students, higher education institutions must rethink and put in place strategies to better support these students. With this in mind, recruitment of non-traditional students in computing related fields is of great interest to increase the number of graduates to meet the future of the workforce needs in particular in the emerging technology (EmTech) fields. Therefore, we propose a panel to discuss opportunities for re-entry computing education and career paths. The panel of experts will share their respective re-entry programs to spark conversations and reflect on their work-in-progress. The objective of the panel is to share experiences, lessons learned, and ideas to create and promote initiatives to support structures for re-entry to the computing education and professional pipeline.**

***Keywords*— computing education; non-traditional students, formal and informal learning; academic degree; emerging technology**

I. Summary

While significant efforts have been made in recruitment, retention, and graduation of traditional students, particularly underrepresented minority groups, in computing related fields there is a fast-growing interest to bring non-traditional students into the computing pipeline through both formal and informal learning settings due to the rise of the non-traditional student demographic at colleges and universities across the U.S. According to the National Center for Education Statistics, enrollment in degree-granting colleges of students ages 25 to 34 years old increased by 35% between 2001 and 2015. The enrollment is projected to increase by 11% between 2015 and 2026 [1].

With the computing job industry projected to grow much faster than other industries over the next 10 years [2], some niches within the field, such as machine learning, data science, cybersecurity, mobile computing, AI/ML and etc., are expected to grow job opportunities more quickly than others. The demands for computing jobs throughout the nation can only be fulfilled by creating opportunities for the largest untapped talent pool, which is returning learners, meaning individuals who had a career break or wants a career switch to make their way back to workforce. In addition, formerly incarcerated individuals are part of the untapped talent pool too. By exposing them to in-demand computer science (CS) skills in the area of emerging technology (EmTech), former prisoners will have a better opportunity to transition into the workforce with high wage positions and as such the less likely they will return to crime [3]. Hence, it is timely, and perhaps imperative to build the capacity of returning learners by enabling them to (re-)enter the computing related academic degrees, so they can fill the void of next generation computing jobs. However, academia has very strict decorum which offers little to no access to diverse pathways for returning learners to re-enter the computing related academic programs. Even though there has been an increase in the number of informal learning pathways to enter into computing fields, there is no solid evidence and understanding of how such informal learning paths facilitate adult learners to learn CS skills that enable them to rewrite their career paths [4].

To facilitate greater discussion on this critical, yet timely topic, we propose a panel with a goal to brainstorm and discuss best practices about – a) what do academic institutions lack to facilitate an easier transition of returning students, who may not have any relevant background, into computing/CS academic programs, b) what can be done by academic organizations to develop academic programs targeting non-traditional learners, c) what are the limitations of current computing/CS curricula for returning students to get into (or even enroll in classes with a focus on) EmTech topics, d) how do learners returning from career break interested in computing/CS, fit within today's and tomorrow's workforce consisting of many EmTech specialties, and e) what can academia, specific to computing/CS disciplines, do to create more inclusive environment and pathways for learners who are interested in returning to computing/CS related educational pipeline.

II. Position Statements

A. *Elodie Billionniere (Moderator)*

As an Associate Professor at Miami Dade College, I lead efforts to raise cloud literacy in Miami-Dade County with a NSF ATE project Dade Enterprise Cloud Computing Initiative (DECCI) in partnership with Amazon Web Services. DECCI provides students with project-based learning opportunities and access to leading AWS technology, giving them a competitive advantage by strengthening academic offerings that lead to not only an academic credential, but also an industry certification to meet the workforce demand. Our Cloud Computing Center hosts all the cloud computing classes, summer bootcamps, accelerated training, workshops, and conferences.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

B. Quincy Brown

As the Senior Director of Innovation Research at AnitaB.org., I lead efforts to support entrepreneurs and founders as well as research and evaluation activities. I was previously a Program Director for STEM Education Research at the American Association for the Advancement of Science and a Senior Policy Advisor in the White House Office of Science and Technology Policy. I am a co-founder of blackcomputeHER.org, which provides introductory data science skills and professional development opportunities to black women in technology.

C. Farzana Rahman

As an Associate Professor, I had developed and taught various courses mobile development, secure mobile computing, and mobile healthcare. I am the founder of BWCSE, the first platform, aiming to elevate the status of Bangladeshi women in computing research and education. The impact of this platform includes over 10 thousand female computing students using the platform and resources to advance their career to diversify the pipeline of computer science professionals. I directed a "tiered mentoring program" and an REU with the help of multiple industry grants to diversify the face of mobile development community

D. Hyunjin Seo

As an Associate Professor and Docking Faculty Scholar in the School of Journalism and Mass Communications at the University of Kansas, I serve as the founding director of the KU Center for Digital Inclusion. Currently, I am leading a National Science Foundation-funded program offering evidence-based technology education to women who were formerly incarcerated and are now restarting their lives outside the criminal justice system. Through this three-year project, my team is developing curriculum and online modules to broaden technology education to this and other underserved populations who are re-entering the tech workforce and education pipeline.

III. Panel Structure

The moderator, Dr. Elodie Billionniere will provide the panel background and motivation and introduce the panelists. Each panelist will be given 10 minutes to present their respective positions. Dr. Farzana Rahman will share her expertise in designing and delivering effective strategies for re-entry into computing academic degrees through mobile computing related courses, bootcamps and informal learning paths. Dr. Quincy Brown will share the curriculum and insights about BlackcomputeHER Data Science Executives program re-entry of professional Black women. Dr. Hyunjin Seo will share her experience in developing and facilitating evidence-based technology education, in formal and informal settings, to formerly incarcerated individuals and are now restarting their lives outside the criminal justice system. Following the presentation, the moderator will facilitate audience discussion in small groups to brainstorm and identify a collective solution to various questions related to the challenges and lessons learned with the implementation of re-entry programs targeting non-traditional students in computing discipline. Compilation of the group discussion documents with the list of the top three challenges/strategies will be identified for each question and the floor will be open for further discussion as a whole group. We will create a mailing list consisting of interested panel participants to stay connected after the conference and to share the panel summary with discussion points.

Through this panel, we aim to reach a broader audience who is interested in advancing the current state of knowledge and understanding on what will support non-traditional learners to reenter computing discipline. Hence, upon completion of this panel, the attendees will have access to a networking community of educators and industry professionals whose expertise is to:

- identify what academia lacked before, what it lacks now and what can be done by academic organizations to develop academic programs targeting non-majors and non-traditional students.
- identify limitation of computing and/or CS curricula to have a concentration in (or even enroll in classes with a focus on) emerging technology such as cybersecurity, data science, cloud computing and etc.
- explore and identify barriers and challenges for re-entry computing and/or CS discipline.
- identify strategies used currently to reenter the educational pipeline of computing and/or CS discipline.
- discuss interest-based learning approaches for adults who lack prior experience in computing and/or CS discipline.
- list out existing programs, 2 year to 4-year transitional programs, informal learning settings and skill building opportunities for computing and CS discipline.
- facilitate greater dissemination and exchange of expertise, which can generate effective and innovative pathways for re-entry in computing and/or CS disciplines.

References

[1] W. J. Hussar and T. M. Bailey, "Projections of Education Statistics to 2026," U.S. Department of Education, Apr. 2018. [Online]. Available: https://nces.ed.gov/pubs2018/2018019.pdf.

[2] S. Fayer, A. Lacey, and A. Watson, "STEM occupations: past, present, and future," U.S. Bureau of Labor Statistics, Jan. 2017. [Online]. Available: https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf.

[3] M. Pogrebin, M. West-Smith, A. Walker, and N. P. Unnithan, "Employment isn't Enough: Financial Obstacles Experienced by Ex-prisoners During the Reentry Process," *Criminal Justice Review*, vol. 39, no. 4, pp. 394-410, 2014, doi: 10.1177/0734016814540303.

[4] L. A. Lyon and J. Denner, "Informal Learning in Computer Science: Social and Conceptual Factors Related to Women's Persistence," informalscience.org. https://www.informalscience.org/informal-learning-computer-science-social-and-conceptual-factors-related-womens-persistence (accessed Feb. 14, 2020).

Broadening Participation: The Community College as a Key Partner

Amardeep Kahlon
Austin Community College
Austin, TX USA
akahlon@austincc.edu

Deborah Boisvert
University of Massachusetts Boston
Boston, MA USA
deborah.boisvert@umb.edu

Lori Postner
Nassau Community College
Long Island, NY USA
lori.postner@ncc.edu

***Abstract*—There is a looming shortage of computing professionals in the United States and globally. The shortage of women and minorities further exacerbates this shortage. Community colleges are inherently diverse spaces and can play a significant role in broadening participation in computing (BPC) as well as in adding more graduates to the field. This panel will discuss strategies to include community colleges as a key partner in the conversation on broadening participation. In addition to the broader efforts, the panelists will discuss BPC efforts at their institutions.**

Keywords—broadening participation in computing, women in tech, minorities in tech, community college

I. THE PROBLEM AND THE SOLUTION

Data from the National Center for Women & Information Technology (NCWIT) show that by the year 2026, the number of computing related job openings in the US are expected to be 3.5 million. Yet, only 19% of these jobs will be filled by students graduating with a bachelor's degree—leaving a large gap. The computer science & information technology job sector is growing fast yet institutions of higher education have been unable to produce enough graduates to meet this growing demand. The lack of women and other underrepresented minorities reduces an already diminished workforce much further.

Institutions of higher education—both universities and community colleges—can work to bridge the diversity and workforce gap through collaborative efforts. In this panel, the panelists will discuss include strategies to build a more diverse student body and resources to attract more women to computer science/information technology at community colleges while building pathways to the university. The panelists will discuss resources—at the local and national level— that can be utilized by institutions of higher education, in particular community colleges, while designing and developing curriculum, spaces, and activities to draw more minorities and women into the field.

Most importantly, the panelists will discuss the key role of community colleges in the BPC conversation, including the outcomes from a workshop held at Google in January 2018— the Authentic Inclusion of Community Colleges in Broadening Participation in Computing workshop.

II. PANELISTS

AMARDEEP KAHLON (MODERATOR) is a Professor of Computer Science and director of Fast Track to Success at Austin Community College. She firmly believes that community colleges can play a key role in broadening participation in computing. Compared to a four-year school, the community college population is very diverse, not just in ethnicity, race, age, and gender but also in levels of educational attainment. It is imperative for community colleges and four-year schools to work together to remove the barriers to transfers thereby increasing the diversity and the numbers of CS/IT graduates. Her work at the community college includes directing a successful Women in IT program and articulation pathways and share will share the lessons learned from these experiences.

DEBORAH BOISVERT, Executive Director of BATEC Center for Computing at UMass Boston, is dedicated to broadening participation in computing through professional development for educators, problem-based learning for students, and strategic planning for education, industry, and government. She serves on the Steering Committee for CSforMA, a coalition of education (PK-12 and Post-Secondary), business, industry, government, and community leaders dedicated to ensuring that ALL K-12 students in Massachusetts receive high-quality instruction in computer science in every grade level from Kindergarten through 12th grade. She believes that a holistic system of problem-based coursework and multiple touchpoints in an upward trajectory must interweave awareness, preparation and advancement throughout the academic and work-based learning components to increase the success of minority students. This belief has accentuated the need for community colleges as an integral part of the Broadening the Participation conversation.

LORI POSTNER is Professor of Computer Science at Nassau Community College, a part of the State University of New York (SUNY). As an attendee at the NSF workshop held at Google, as well as a participant in the Lighthouse for CS online course for community college faculty, she has become passionate about ways to broaden participation in computing through community college involvement. She is the Co-PI on an NSF grant focused on incorporating HFOSS (humanitarian free and open source software) into the computing curriculum. By using the lens of computing for social good, she hopes to attract students from traditionally under-represented populations. As a community college professor, she has a diverse population of students and sees the opportunity to change the landscape of who enters and persists in computing. She is also acutely aware of the challenges that community college students face completing their degrees and transferring to 4-year programs.

III. REFERENCES

[1] J. Juszkiewicz , “Trends in Community College Enrollment and Completion Data”, Washington, DC: American Association of Community Colleges, November 2017.

[2] C. Calhoun, D. Boisvert, J. Denner, W. DuBow, A. Kahlon, L. Lyon, M. Williamson “The authentic inclusion of community colleges in broadening participation in computing: A workshop report” Gainesville, FL: Santa Fe College. December 2018.

LIGHTNING TALKS

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Portland, Oregon & Online Virtual Conference
March 11, 2020

The MSCS New Pathways Consortium – a National Invitation

Carla Brodley
Khoury College of Computer Sciences
Northeastern University
Boston, MA, USA
c.brodley@northeastern.edu

Jan Cuny
Khoury College of Computer Sciences
Northeastern University
Seattle, WA, USA
j.cuny@northeastern.edu

Abstract— **High tech is the U.S. economy's fastest growing sector. Yet, the current tech talent pipeline falls far short of meeting demand. What's more, the demographics of the tech workforce remain stubbornly out of sync with the overall population. This is in large part because our education system still struggles to attract diverse people into computational disciplines. Women represent more than 50% of Bachelor's degree recipients, but only 19% of computer science (CS) graduates. Similarly, underrepresented minorities represent 25% of Bachelor's degree recipients, but just 10% of CS graduates. The diversity of thought, race, background, and gender in CS is essential to building a robust, high quality, and ethical tech sector.**

One place where innovation might bridge the gap – a place historically overlooked by higher education – is the Master's degree. Since 2013, Northeastern University's Khoury College of Computer Sciences has been testing, refining, and growing the Align program, a Master's of Science in computer science (MSCS) for people who studied something *other* than CS as undergraduates.

The goal is to create a new pathway or onramp to CS for all students, paying particular attention to the recruitment and success of women and underrepresented minorities. In mid-2019, we launched the MSCS New Pathways Consortium – an effort to collaborate with colleges and universities across the country to scale this approach. Here, we invite others to join the Consortium and, together, make the MSCS the new MBA, a professional degree that people can access regardless of prior experience and knowledge of computing.

Keywords—Computer science education; diversity; non-majors

I. Northeastern's Align Program

Align [1] is novel in several ways

1. Students start the program with an intensive two-semester bridge. The bridge brings students from any discipline up to speed, preparing them to take to take Master's level CS courses right along with students who were CS majors as undergraduates. (Students who are concerned with the depth or recency of their Math backgrounds can opt for a two-week Math Prep seminar before their first semester.)

2. Students also have the opportunity to enhance their degree work with experiential learning in the form of an internship or co-op, usually after the second of the three semesters in the MS program. A great learning opportunity, it also provides them with proof of their newfound skills for their resume.

3. The Align staff provides specialized marketing and recruiting that reaches prospective students who represent a diversity of background, socioeconomics, race, ethnicity and gender. They also provide all students with an inclusive environment and a range of academic support and career advising that ensures their success.

From a start in Seattle with just 11 students in 2013, the program has grown quickly. It is now offered at four sites in the Northeastern University Network: Boston, Seattle, Silicon Valley, and San Francisco; three additional sites, in Vancouver, Toronto and Portland, ME will open in academic year 2020-2021. As of this semester, 1016 students are enrolled and 195 have graduated. The students have come from more than 100 different undergraduate disciplines, ranging from history and biology, to fine arts. Of the currently enrolled population: 48% identify as women, and of the domestic students, 21% are from the groups traditionally underrepresented in CS. The Align program is now experimenting with ways to incorporate research experiences along with possible program modifications to support students who may want continue on to a Ph.D. program.

We began this work with the premise is that CS skills are essential to our economy – today *every* company is a tech company – and that the MSCS degree should be made accessible to graduates from any discipline, much like the MBA or JD. The MSCS degree, however, won't achieve MBA or JD-like status through the efforts of Northeastern alone. A much larger community is needed.

II. The MSCSNew Pathways Consortium

To begin building that larger community, Northeastern has joined with four other institutions – Columbia University, the Georgia Institute of Technology, the University of Illinois Urbana Champaign, and the University of North Texas – to form the MSCS New Pathways Consortium. The Consortium

978-7281-7172-2/20/$31.00 © 2020 IEEE

is an open-source, collaborative, and precompetitive effort to establish accessible onramps to MSCS degrees for a broad range of individuals across the United States.

Members of the consortium may have very different implementations of their MSCS programs but they share the common goal of making their programs broadly accessible and they share a common set of values and practices:

> **On-ramp.** We will design Master's programs that have on-ramps that meet individuals where they are at and then catch them up such that they can enter the traditional direct-entry MS in CS programs and ultimately be competitive in the marketplace.
>
> **Diverse**. We employ outreach and recruitment strategies in pursuit of a student body with demographics that match those of the overall United States undergraduate population - 85% domestic, 50% women, 25% underrepresented minorities.
>
> **Pedagogical**. We will recruit faculty who are motivated by a diverse audience, do not ascribe to a "geek gene," and are interested in building a more inclusive tech talent pipeline.
>
> **Co-curricular support**. We will complement dedicated faculty with student advisors who work closely with students and who support them in particular during the on-ramp.
>
> **Transparency.** On a regular basis, we will share with one another – in a format that is comfortable and appropriate for each institution – information regarding enrollment, demographics, student performance, etc. And, where possible, we will collaborate to share our learnings more broadly, for example speaking at conferences and writing articles.

The Consortium will be structured much like a Networked Improvement Community (NIC) as promoted by the Carnegie Foundation for the Advancement of Teaching [2]. That is, Consortium members share a common goal with specific, measurable outcomes, and they collaborate to develop best practices in achieving that goal, aiming not just to understand "whether some practice works," but to understand "how to make it work reliably and across a range of universities and colleges." We expect that the Consortium will be a source of innovation, providing social connections to accelerate testing and understanding new approaches to recruitment, curriculum, teaching, and student support services across different academic environments. This will allow institutions to choose among innovations and best practices wisely, adapt them appropriately for their local environment, and identify where innovation is needed. It is our hope that these joint efforts will speed the development and deployment of additional MSCS programs across the country.

III. THE INVITATION

We invite and encourage other universities and colleges to join the MSCS New Pathways Consortium and, together, be a part of building a dynamic and collaborative consortium of colleges and universities across the country that will make the MSCS like the new MBA – accessible to all.

ACKNOWLEDGMENTS

We wish to acknowledge Aidan Connell and Catherine Gill, both at Northeastern University, who contributed significantly to the design and implementation of Align and the development of the Consortium. We also wish to acknowledge Pivotal Ventures, Facebook and Google for their partnership in building the Consortium.

[1] C. Brodley et al., "An MS in CS for non-CS majors: moving to increase diversity of thought and demographics in CS," Proceedings SIGCSE '20, in press.
[2] A. S. Bryk, L. M. Gomez, A. Grunow, and P.G. LeMahieu, Learning to Improve: How America's Schools Can Get Better at Getting Better, Cambridge, MA: Harvard Education Press, 2015.

Shall We Play a Game? : Building Capture the Flag Games for Non-Traditional Players

Ann-Marie Horcher, Ph. D.
Central Michigan University
horcheram@gmail.com

***Abstract*—Capture the Flag contests are a common way to develop and exercise cybersecurity skills. One of the ways to reach underrepresented groups, such as women and minorities, is provide learning options that reduce cultural bias. This research used a game framework designed for the participants to build a series of Capture the Flag challenges together and create an original Capture the Flag competition for their peers at a university or conference to play.**

Keywords— CTF, cybersecurity, adaptive gamification, design

I. Introduction

Gamification, or using game-type elements in non-gaming contexts, has the potential to improve user experience and engagement [1]. Electronic versions of Capture the Flag (CTF) contests have been adopted as a popular gaming model in the cybersecurity community and cybersecurity education. The games are used to develope and exercise cybersecurity skills and recruit [2]. These contests generally have themes and test different capabilities in teams or for single competitors. Like the rest of cybersecurity, CTF contests typically attract fewer underrepresented minorities [3]. The games reflect the interests of the designers, who are usually established cybersecurity professionals rather than underrepresented minorities [4]

Women and underrepresented minorities have not been attracted to cybersecurity programs and computer science in general, resulting in a lack of diversity in the potential workforce [5]. One of the ways to reach underrepresented groups, such as women and minorities, is provide learning options that reduce cultural bias [6]. Cybersecurity education researchers Codish and Ravid advocated for adaptive game framework that allows a game to be tailored to users of the game [7]. A tailored game has greater potential for greater enjoyment and engagement, which is key both in cybersecurity education and recruitment [8]. However, games in general reflect the gendered bias of the designers in the portrayal of characters, and in the style of activities [9]. Putting underrepresented minorities in the designer's role has resulted in designs that are more inclusive for all [10].

This research used a game framework designed for the participants to build an original Capture the Flag game for their peers at a university or conference to play. The platform not only captures the competitor's performance, but also gives the creators feedback on which challenges are most popular and effective.

Experiential learning theory provides students with a four step process that moves from concrete learning experience to contemplation and conceptualization, and finishes with active experimentation [11]. Using a stable technology platform to deliver the game content, this research frees the participants' creativity to devise the challenges from story and visual perspectives. Finally by taking on the "creating" role in Bloom's taxonomy the participants achieve the highest level learning that has the greatest longevity [12].

.

II. Background

The research of gamification in many disciplines including Science, Technology, Engineering and Math (STEM) has resulted has resulted in the recognition of the need for adaptive gaming to achieve the greatest efficacy [13]. While games cannot be one size fits all [1], there are design principles that can be applied to improve engagement [14]. Furthermore though the popularity of gamification is growing, resources to support the game delivery are scarce, and open source is a key option to support such sharing [1]. To achieve the high level of user acceptance and learning, the learning must be like playing [15]. Even outside the academic setting, user evaluation shows game-based learning models have a high level of acceptance if enjoyment is adopted as a design principle. [16].

III. Theory

This research used design science research (DSR) approach, which is research into or about design using design as a research method or technique [17]. It can be an iterative process, as information from an evaluation influences the design of another element [18]. In this research an artifact consisting of a mobile application with an administrative interface was created used to deliver the game content.

Choosing the design science approach is common in gamification research [19]. The artifact created to instantiate the research content provides a user interface to experience the game, and an instrument to directly collect data about the experience [20]. For adaptive gaming the iterative approach of DSR based on the evaluation of the collected data mirrors the adaptive nature of the framework.

IV. Procedure

The participants agree on a theme for their CTF game. The participants then form teams of 2-3 people and choose a cybersecurity challenge to deliver. A list of common cybersecurity challenges tested in CTF games was provided including the following: encryption, SQL injection, Python,

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

UNIX statements, etc. The teams chose from the list or create their own. The teams then choose a character related to the theme of the game who will provide backstory for their challenge. A challenge has a "flag" associated with it that can be an answer to question, entry of a string of characters, or the correct identification of an image. The teams also find free-for-use graphics or create original graphics to identify their character and enhance the visuals of the game. The game platform is built on the Google Firebase Platform. The Firebase platform supplies an area to store files, a database component, and an authentication component. The game content is a series of entries in a database, with Angular JS (JavaScript) screens. A sample version of the game can be seen in Figure 1, in this case a superhero theme. At the end of the game the competitors are invited to give feedback only for the challenges they completed. (Figure 1)

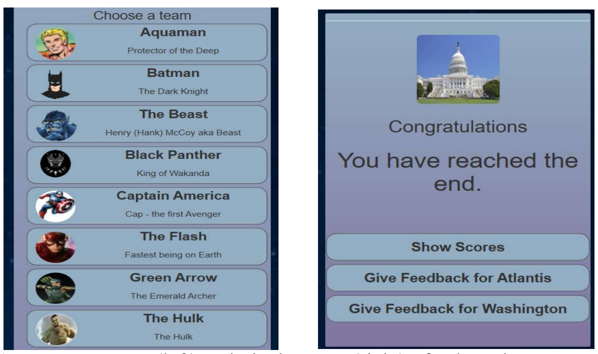


Fig 1: Home Screeen (left) and Final Screen (right) of Adapted CTF game

After the game is constructed, a link to the content is created and can be distributed to invite more participation. At the end of an agreed upon time-period, scores are calculated and winners announced. Game designers also can receive recognition based on how the challenge was perceived.

V. Discussion and Future Directions

The first iteration of the adaptive game framework revealed some things to be addressed. The selection of challenges adjusted so that all the challenges are at least attempted. To further the enjoyment of the games, scores and a leaderboard need to be more prominent [21].

References

[1] S. Deterding, M. Sicart, L. Nacke, K. O'Hara, and D. Dixon, "Gamification. using game-design elements in non-gaming contexts," presented at the CHI '11 Extended Abstracts on Human Factors in Computing Systems, Vancouver, BC, Canada, 2011.

[2] L. McDaniel, E. Talvi, and B. Hay, "Capture the Flag as Cyber Security Introduction," in *2016 49th Hawaii International Conference on System Sciences (HICSS)*, 2016, pp. 5479-5486.

[3] A. Pattanayak, D. M. Best, D. Sanner, and J. Smith, "Advancing cybersecurity education: pink elephant unicorn," presented at the Proceedings of the Fifth Cybersecurity Symposium, Coeur d' Alene, Idaho, 2018.

[4] E. Guzman, L. Oliveira, Y. Steiner, L. C. Wagner, and M. Glinz, "User feedback in the app store: a cross-cultural study," presented at the Proceedings of the 40th International Conference on Software Engineering: Software Engineering in Society, Gothenburg, Sweden, 2018.

[5] M. S. Kirkpatrick and C. Mayfield, "Evaluating an Alternative CS1 for Students with Prior Programming Experience," presented at the Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education, Seattle, Washington, USA, 2017.

[6] S. Gorka, A. McNett, J. R. Miller, and B. M. Webb, "Improving the Cybersecurity and Information Assurance Pipeline: Impact of High School After-School Program," presented at the Proceedings of the 20th Annual SIG Conference on Information Technology Education, Tacoma, WA, USA, 2019.

[7] D. Codish and G. Ravid, "Adaptive Approach for Gamification Optimization," presented at the Proceedings of the 2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing, 2014.

[8] R. Weiss, C. W. O'Brien, X. Mountrouidou, and J. Mache, "The Passion, Beauty, and Joy of Teaching and Learning Cybersecurity," presented at the Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education, Seattle, Washington, USA, 2017.

[9] G. Gao, A. Min, and P. C. Shih, "Gendered design bias: gender differences of in-game character choice and playing style in league of legends," presented at the Proceedings of the 29th Australian Conference on Computer-Human Interaction, Brisbane, Queensland, Australia, 2017.

[10] B. J. Westphal, H. Lee, N.-M. Cheung, C. G. Teo, and W. K. Leong, "Experience of designing and deploying a tablet game for people with dementia," presented at the Proceedings of the 29th Australian Conference on Computer-Human Interaction, Brisbane, Queensland, Australia, 2017.

[11] A. B. Talone, P. Basavaraj, and P. J. Wisniewski, "Enhancing Human-Computer Interaction and User Experience Education through a Hybrid Approach to Experiential Learning," presented at the Proceedings of the 18th Annual Conference on Information Technology Education, Rochester, New York, USA, 2017.

[12] T. Amira, M. Lamia, and H. Mohamed, "Flipped classroom for algorithmic teaching," presented at the Proceedings of the 2nd International Conference on Networking, Information Systems & Security, Rabat, Morocco, 2019.

[13] É. Lavoué, B. Monterrat, M. Desmarais, and S. George, "Adaptive Gamification for Learning Environments," *IEEE Transactions on Learning Technologies,* vol. 12, no. 1, pp. 16-28, 2019.

[14] M. Böckle, I. Micheel, M. Bick, and J. Novak, "A Design Framework for Adaptive Gamification Applications," in *Proceedings of the 51st Hawaii International Conference on System Sciences*, 2018.

[15] D. Ismailovic, J. Haladjian, B. Kohler, D. Pagano, and B. Brugge, "Adaptive serious game development," presented at the Proceedings of the Second International Workshop on Games and Software Engineering: Realizing User Engagement with Game Engineering Techniques, Zurich, Switzerland, 2012.

[16] Z. Stylianos, T. Maria, E. L. Evdoxia, D. Anastasios, I. Dimosthenis, and T. Dimitrios, "User Acceptance Evaluation of a Gamified Knowledge Sharing Platform for Use in Industrial Environments," *International Journal of Serious Games,* vol. 6, no. 2, 06/24 2019.

[17] A. R. Hevner, S. T. March, J. Park, and S. Ram, "Design Science in Information Systems Research," *Management Information Systems Quarterly,* vol. 28, no. 1, 2004.

[18] V. Vaishnavi and B. Kuechler. (2004, October 3). *Design Science Research in Information Systems*. Available: http://desrist.org/desrist

[19] A. Knutas, R. van Roy, T. Hynninen, M. Granato, J. Kasurinen, and J. Ikonen, "A process for designing algorithm-based personalized gamification," *Multimedia Tools and Applications,* journal article vol. 78, no. 10, pp. 13593-13612, May 01 2019.

[20] S. Acharya, R. Matovu, A. Serwadda, and I. Griswold-Steiner, "Gamification of Wearable Data Collection: A Tool for both Friend and Foe," presented at the Proceedings of the 2019 3rd International Conference on Compute and Data Analysis, Kahului, HI, USA, 2019.

[21] A. Domínguez, J. Saenz-de-Navarrete, L. de-Marcos, L. Fernández-Sanz, C. Pagés, and J.-J. Martínez-Herráiz, "Gamifying learning experiences: Practical implications and outcomes," *Computers & Education,* vol. 63, no. 0, pp. 380-392, 4// 2013.

Supporting Research on Inclusion in K-12 Computer Science Education using CSEdResearch.org

Monica M. McGill
Department of Computer Science, Knox College
CSEdResearch.org
Galesburg, IL USA
Email: monica@csedresearch.org

Adrienne Decker
Department of Engineering Education
University at Buffalo
Buffalo, NY USA
Email: adrienne@buffalo.edu

***Abstract*—CSEdResearch.org was originally conceived in order to collect data necessary to discover empirically-based best practices for teaching K-12 computing across the demographic spectrum, with an eye towards improving the efficacy of outreach activities and curriculum for underrepresented groups. This resource includes evaluation instruments for computing education and a repository of articles related to K-12 computing education with the capability of filtering by demographic, such as gender, race/ethnicity, and disabilities. Instructors, researchers, and evaluators interested in inclusion and diversity in computer science education can use the CSEdResearch.org resources to quickly find relevant articles and evaluation instruments. The site is easy to engage in as a contributor and as an end-user. We encourage continued collaboration and feedback from users as this resource evolves.**

***Keywords*—K-12, research, evaluation, inclusion, diversity, resource**

I. Introduction

CSEdResearch.org was created for the purpose of investigating how underrepresented groups are faring in K-12 computing education and how early exposure affects their post-secondary course and major choices [1], [2], [3]. The primary features of the site assist in conducting this type of research.

The dataset foundational to this work currently has data curated from over 600 published articles (2012-2019), with more continually being added. The publication venues include ACM International Computing Education Research, ACM Innovation and Technology in Computer Science Education, ACM SIGCSE Technical Symposium on Computer Science Education, ACM Transactions on Computing Education, Frontiers in Education, IEEE Global Engineering Education Conference, IEEE Transactions on Education, Journal of Educational Computing Research, Koli Calling, and Taylor & Francis' Computer Science Education[1]. The data includes student and teacher demographics and searches can be conducted on this data (and more).

Using this resource can save users precious time when searching for research relevant to and for dissemination of their own research. This resource is continually expanding to include materials and search mechanisms for a variety of K-12 students, including learner groups of various abilities, genders, socio-economic status and races/ethnicities.

Within this extended abstract, we articulate the primary features of the site that enable this process, including a refined search system for related articles, a refined search system for evaluation instruments, how to access our data for your own studies, and how to contribute to the dataset.

II. Article Summaries

Users can perform searches of articles related to K-12 computing education using the convenient filtering on the demographics of the students or teachers that you would like to learn more about (see Figure 1). This is a quick way to save time finding articles, for example, related to girls learning computing in summer camps or boys learning programming using e-textiles.

The analysis being performed on the data has allowed us to consider longitudinal trends for various demographic groups [4]. For example, we learned that less than 5% of studies report data on disabilities of participants in research studies. We will continue to track this data over the next few years to call out trends and inform researchers how reporting in these areas can be improved.

III. Evaluation Instruments

Every program, be it a new integrated computing curriculum or an after school outreach activity, often requires an evaluation to determine how it impacted students, teachers, and/or others peripherally involved in the process. This could be funded or unfunded based on the needs of the program.

This material is based upon work supported by the U.S. National Science Foundation under Grant Nos. 1625005, 1625335, 1757402, 1745199 and 1933671.

[1]The Workshop in Primary and Secondary Computing Education is currently being added to the dataset

978-1-5386-5541-2/18/$31.00 ©2020 IEEE

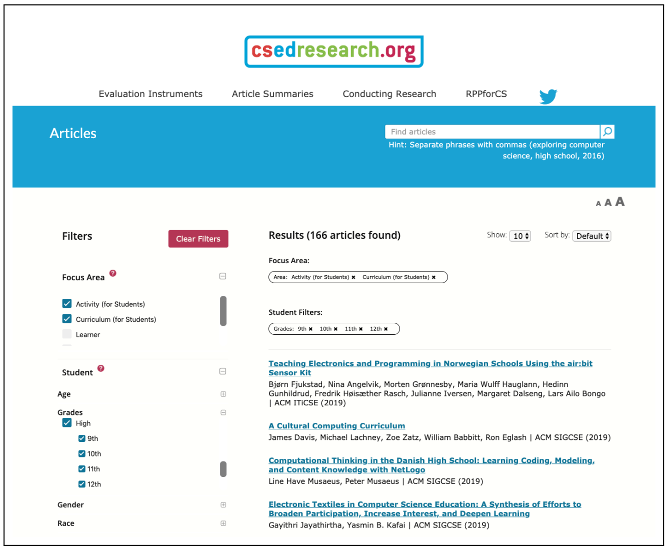


Fig. 1. Categorized article data make it easy to locate K-12 articles focused on specified demographic groups.

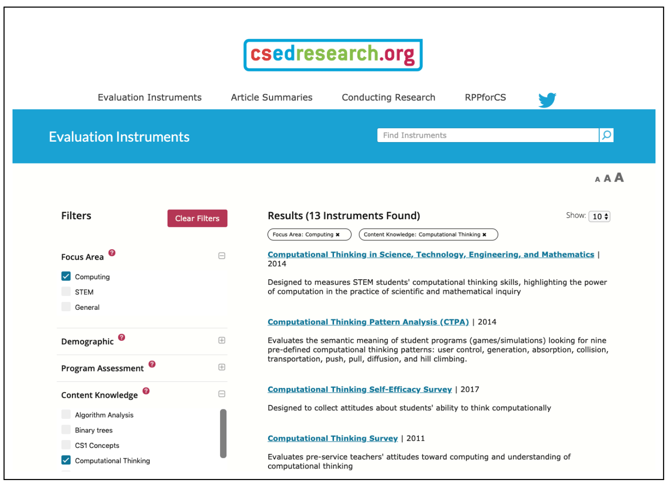


Fig. 2. Categorized evaluation instrument data make searches easy.

CSEdResearch.org's site provides the capability for users to quickly find useful evaluation instruments that have already been created and used. Some of these have existing evidence of reliability and validity. These instruments have been manually curated and tagged appropriately and users can find relevant instruments by selecting appropriate filter criteria (see Figure 2).

IV. Available Data

The data curated for CSEdResearch.org is available to the public. Although not in a centralized public repository at the moment, researchers who would like access to the data can contact our team. We can provide a fully copy of the dataset, or we can provide a subset of data in .csv delimited files.

V. Contributing to the Dataset

Though much of the data is curated manually based on the pre-specified journals, users can also submit their own articles and evaluation instruments for addition to the growing set of data.

We also provide a mechanism for giving feedback and ideas on improving the site for those performing research on diversity. By providing this important feedback, we can make the site even more meaningful for the CS education community studying underrepresented groups. As the site evolves and becomes more used within the community, the potential exists for improving the quality and the dissemination of research on diverse student learners.

VI. Conclusion and Future Work

The CSEdResearch.org dataset is a project dedicated to improving high quality research in K-12 computing education. We seek to drive this research forward so that the community can start to develop a better understanding of what works for various demographic groups based on empirical evidence. This data and the site is a free resource to the community that is continually be improved to better meet the needs of researchers in achieving this goal. Near future work includes:

- User login capabilities for providing feedback on evaluation instruments
- Capabilities for administering surveys directly from the site
- Capabilities for adding articles to the dataset to further increase article dissemination
- Dynamically generated heatmaps of the data embedded into the site
- Additional research guides
- Sharing the data through jyputer and/or github

We will continue to update the community on progress as the site continues to grow.

Acknowledgment

This material is based upon work supported by the U.S. National Science Foundation under Grant Nos. 1625005, 1625335, 1757402, 1745199 and 1933671.

References

[1] M. M. McGill and A. Decker, "Computer science education repository," 2017. [Online]. Available: https://csedresearch.org
[2] A. Decker and M. M. McGill, "A systematic review exploring the differences in reported data for pre-college educational activities for computer science, engineering, and other stem disciplines," *Education Sciences*, vol. 9, no. 2, p. 69, 2019.
[3] M. M. McGill and A. Decker, "Defining requirements for a repository to meet the needs of k-12 computer science educators, researchers, and evaluators," in *2018 IEEE Frontiers in Education Conference (FIE)*. IEEE, 2018, pp. 1–9.
[4] B. Upadhyaya, M. M. McGill, and A. Decker, "A longitudinal analysis of k-12 computing education research in the united states: Implications and recommendations for change," in *2020 SIGCSE Technical Symposium*. ACM, 2020.

POSTERS

2020 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)

Portland, Oregon & Online Virtual Conference
March 11, 2020

Computational Thinking for STEM Teacher Leadership Training at Louisiana State University

Fernando Alegre
Gordon A. Cain Center for STEM Literacy
Louisiana State University
Baton Rouge, LA, U.S.A.
falegre@lsu.edu

Juana Moreno
Physics & Astronomy and Center for Computation & Technology
Louisiana State University
Baton Rouge, LA, U.S.A.
moreno@phys.lsu.edu

Trent Dawson
School of Education
Louisiana State University
Baton Rouge, LA, U.S.A.
dtrent2@lsu.edu

Egbeyong E. Tanjong
Computer Science & Engineering
Louisiana State University
Baton Rouge, LA, U.S.A.
etanjo1@lsu.edu

David H. Kirshner
School of Education
Louisiana State University
Baton Rouge, LA, U.S.A.
dkirsh@lsu.edu

***Abstract*—We developed and piloted a new course titled Computer Science Teaching Methods (CSM) in the fall semester of 2019. This course was based on materials developed from a previous program that trained high school teachers in computational thinking and programming through LSU's Cain Center. Pedagogical content knowledge informed the design of this course. Also, data gathered from teacher and instructor interaction at multiple sites during the summer STEM professional development program contributed to the courses' design. The CS Methods course targeted undergraduate computer science majors who were considering a career in teaching or who were interested in CS pedagogy. We encountered several challenges recruiting and retaining students and found that computer science students attracted to teaching careers do not fall into the stereotype of most computer science majors. Participation of women was higher than the average undergraduate CS courses. A disconnect appeared between the pedagogical practices promoted for teaching computing at the high school level and those being practiced at the college level. After learning about the 5E pedagogical model for teaching computing, students expressed interest in the potential of using more student-centered instruction, not only for high school instruction, but also for their own college courses. An area of disconnect also emerged in the programming formats, as all the students were comfortable with Java but all were unfamiliar with popular block-based programming platforms, such as Scratch. The transition from the CS curriculum taught in high schools to what follows in college needs to be smoother.**

Keywords: computational thinking, computer science teachers, Research Practitioner Partnership

I. Introduction

In the fall of 2019, Louisiana State University (LSU) ran the first pilot of a new undergraduate course for computer science students interested in becoming K-12 educators. LSU is a UTeach replication site, and this course is intended to be the first one in a sequence to earn a teaching certification along with their CS undergraduate degree. Its design was informed by experiences gained in the LSU STEM Pathway's Summer Teacher Training Institute, which began in 2017. Teachers at the summer institute undergo a six-week intensive training in which they learn the content and pedagogy of a course in the Computing STEM pathway.

This course was not an isolated effort, but it is part of a Research-Practitioner Partnership (RPP) with a local school district. The RPP allows the student-teachers to observe, practice teaching, and receive mentoring from current in-service teachers who were trained at LSU's summer institute. Through the curriculum and RPP the teachers and pre-service student teachers bring computer science education to all the students in the district. Through the sharing of student data, lesson feedback, and observational pre-service teacher lesson execution, a feedback loop for course refinement is generated. The student outcomes are reviewed and the analysis is used to improve both the training of in-service and the pre-service teachers. This CS education model might also be of interest to researchers on equity and access in STEM education.

Although CS enrollment at LSU has almost doubled over the last five years, LSU's undergraduate STEM teacher preparation program (GeauxTeach) and LSU's four graduate programs for teachers did not offer an introductory computational thinking or programming course before the 2019-2020 academic year. The Computer Science Teaching Methods (CSM) was closely structured after the LSU Computing Pathways Program. The Computing Pathway provides high school students an opportunity to enroll in a series of elective project-based courses which lead to a career-tech diploma or to an enhanced university-prep diploma. LSU STEM Pathways Program has an introduction to computational thinking and programming course embedded in each of its four branches: Pre-Engineering, Digital Design and Emergent Media, Computing, and Biomedical Sciences. The pathways are designed

Acknowledge support of the U.S. Department of Education Supporting Effective Educator Development award No. U423A180139.

to provide high school students with a background in CS. An area of critical shortage in our state has been the supply of teachers with training in CS and specialized STEM discipline, like engineering. Very few computer science teachers graduated from Louisiana universities in recent years [1]. The development of the CSM course is a first step in creating a CS teacher certification program at LSU.

II. Computer Science Teaching Methods Course

The course covers four units: (1) pedagogical content knowledge for secondary CS; (2) the 5Es pedagogical model; (3) self-paced learning and teaching of an introductory high-school course; and (4) a field teaching experience, which is by no means exhaustive, given that the area of K-12 CS pedagogy has many topics to investigate [2], [3].

In the first unit, we covered the seven big ideas from the AP Computer Science Principles framework, as well as standards and guidelines for teaching CS, and specific high school professional practices, such as managing students' classroom use of computers, strategies for fostering student collaboration, and techniques for maintaining student productivity.

The second unit is focused on the 5E instructional model. This was selected to align the CSM with the current structure of LSU's GeauxTeach program.

The third unit placed the college students into a hands-on learning approach to the abridged Introduction to Computational Thinking (ICT) high school curriculum. ICT is focused on the concepts of programming with mathematical connections to Algebra 1, in which most of the state's ninth graders are concurrently enrolled. The undergraduate students began preparing to teach by creating a lesson to teach to their fellow classmates. Each lesson was then peer reviewed.

The final unit focused on a pre-service field teaching experience. Students attended a local high school and observed a classroom for two days. Then they prepared a lesson from ICT and spent three class days teaching it to the classes they had previously observed.

III. Qualitative Research Study

Five CS majors with no prior teaching experience, lesson planning, or learning theory instruction completed the course. Two of five (40%) students were female. The course instructor is a computer scientist and course developer with multiple years of experience teaching high school CS courses. We conducted a post-course research study that sought to understand students' attitude and opinions on the course. We distributed an online survey, and conducted individual interviews with ten questions centered around three broad research questions:

1) How do CS undergraduate students describe the similarities and/or differences between the CSM course and other undergraduate CS courses?
2) How do CS undergraduates describe their learning of CSM after completing the CSM course?
3) How do CS undergraduate students describe their experience with the 5Es instructional model after completing the CSM course?

We transcribed interview data to text, imported the text into a qualitative coding platform and distributed out to researchers for individualized coding. We coded each response to accurately reflect the attitude and opinion of the interviewees. Following coding, responses were merged to help identify broad patterns and overarching themes. We will use the data to inform quality improvements of the course.

Four of the five students liked the course. Three of five found the course useful. All students reported their field teaching experience as the accomplishment they were most proud of. All but one student saw the course as valuable. Most students reported the amount of course work was higher than other CS courses. Four of five students believed that they gained skills in teaching, lesson planning, and time management. Adapting to the 5Es instructional model, in contrast with traditional, lecture-based CS courses, was viewed as a challenge.

The 5Es instructional model was novel to both the CSM instructor and the students accustomed to traditional lecture-based formats. At LSU upper-level-undergraduate CS courses tend to be large (50 or more students) and students passively listen to the instructor lecture. The CSM classes were taught using the 5E model. The students reported that the student-centered, high participation format of 5E model was unfamiliar and at times disconcerting. Student overall feedback reported positive experiences with 5Es Engagement, the first phase, aimed at quickly provoking learners' interest. However, frustration ensued during Exploration, the second phase, because coding nuances necessary for meaningful exploration go missing unless the instructor slightly modifies 5Es to include scaffolding with starter code.

IV. Conclusion

With the growing STEM economy and demand for computer-capable citizens, school districts are exploring innovative curricular approaches. However, the critical shortage of educators with STEM training severely limits statewide access. University-based teacher preparation programs have a critical role to play in reversing this situation by offering computational thinking and programming content and pedagogy courses for all candidates, and setting appropriate participation expectations for program completion. Programs to certify STEM majors, and in particular CS majors, might need to emphasize the merits of a student-centric pedagogy which most students have not experience in their secondary or post-secondary education. The new course proposed here is the first step towards fulfilling the needs of pre-service K-12 teachers to prepare the next generation of computing literate citizens.

References

[1] Code.org Advocacy Coalition and CSTA, 2018, "State of Computer Science Education," https://code.org/advocacy/state-facts/LA.pdf.

[2] M. Guzdial, A. Kay, C. Norris, and E. Soloway, "Computational thinking should just be good thinking," *Communications of the ACM*, vol. 62, no. 11, pp. 28–30, 2019.

[3] P. J. Denning, "Remaining trouble spots with computational thinking," *Communications of the ACM*, vol. 60, no. 6, pp. 33–39, 2017.

Supporting Teachers to Integrate Computational Thinking Equitably

Merijke Coenraad
College of Education
University of Maryland
College Park, Maryland, USA
mcoenraa@umd.edu

Kelly Mills
Digital Promise Global
Washington, D.C., USA
kmills@digitalpromise.org

Virginia L. Byrne
College of Education
University of Maryland
College Park, Maryland, USA
vbyrne@umd.edu

Diane Jass Ketelhut
College of Education
University of Maryland
College Park, Maryland, USA
djk@umd.edu

***Abstract*— Broadening participation and increasing equity in computer science (CS) have been goals of the computing field for decades. Initiatives seeking to increase access to CS have led to an increase in elementary schools teaching computational thinking (CT), but students are often instructed by classroom teachers who have no formal training in CT or CS. Our project prepares in-service and pre-service elementary teachers to integrate CT into their science lessons. While our overall goal was to increase CT access for all students, we found some teachers enacted CT in ways that did not always provide equal access to all students. Although our professional development adopted a *CS for All* approach, without explicit supports, a group of teachers implemented CT in ways often upholding the current trends of inequity and power structures within CS. Our findings suggest teachers would benefit from explicit support to provide opportunities for students currently underrepresented in CS and to offer more equitable opportunities to students regardless of their CS background.**

Keywords—computational thinking, professional development, equity, computer science education, science education

I. Introduction

Computer science (CS) historically and presently is characterized by an underrepresentation of women, people of minoritized races and ethnicities, and people with disabilities across the school to career pipeline [1]. *CS for All* has become a rallying cry for increasing CS opportunities across students' educational experiences. To help students learn CS, computational thinking (CT) is introduced to teach "the thought processes involved in formulating problems…so that the solutions…can be effectively carried out by an information-processing agent" [2]. Exposure to CT in elementary school gives students a foundation on which to pursue CS through their education and possibly into their career choices [3].

To work within the time constraints of a school day and the multidisciplinary nature of CT, educators are integrating CT education throughout the curriculum [4]. For this integration to be successful, elementary teachers need support in CT during their teacher education program or professional development (PD). Current efforts provide teachers with learning experiences in knowledge of CT concepts, tools, and practices including the role of CT in everyday life and CT pedagogy. However, researchers have recently begun to investigate how to support teachers to integrate CT into their disciplines [5], [6].

We offer exploratory data of how teachers presented CT to their students and the equity challenges they faced. Our findings suggest teachers would benefit from more explicit support to integrate CT equitably and provide opportunities that break down gendered and ableist power structures in CT.

II. Methods

Our project supports teachers to integrate CT in elementary science. Pre-service and in-service teachers met once per month for four months to discuss the core practices of CT and design CT infused science lessons. In total, 40 teachers participated (37 women, 3 men; 21 pre-service, 19 in-service). At the culmination of the PD, teachers wrote and implemented a CT-infused lesson plan in their science classes.

We analyzed researcher field notes and teacher focus group transcripts. Multiple researchers recorded field notes during and following each session. In the final PD session, teachers shared their experiences in focus groups of 2-5 teachers and a researcher. These focus groups were audio and video recorded, and professionally transcribed.

These data were analyzed inductively. First, researchers used open ended initial coding [7] to note areas of interest related to equity and teacher attitudes in the lesson plans. The researchers met to discuss their inductive coding and determine a codebook [7]. Then, a researcher coded the data using a set of codes derived from the open coding: teacher understanding, perceived student ability, students overcoming expectations, giving technology to tech-oriented students, student experts, and opportunities for advanced students. Based on this coding, two major themes emerged: *Opportunities for Advanced Students* and *Using Students as Experts*.

III. Findings

Within the data, we found six teachers discussed providing *Opportunities for Advanced Students* and eleven teachers *Using Students as Experts*. In the following sections, we present these two themes. For clarity and length, these trends are explored as representative cases of two teachers' CT integration.

A. *Adrienne: Opportunities for Advanced Students*

Adrienne is an in-service teacher who teaches 3rd grade and has been teaching for 15 years. She teaches at a school with 10.3% students with disabilities, 41.3% students receiving free and reduced priced lunch, and 10% English Language Learners. Her school is 80.3% underrepresented minorities. In her lesson plan, Adrienne focused on data analysis. She led a simulation game about fish finding resources within their habitat. The class

National Science Foundation STEM + C Grant 1639891

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

collected data and analyzed the changing population by creating a graph. While in this lesson plan Adrienne gave her full class the opportunity to engage in CT through data analysis, on multiple occasions, Adrienne discussed giving more complex CT opportunities to her advanced students. Researchers noted that Adrienne discusses integrating CT by highlighting CT as an *"opportunity for above average students to learn…[and] explore at their own pace."* Adrienne mentioned in the focus group that, *"it's good for TAG [Talented and Gifted] students. Because I use computational thinking as extensions all the time."* These comments indicate Adrienne viewed CT as most beneficial to her advanced students and as an extra activity for students who finished early or needed a challenge.

B. *Eleanor: Using Students as Experts*

Eleanor is a 3rd grade in-service teacher with 13 years of experience. She teaches at a school with 8.8% students with disabilities, 9.9% students receiving free and reduced priced lunch, and 11.6% English Language Learners. 21.1% of her school is underrepresented minorities. Eleanor began Scratch [8] activities with her entire class by integrating the activities into science and other disciplines. Yet, the experience of integrating Scratch was not always smooth for Eleanor. When Eleanor shared her experiences, she *"was frustrated with not being able to help"* with questions about programming in Scratch. Instead, Eleanor assigned three students to be the experts in the class. This contributed to an expert student wanting to *"make his own [Scratch] account"* based on his leadership experience. Eleanor reports, *"she would do it [Scratch] again and that the kids loved it,"* but she hopes *"to be more knowledgeable next time so she can help students more."*

IV. Discussion

When the teachers included CT in their lesson plans, the implementations of some resulted in mixed success regarding our *CS for All* goals. While we aimed to get all students involved in CT through integration in elementary science classes, teachers needed more support to break down the structural inequities within the broader computing field. One possible explanation for teachers implementing CT this way is we included only limited conversations on how to create opportunities for all students and how using CT selectively can perpetuate structural inequity. Additionally, we did not provide teachers with enough pedagogical and tool knowledge and some teachers were only prepared to use CT as extensions or opportunities for students who already had the skills. Teachers gave *Opportunities to Advanced Students* who did not need assistance and *Used Student Experts* to help other students. Unfortunately, in doing so, the teachers may have signaled to students who among them was good at CT. Teachers often referred to their experts with *"he"* and *"him,"* highlighting the choice of boys as experts. Additionally, the students who were selected as experts had often been exposed to programming outside of school.

Teachers would benefit from more support in developing content knowledge and pedagogical knowledge of how to integrate CT with their students, as well as knowledge of CT tools to support all students in learning and using CT rather than advanced or experienced students. Based on our experiences we recommend PD opportunities provide teachers with:

- Strategies for utilizing expert students in a manner that does not inadvertently signal only certain students are knowledgeable in CT
- Explicit discussions about underrepresented groups in CS and the stereotypes around who is capable of CT
- Structure during co-design lesson planning to allow teachers to think through CT implementation challenges with a researcher familiar with CT
- Support in answering questions that come up during CT integrated lessons and time to share questions that have come up within classrooms
- Concentrated support on the practices perceived to be more difficult such as systems thinking and programming

To meet the *CS for All* goals of our project and the broader community, teacher education programs need to have explicit conversations about the populations currently underrepresented in computing, common stereotypes within computing, and strategies for helping to counteract the stereotypes to broaden participation. Additionally, PD sessions need to provide further support for teachers to not only find resources, but also to use CT tools and knowledge and integrate them in their pedagogy. In learning from our experiences, projects with a *CS for All* goal should include learning objectives about the goals of increasing CS and CT opportunities for all students through integration in general subjects, and prepare teachers in strategies for overcoming the subtle but inequitable practices contributing to the underrepresentation of women, marginalized populations, and individuals with disabilities.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 1639891.

References

[1] S. Zweben and B. Bizot, "2017 CRA Taulbee Survey: Another year of record undergrad enrollment; Doctoral degree production steady while master's production rises again," Comput. Res. Assoc. News, vol. 30, no. 5, pp. 1–47, 2018.

[2] J. Cuny, L. Snyder, and J. Wing, "Demystifying computational thinking for noncomputer scientists," 2010.

[3] National Research Council, "Report of a workshop on the scope and nature of computational thinking," Washington, DC, 2010.

[4] M. Israel, J. N. Pearson, T. Tapia, Q. M. Wherfel, and G. Reese, "Supporting all learners in school-wide computational thinking: A cross-case qualitative analysis," Comput. Educ., vol. 82, pp. 263–279, 2015.

[5] C. Mouza, H. Yang, Y. C. Pan, S. Yilmaz Ozden, and L. Pollock, "Resetting educational technology coursework for pre-service teachers: A computational thinking approach to the development of technological pedagogical content knowledge (TPACK)," Australas. J. Educ. Technol., vol. 33, no. 3, pp. 61–76, 2017.

[6] A. Yadav, N. Zhou, C. Mayfield, S. Hambrusch, and J. T. Korb, "Introducing computational thinking in education courses," in Proceedings of the 42nd ACM technical symposium on Computer science education - SIGCSE '11, 2011, pp. 465–470.

[7] J. Saldaña, The coding manual for qualitative researchers, 3rd Editio. Thousand Oaks, CA: Sage, 2015.

[8] M. Resnick et al., "Scratch: Programming for All.," Commun. ACM, vol. 52, no. 11, pp. 60–67, 2009.

Connecting with Computing: Exploring Black/African-American Women's People-Centered Interests in Computing Sciences

Edward Dillon
Department of Computer Science
Morgan State University
Baltimore, MD, USA
edward.dillon@morgan.edu

Krystal L. Williams
Department of Educational Leadership, Policy & Technology Studies
The University of Alabama
Tuscaloosa, AL USA
krystal.l.williams@ua.edu

***Abstract*—Promoting inclusivity and increasing the representation of women in the field of Computer Science (CS) has been an ongoing initiative. When it comes to Black/African-American (AA) women, their underrepresentation in CS is even more disproportionate. CS is a field that is ever-evolving, but its ability to be perceived as a field that is inclusive-to-all has been a continuing challenge. One notable reason is that CS comes off as a field that lacks altruism by nature. For instance, literature shows that women tend to gravitate away from CS for fields that align more with their interests for helping others. However, CS in nature can create spaces that provide platforms for women, especially women of color, to express their personal interests.**

This article addresses such potential in CS by discussing a two-year study that was conducted on 51 Black/African-American female students who were enrolled in an introductory and intermediate CS course at a historically black university in the mid-Atlantic United States. In these respective courses, the assigned final project allowed students to choose their own original projects while showcasing their learned computational knowledge and developed programming competencies. The objective of this study was to observe the types of project topics that these 51 women, in particular, chose for their assigned final projects in these respective courses. The results revealed that 92% of the topics chosen tended to be ones that were altruistic in nature. Likewise, this study reflects potential support for the ability of CS to exhibit inclusive spaces for such interests.

Keywords—Black/AA women, altruism, CS spaces

I. Introduction & Relevant Literature

Increasing diversity and inclusivity within the field of Computer Science (CS) has been a longstanding issue--especially broadening participation for women. Within higher education, women have been underrepresented amongst CS majors for some time [4]. Also, research suggests biases against women within the labor market [3, 6]. Despite the need for more women in CS, literature indicates that there are critical gender differences related to STEM interests that must also be acknowledged-- specifically *the general preference among women for occupations that center around working with people versus things* [5]. While research discusses the interests of women in general and how they inform STEM-related decisions, studies concerning Black/African American (AA) women's STEM interests are scant. Furthermore, there is a need to explore the interests of these women in CS given their underrepresentation even relative to women from other racial/ethnic groups [7]. Moreover, scholarship notes that collegiate Black/AA women in computing sciences report feelings of cultural isolation and subordination [2]. Given the specific barriers of Black/AA women in CS, and literature which suggests a general preference amongst women for professions that emphasize working with people, this study explores how such an orientation may manifest amongst Black/AA undergraduate women within undergraduate CS coursework.

A. Motivating Research Questions

The following research questions are examined: 1) To what extent do Black women exhibit a people-centered interest within their undergrad CS coursework? 2) Is such an interest higher for Black/AA women vs Black/AA men? 3) In what ways does such an interest manifest amongst Black/AA women?

II. Research Design

A. Target Courses

This study was conducted as a pilot study over a two-year semester span from Spring 2017 to Spring 2019 using data from a CS2 programming course and an advanced programming course at a historically black university in the mid-Atlantic region of the United States. The CS2 course exposes students to introductory-level programming in Python while the advanced programming course exposes students to intermediate-level programming in C++. Each course contains a final project that examines the students' ability to self-identify a computational problem that is original in nature, identify and apply the appropriate data structures and coding paradigms to solve it, and confidently defend the data structures and coding paradigms chosen to build their solution. During the latter semesters, students conducted their final projects in groups in an effort to develop group-based learning experiences and skills.

B. Procedure

Document analysis [1] was conducted using data from the two CS courses. These particular courses were selected for this study because: *1) they are taught by the same instructor* and *2) a final project is consistently a requirement for course completion*. Document analysis of the final project topics was used to generate themes that represent the nature of the students' expressed topic of interest. These interests were then

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

categorized on the basis of people-centered vs non-people-centered foci. Eighty-one projects were evaluated: 45 projects were done by male students (control group), while 36 projects were linked to the observed women students (experimental group).

III. Data Analysis & Findings

A. Demographics

This sample included 51 females and 53 males enrolled in the indicated CS courses. Ninety-one percent of the male students were Black/AA, 4% were Asian, 4% were Hispanic/Latino, and 2% were Arabian. No non-Black female students were enrolled in the courses. The sample included students ranging from freshmen to seniors. Ninety-three percent of these students were CS majors.

B. Centralized Themes

Figure 1 provides a dual bar chart reflecting the trending topics from all 81 projects, which are separated by the control and experiment groups, respectively. Based on analysis of the final projects, the following themes emerged regarding the students' final project topical areas: *Education*, *Entertainment*, *Financial*, *Food, Health*, *Sports*, *Travel*, and *Other*. For the experimental group, projects related to *Education* and *Health* were most prevalent, followed by projects related to finances. For the control group, projects most often fell into the *Other* category followed by the *Financial* theme. Amongst the experimental group, there were also 7 projects that exhibited multi-theme characteristics (these scenarios were not the case for the control group). These 7 projects were classified as: *Education/Financial*, *Education/Health*, *Financial/Health*, or *Financial/Travel*, respectively.

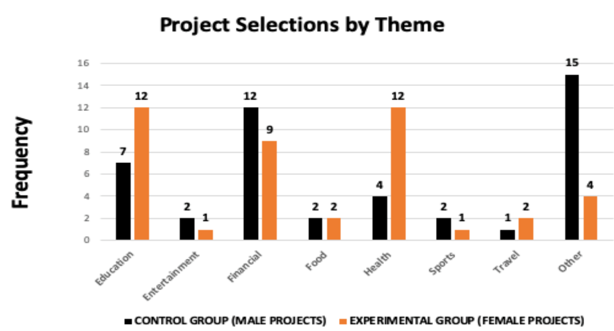


Fig. 1. Centralized Project Themes and their frequencies of occurrence.

C. Projects: People-Centered vs. Non-People-Centered

Another aspect of this analysis was to determine gender differences regarding people-oriented vs non-people-oriented topical areas. Amongst the control group, 51% of the projects emphasized working with people in some capacity. Subjects regarding *Financial* and *Education* exhibited the highest trends for this group (as noted in Figure 2). Amongst the experimental group, 92% of the projects were people-oriented in nature. Subjects regarding *Health*, *Education*, and *Financial* exhibited the three highest trends for this group. When observing the projects categorized as *Other* for both groups, it was found that only 20% of these projects amongst the control group were people-centered, while 100% of these projects amongst the experimental group were people-centered.

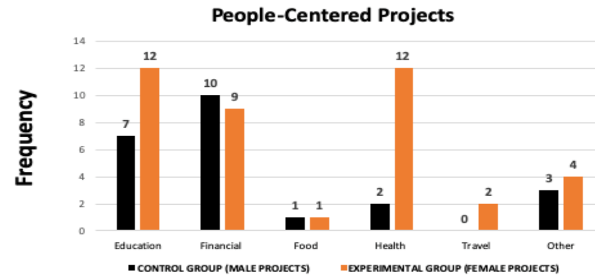


Fig. 2. Projects that were found to be People-Centered (both groups).

IV. Discussion & Conclusion

Guided by existing literature regarding interest differences by gender and implications for STEM [5], this study explored the particular interests of Black/AA women in CS. Such a focus is important given the low representation of this demographic in CS, and the need to better understand their interest to broaden their participation in CS fields. The Black/AA women in this study exhibited people-centered interests within their undergraduate CS coursework at higher rates than their male counterparts. They connected these interests employing their computational competencies to address real-world issues in areas that emphasize working with people. The ability to make these connections was fostered by a final project that allowed students to choose a project topic related to their interests and employ appropriate CS computational skills to develop a solution to address that topic. From a pedagogical and inclusivity standpoint, this study suggests that decisions employed when designing student assignments may help to create an inclusive classroom that allows students to explore their interests in authentic ways. Such an approach may also be a fruitful way for women to explore the ways in which CS can be understood as a field with applications that focuses on working with people and helping others.

References

[1] G. A. Bowen, "Document analysis as a qualitative research method," Qualitative research journal, vol. 9(2), 2009, pp. 27-40.

[2] BWiC. Black Women in Computing, 2016, Retrieved from http://blackwomenincomputing.org/about-2/.

[3] S. Kolhatkar, "The tech industry's gender-discrimination problem," The New Yorker, pp 20, November 2017.

[4] R. D. Robnett, "Gender bias in STEM fields: Variation in prevalence and links to STEM self-concept," Psychology of Women Quarterly, vol. 40(1), 2016, pp. 65-79.

[5] P. Sankar, "The pervasive bias against female computer science majors.," Fortune Magazine, 2015.

[6] J. Steinke, M. K. Lapinski, N. Crocker, A. Zietsman-Thomas, Y. Williams, S. H. Evergreen, & S. Kuchibhotla, "Assessing media influences on middle school–aged children's perceptions of women in science using the Draw-A-Scientist Test (DAST)," Science Communication, vol. 29(1), 2007, pp. 35-64.

[7] R. Su, J. Rounds, and P. I. Armstrong, "Men and things, women and people: a meta-analysis of sex differences in interests," Psychological bulletin, 135(6), 2009, pp. 859 - 884.

A Study of the Scrumage Teaching Approach: Student Learning and Attitude Changes

Shannon Duvall
Computer Science Department
Elon University
Elon, NC, USA
sduvall2@elon.edu

Dugald R. Hutchings
Computer Science Department
Elon University
Elon, NC, USA
dhutchings@elon.edu

Scott Spurlock
Computer Science Department
Elon University
Elon, NC, USA
sspurlock@elon.edu

Robert C. Duvall
Computer Science Department
Duke University
Durham, NC, USA
rcd@cs.duke.edu

***Abstract*— Best practices for teaching a diverse population include incorporating several modes of instruction, providing a variety of resources, and encouraging collaboration. However, traditional classroom management does not necessarily support these best practices. Scrumage (SCRUM for AGile Education) is a recently proposed classroom management technique in which students are given autonomy to choose individually from a variety of pedagogies (e.g., traditional lectures, active learning, a flipped-based approach, etc.), resulting in multiple simultaneous pedagogical methods in a single course. In addition, students in a Scrumage classroom must frequently reflect on the effects of their choices. In this work, we compare Scrumage and traditional sections of an introductory programming course. Scrumage students showed improved attitudes about learning, especially in the areas of Effort Regulation (perseverance in problem solving) and Control of Learning (taking responsibility for learning success). We believe that by promoting positive attitude changes and better content learning, Scrumage has potential for widening the retention of students in Computer Science.**

Keywords—Computer Science Education, Pedagogy, Inclusion, Classroom Management, Scrum

I. Introduction and Related Work

Professors who want to teach in a way that is inclusive to diverse populations adopt course goals beyond content learning objectives, such as creating a welcoming environment, celebrating individual differences, and fostering a growth mindset. Research shows that students are more successful when they have positive attitudes about learning, confidence in their abilities, and an accurate view of their own progress [1], [2].

It is not always clear how to practically achieve this type of goal in a typical classroom, however. For example, using peer instruction or team learning may be helpful for promoting persistence in underrepresented racial groups, but these practices can be disengaging or overwhelming for people with autism spectrum disorders. As Rose et al. concludes, “There is no one means of engaging students that will be optimal across the diversity that exists” [3].

The diverse needs of diverse learners are recognized by the Universal Design for Learning (UDL) theoretical framework [4]. UDL enumerates three key principles: that learning should utilize multiple means of representing new material, multiple means of expressing knowledge, and multiple means of engagement [3]. However, UDL is a set of *principles*, not a set of *practices*. In other words, how individual educators go about the implementation of the principles is neither prescribed nor obvious.

II. Scrumage Course Management

We propose implementing UDL principles using a novel class management system called Scrumage [5]. The aim of Scrumage (SCRUM for AGile Education) is to give students the power to choose their own pedagogical approach, despite the fact that other students in the same course may be choosing differently. Rather than the professor choosing, e.g., traditional lectures, flipped classroom, or game-based class, and then imposing the choice on all the students, instead the Scrumage technique presents each of these as options for the learner.

Allowing a wide variety of choices requires simultaneously conducting differing methods of teaching and learning in a single course. To manage the classroom in a structured and organized way, Scrumage borrows techniques from the Scrum project management system widely used in industry by allowing self-regulating teams to plan and schedule the completion of work by collaborating in short bursts called sprints. In Scrumage, the “work” being undertaken is learning and the fulfillment of course objectives; the client is the instructor. The completion of specific deliverables (i.e., assignments) are a byproduct of the main “project” of mastering the material at hand. To mirror the values of both Scrum and UDL, Scrumage emphasizes giving students as much control over course management choices as possible and encouraging them to try new methods as the course progresses. Students are generally allowed to work in teams whose size and processes are largely unregulated by the professor. Importantly, students get to choose individually how they use class time by making requests from the professor. Learning methods like reading the textbook, listening to a lecture, watching a video, or completing a worksheet are not generally required activities but rather comprise a menu of options from which students can choose. In this way, students avoid learning activities they believe to be ineffective and thus are more committed and engaged in the activities they do choose. At the end of the unit, or sprint, students are assessed in usual ways with assignments, quizzes, or tests. They then complete a retrospective in which they reflect on their success – both in how they performed (as reflected by

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

grades) and also as to which learning activities were most effective for them, allowing for more informed decisions on how to learn in the next sprint. The Scrumage approach includes a systematic way of implementing several best practices for inclusion and diversity: presenting multiple choices for learning, encouraging (but not requiring) social interactions among learners, providing a rapid feedback loop with several small assessments, and offering opportunity for reflection and change.

III. Methodology

We administered pre- and post-surveys to examine 6 sections of an introductory computer science course (CS1) at a liberal arts institution in the southeastern United States. Of the 6 sections, 3 were delivered using Scrumage and 3 were delivered using a more typical approach that blended lecture, live demos, and in-class labs, which we refer to as a *traditional* approach. We determined changes in student learning attitudes by adapting the “Motivated Strategies for Learning Questionnaire” [6] to examine 4 categories: Effort Regulation, Metacognitive Self-Regulation, Help Seeking, and Control of Learning Beliefs. To determine student content acquisition, we wrote a 12-question survey based on the *SCS1* assessment [7].

IV. Results

Across all sections, concepts test scores increased from the start to the end of the semester, with an average starting score of 29% and an average ending score of 42%. Overall, students in Scrumage sections (N=18) outperformed traditional-section students (N=24), with an ending average score of 51% versus 36%, suggesting better content learning. Fig. 1 shows how the distribution of scores changed from start to end using a kernel density estimate (KDE) for Scrumage (left) and Traditional (right) sections, with the solid curves showing starting scores and the dotted curves showing ending scores. In both pedagogies, improvement is evident, i.e., the dotted curves are shifted to the right of the solid curves. However, improvement among Scrumage students was greater on average and more uniformly distributed than among traditionally-taught students.

The learning attitudes survey results show several key differences between the pedagogy methods as well. Fig. 2 shows the average change in score from pre- to post-test for each attitude category for 32 Scrumage students and 25 Traditional students. Generally, changes were not dramatic but typically moved in different directions, other than Metacognitive Self-Regulation (strategies for planning, monitoring, and modifying a student’s own cognition), where students from both pedagogies saw a slight average increase.

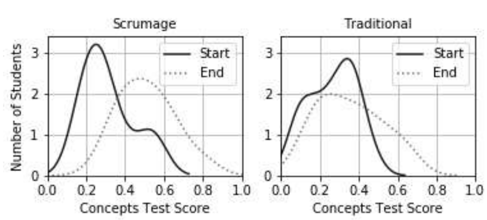


Fig. 1. The distribution of scores from pre- and post-test (solid and dotted lines, respectively) is shown for Scrumage (left) and Traditional (right) using a Kernel Density Estimate.

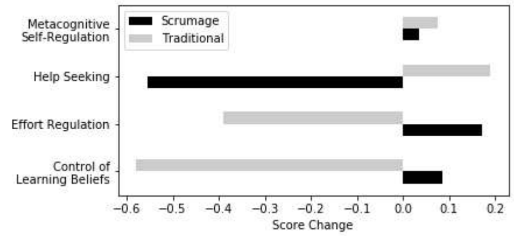


Fig. 2. Within each Attitudes Survey category, the mean score change from pre- to post-test is shown for Scrumage (black) and Traditional (gray).

For questions in the Help Seeking category, relating to student efforts to get help with the material, Scrumage student scores decreased from the start to the end of the course, while traditional student scores increased. We hypothesize that Scrumage students may have been less inclined to seek help due to the focus in Scrumage of providing students with a variety of resources in each sprint, empowering them to find answers on their own. Also, because students typically worked in teams, which offer a built-in mechanism for getting help, they may not have viewed working within their team as “seeking help.” For questions in the Effort Regulation category (relating to students’ perseverance and work ethic) and Control of Learning Beliefs (addressing students’ feelings of being capable of learning the course material), Scrumage scores mildly improved on average, while traditional scores dropped more precipitously. It appears that many students in traditional computer science courses come to doubt their own ability to learn the material, irrespective of the amount of effort expended, while Scrumage students did not encounter the same frustrations. We conjecture that Scrumage students feel a greater sense of agency in their own learning. These results lead us to believe that using the Scrumage framework may help beginner programmers develop resilience and persistence in problem solving rather than adopting a negative attitude.

References

[1] J. Ehrlinger and E. A. Shain, “How accuracy in students’ self perceptions relates to success in learning,” *Applying Science of Learning in Education*, p. 142-151, 2014.

[2] Susan A. Ambrose and Marsha C. Lovett, “Prior Knowledge is More Than Content: Skills and Beliefs Also Impact Learning,” *Applying Science of Learning in Education*, pp. 7–19, 2014.

[3] D. H. Rose, W. S. Harbour, C. S. Johnston, S. G. Daley, and L. Abarbanell, “Universal design for learning in postsecondary education: Reflections on principles and their application,” *Journal of postsecondary education and disability*, vol. 19, no. 2, pp. 135–151, 2006.

[4] D. Rose, “Universal Design for Learning,” *J Spec Educ Technol*, vol. 15, no. 3, pp. 45–49, Jun. 2000.

[5] S. Duvall, D. R. Hutchings, and R. C. Duvall, “Scrumage: A Method for Incorporating Multiple, Simultaneous Pedagogical Styles in the Classroom,” in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, Baltimore, Maryland, USA, 2018, pp. 928–933.

[6] P. R. Pintrich, T. Garcia, W. J. McKeachie, and D. A. F. Smith, *Motivated strategies for learning questionnaire*. Regents of the University of Michigan, 1991.

[7] M. C. Parker, M. Guzdial, and S. Engleman, “Replication, Validation, and Use of a Language Independent CS1 Knowledge Assessment,” in *Proceedings of the 2016 ACM Conference on International Computing Education Research*, Melbourne, VIC, Australia, 2016, pp. 93–101.

A Baseline Analysis of the Research Questions of NSF-Funded Research-Practice Partnerships and the Knowledge They Generate

Jordan Esiason
SageFox Consulting Group
Amherst, USA
jesiason@sagefoxgroup.com

Rebecca Zarch
SageFox Consulting Group
Amherst, USA
rzarch@sagefoxgroup.com

Stacey Sexton
SageFox Consulting Group
Amherst, USA
ssexton@sagefoxgroup.com

Alan Peterfreund
SageFox Consulting Group
Amherst, USA
apeterfreund@sagefoxgroup.com

***Abstract*—This study will present a baseline analysis of the types of research questions generated by 61 Computer Science (CS) for All: research-practice partnership (RPP) projects in computing education, providing insights into the types of research questions being pursued by RPPs with the intent to assess the potential knowledge being generated through these projects. These RPPs are designed to both democratize research and produce generalizable knowledge related to broadening participation in computing education (BPC). Thus the questions being pursued should reflect pressing needs of CS education practice. Through a review of 208 research questions, this study examined the research questions for the types of knowledge generated and by the focus area of the question. The latter set of codes were then broken into further subcategories for analysis. Results demonstrate a relative lack of focus on broadening participation in computing (BPC) or RPP function, which may impede the completion of CS research and implementation goals. Results also appear to demonstrate very little focus on investigating the broader applicability of research findings. By encouraging greater inclusion of BPC and RPP research questions as well as greater focus on scalability of findings in future RPPs, CS-related goals can potentially be more efficiently achieved. Future work will include tracking changes in research questions and identifying research questions addressing problems of practice specific to the practitioner partners in RPPs.**

Keywords— Broadening Participation, Computer Science Education, Research Question Quality, Research-Practice Partnership

I. Introduction

The National Science Foundation's (NSF) investment in the CS for All: RPP (NSF 17-525, 18-537) program focuses on RPPs as a model to foster the research and development needed to bring CS and Computational Thinking to all schools. The CS for All: RPP projects share dual objectives of promoting BPC and conducting research in CS education. From there, they differ broadly in their approach. Some seek to scale teacher professional development widely, some are investing in culturally responsive curriculum and pedagogy, while others may be conducting research on a specific learning tool. The knowledge generated by this body of projects has the potential to rapidly expand the knowledge base and BPC in CS education. By building upon previous work [1] investigating the research questions used by RPPs funded by the Institute of Education Sciences, using this research as a baseline to examine how research questions evolve in the future, and continuing to encourage the inclusion of BPC and RPP research questions as well as a greater focus on scalability of findings in these and future RPPs, their research can have greater impact and reach.

II. Methods

Research questions were identified for each project based on data drawn from project proposals or by direct submission to the authors. Projects fell into one of three cohorts depending on the year they received their first NSF award. Research questions from the first two cohorts were coded for the type of knowledge generated (table 1) with the intent to replicate previous research on RPP research questions [1]. The remainder were not coded according to this framework, as the authors concluded that a true reproduction of prior work could not be performed due to differences in focus between projects funded by the NSF and the funding organization in the original work. A second coding system was agreed upon by three of the authors based on the content of the first two cohorts' research questions (table 2), with the intent to classify questions based on the focus area addressed by the question. These focus area codes were then broken down by more specific concerns being addressed.

TABLE I. Knowledge Code Definitions

Code	Definition
Information-gathering	Information-gathering provides answers to descriptive and/or predictive questions such as: How many …? or What is the relationship between …?
Data Quality	Data quality questions provide information about the availability, validity, and reliability of data, answering questions such as: What data do we have or need?
Evaluation	Evaluation questions ask: What is the effect of this program or policy?
Design	Design questions ask: What new materials, activities, and/or systems would address this problem?

This material is based upon work supported by the National Science Foundation under Grant No. #1745199.

TABLE II. FOCUS AREA CODE DEFINITIONS AND HIERARCHY

Code	Subcode	Definition
CS-Related	Teacher PD	Teacher professional development-related.
	Teacher Impact	Impact on teachers.
	Student Learning	Impact on student learning.
	Student Experience	Impact on students (not related to learning).
	Structural considerations	Design-focused questions such as studying the dynamics within a school district's administration
	Scaling	The application of research findings to other contexts, such as testing a curriculum in one district with the intent to apply this curriculum in others.
RPP-Related	RPP relationships/ communication	Relationships/trust/communication between researchers and practitioners in an RPP.
	Vertical alignment	Alignment of purpose between researchers and practitioners.
	Practitioner support	Proper support for practitioner activities such as intervention implementation.
BPC-Related	Teacher impact	Impact on teacher-level BPC.
	Student access	Barriers to student access to CS.
	Student recruitment	Impact/outcomes regarding the recruitment of students.
	Student retention/supports	Retention of students and support they may need in order to succeed in CS.
	Student experience	Impact on student experience as it relates to BPC, such as student identity.
	Student impact	Impact on students as a result of an intervention, such as how an intervention improves student participation in CS.
	RPP Team-Level BPC	BPC related specifically to the RPP team (such as team diversity).

III. RESULTS

There were 208 research questions included in our study representing 61 projects. These projects represent a diverse sample of the NSF CS for All: RPP community, consisting of a variety of grant sizes, target grade spans, and curricula, among other attributes. One research question did not receive a subcode during final analysis due to lack of clarity.

Assignments of codes to questions from the first two cohorts (175 questions from 50 projects total) revealed that most projects had questions explicitly related to information-gathering (64%), then to design (52%), evaluation (38%), and finally data quality (6%).

Assignment of CS subcodes demonstrates that most projects with CS-related subcodes explore teacher (60%) or student (62%) learning and experiences, however very few investigate the broader applicability of their findings to other schools or districts (20%). Just over half of all projects had any research questions relating to either RPPs (18%) or BPC (49%).

TABLE IV. CODE FREQUENCY AMONG PROJECTS

Code	Subcode	Frequency (N=61)
CS-Related	Structural considerations	61%
	Student Experience	52%
	Teacher PD	46%
	Teacher Experience	36%
	Student Learning	26%
	Scaling	20%
BPC-Related	Student access	31%
	Student retention/supports	15%
	Student Experience	13%
	Student recruitment	11%
	Teacher impact	11%
	Student impact	8%
	RPP-Team-Level BPC	2%
RPP-Related	Research-Practitioner relationships/ communication	15%
	Vertical alignment	5%
	Practitioner support	5%

IV. CONCLUSIONS

The analysis suggests that despite the large amount of grant-funded research being performed, many projects are still involved in information-gathering activities to try to understand the landscape of CS education offerings and practices. This could reflect the relative infancy of this field of study rather than any omissions in research focus, however. There also appears to be a limited emphasis on issues known to impact CS education such as BPC than on simply delivering and evaluating improved curricula, teacher professional development, or other interventions. Additionally, very few projects appear to focus on the scalability of the research being completed (20%). This could limit developed interventions by preventing them from being expanded upon by other projects or adopted by other school districts that may face similar issues. By continuing to strongly encourage efforts targeting issues such as BPC, developing the relatively new concept of RPPs, and encouraging a greater focus on scalability of CS education research findings, it could be possible to improve the reach and efficacy of CS education interventions being performed by NSF-funded RPPs. Future work will include continued tracking of if and how the research questions examined in this study evolve over time and comparison of the baseline questions established in this study to questions from the same projects at a later date.

REFERENCES

[1] K. Thompson, M. Martinez, C. Clinton, and G. Diaz, "Considering Interest and Action: Analyzing Types of Questions Explored by Researcher-Practitioner Partnerships," Educational Researcher, Vol. 46 No. 8, pp. 464-473, October 2017.

Computer Science through Concurrent Enrollment: Barriers and Supports to Broadening Participation

Renee Fall
National Center for Computer Science Education
College of St. Scholastica
Saint Paul, MN, USA
rfall@css.edu

Jennifer Rosato
National Center for Computer Science Education
College of St. Scholastica
Duluth, MN, USA
jrosato@css.edu

***Abstract*— CS Principles (AP-CSP) is giving more girls and under-represented students access to CS education, but CSP has not reached all students. Concurrent enrollment (CE), in which students take CE courses in their high school for college credit, is offered in places and to students who may not have access to Advanced Placement. The CS-through-CE project, an NSF-sponsored Research Practice Partnership, aims to broaden participation in computing by piloting and studying CE implementations of Mobile CSP, an effective CSP curriculum that has now been adapted as a college course. Initial research has identified barriers and supports to implementing Mobile CSP as CE in two contexts (rural, low-SES and urban, diverse, low-SES). This poster will present factors that support or impede implementation of CS-through-CE at the external level (e.g., policy, systems, context), the post-secondary CE program level (e.g., instructor qualifications, student eligibility, school outreach), and school/classroom level (e.g., teacher availability, student recruitment, administrator support). We aim to gather feedback on these results, as well as engage with others with experience with or interest in offering CS-through-CE.**

Keywords—Broadening participation, Computer Science Principles, High school-to-College pathways, Education, Computer science education, Educational programs, Pre-college programs, Mobile applications

I. INTRODUCTION

"Broadening Participation and Building Pathways in Computer Science through Concurrent Enrollment" (CS-through-CE) is a three-year project (Oct. 2018 – Sept. 2021) designed to study implementation and outcomes of concurrent enrollment (CE) programs as a vehicle for broadening high-school–to–college pathways in computer science (CS). Funded by the National Science Foundation as a Research Practice Partnership, the project involves CE programs at Capital Community College (CCC) in Hartford, CT and Southwest Minnesota State University (SMSU) and partner schools in each state. Mobile Computer Science Principles (Mobile CSP) is a College-Board–endorsed curriculum aligned with the Advanced Placement (AP) CSP framework. CS-through-CE is adapting Mobile CSP curriculum, assessments, tools, and teacher professional development in order to pilot a CE version of Mobile CSP in two states, training and supporting up to 40 teachers and classrooms over two academic years.

This material is based upon work supported by the National Science Fdn. under Grant Nos.1837723, 1837112, 1836990, 1836983. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

II. TWO MODELS OF ADVANCED COURSES

Advanced Placement courses are a popular way for high schools to provide rigorous college-level coursework to students in many regions. Bringing CSP to schools through AP as a breadth-first introduction to CS that enrolls more diverse students than AP CS A has proven to be a smart strategy. [1] However, not all schools offer AP CSP and not all students choose to take AP courses. Concurrent enrollment—a form of dual enrollment in which high school teachers are credentialed to teach college-credit bearing courses on-site during the school day—offers an alternative to AP as well as to dual enrollment programs where students leave their school to take courses on a college campus.

Both AP and CE are national models for college credit in high school, but they differ in important ways. AP requires a single high-stakes exam and project (usually done in May), whereas in CE courses, grades are based on students' yearlong work. Students finish an AP exam with a score, but with no guarantee that any given college will accept that score as credit for an elective, required, general education or major course. CE students earn college credit on a transcript from the partner college, which in many cases may transfer to other colleges [2]. AP teachers have ". . . no formal requirements or mandatory professional development . . ." [3], while CE teachers must meet the requirements of the post-secondary institution to teach college-credit courses.

The U.S. Department of Education found dual enrollment to have "positive effects on students' degree attainment (college), college access and enrollment, credit accumulation, completing high school, and general academic achievement (high school)," perhaps more so than AP courses [4]. The reach of dual enrollment is broad, extending across rural, suburban, and urban areas in all 50 states, but few high schools offer computer science via CE.

III. RESEARCH DESIGN

This RPP's shared problem of practice is how to implement CS as a CE offering in a way that broadens participation in computing at the transition from high school to college. Initial research questions jointly developed by researchers and practitioners address this shared problem of practice. Guiding Question: Is Concurrent Enrollment an effective model for broadening participation in computing?

978-1-7281-7172-2/20/$31.00©2020 IEEE

- RQ1: What are the supports and barriers to implementing and sustaining Computer Science Principles (Mobile CSP) as a CE course?
- RQ2: Does a CE implementation of Computer Science Principles broaden participation in computing?

As part of an overall mixed-methods design, the initial research on barriers and supports used qualitative methods to gather and analyze interview data from stakeholders as well as documents. Case studies will be developed to understand the two contexts and issues and opportunities in each. The second question will be addressed using quantitative data on school populations and course enrollments to see to what degree CS-through-CE classrooms mirror the demographics of their schools. The ongoing research agenda will develop through an iterative process of research and implementation in practice with the RPP.

IV. PRELIMINARY FINDINGS

Data were gathered through semi-structured interviews with stakeholders identified through purposive sampling, including college CS faculty, CE program leaders, state higher education and K12 officers, teachers, and school administrators and counselors. Fifteen interviews with participants in both states resulted in approximately 18 hours of data. Researchers used an iterative process of thematic analysis along with a context framework. This poster will present findings about barriers and supports to implementing CS-through-CE at three levels: (1) external context (state-level policy, systems, and context); (2) CE program (e.g., instructor qualifications, student eligibility, school outreach); and (3) school/classroom (e.g., teacher availability, student recruitment, administrator support).

V. CONCLUSION

Broadening participation in computing requires not just innovations in tools, curriculum, pedagogy, and professional development. Research is needed to understand the educational systems and policies and their impacts on computing education access, diversity, and inclusion. Concurrent enrollment shows promise as a mechanism to bring equity-focused CS courses to more students. The barriers and supports identified so far by the CS-through-CE project point to policies and practices that might better promote inclusion. In future years, the project plans to create guides or models to support other CE programs to add CS courses to their offerings. Ongoing research will continue to inform how the project addresses the problem of practice: how to implement CS as a CE offering in a way that broadens participation in computing at the transition from high school to college.

REFERENCES

[1] M. J. Madda, “Is the College Board’s New Computer Science Course Closing the Gap?,” *EdSurge*, Feb. 1, 2017. Accessed: Feb. 1, 2020. [Online]. Available: https://www.edsurge.com/news/2017-02-21-is-the-college-board-s-newest-ap-computer-science-course-closing-the-gap

[2] National Alliance of Concurrent Enrollment Partnerships, “What is Concurrent Enrollment?” NACEP. https://www.nacep.org/about-nacep/what-is-concurrent-enrollment/ (accessed Feb. 1, 2020).

[3] College Board, “AP at a Glance,” AP Central. https://apcentral.collegeboard.org/about-ap/ap-a-glance (accessed Feb. 1, 2020).

[4] U.S. Department of Education, Institute of Education Sciences, “Transition to college intervention report: Dual enrollment programs,” What Works Clearninghouse, February 2017. Accessed: Feb. 1, 2020. [Online]. Available: https://whatworks.ed.gov

The Effects of Native Language on Block-Based Programming Introduction: A Work in Progress with Hispanic Population

Pedro Guillermo Feijóo-García
CISE Department
University of Florida
Gainesville, FL, U.S.A.
pfeijoogarcia@ufl.edu

Keith McNamara, Jr.
CISE Department
University of Florida
Gainesville, FL, U.S.A.
kmcnamara1@ufl.edu

Jacob Stuart
CISE Department
University of Florida
Gainesville, FL, U.S.A.
jacobstuart@ufl.edu

***Abstract*— Computer Science (CS) is an English-centric discipline which still needs to explore how cultural factors such as learners' native language may impact the understanding of CS concepts. We evaluated adult participants with no prior coding experience performing tasks in a conventional block-based programming platform: Scratch. We collected data from these interactions and compared between Native-English speakers, and Hispanic speakers who knew English as a Second Language (ESL). Our findings suggest that learners' native language may not impact their ability to come to a proper solution, but it does affect how they interact with block-based environments, when their native language is inconsistent with the language featured in the tool. This pilot study invites the Computer Science Education (CS ED) community to explore how to effectively reach Hispanic and non-English speaking communities, impacting the community outreach in other regions.**

Keywords— CS Education, Computing Education, CS for All, Language-consistency, CS Inclusion, Block-based technologies

I. Introduction

Block-based instructional technologies have been designed for a decade with the premise that they enhance learning outcomes when removing syntax from the environment [1]. Nevertheless, multiple-language support is only available in less than half of the major block-based educational tools (e.g. Scratch, Alice) [2]. This forces non-native English speakers to learn how to program using a different language. The CS ED community has been trying to make Computer Science (CS) more accessible to the public by helping to overcome identified barriers such as cost, age, race and gender gaps, as well as cognitive and physical disabilities. However, the fact that CS literature is typically English-centric, limits it to be a discipline unable to reach non-English-speaking individuals and communities.

Considering that language barriers might cause communication to breakdown, we conducted this pilot study to explore how language-consistency, and the relation between a user's native language and an interface language, between learners and a conventionally used block-based educational tool such as Scratch, can impact learners' performance when responding to a set of programming activities. In order to know whether it is important for these block-based educational tools to support more languages, we must first establish if language-consistency is negatively impacting learners' abilities to grasp coding concepts when using these platforms. We manipulated language- consistency, as our independent variable, with two levels: English-Speaker & English-Interface (EE) and Spanish-Speaker & English-Interface (SE). We hypothesized that the lack of language-consistency between a novice's native language and the interface they use will negatively impact their effectiveness, confidence, and exploration capacity when introduced to block-based programming environments.

II. Relevant Literature

In recent years, there have been studies in the CS ED community that suggest language is a factor that should be considered when designing tools for education. Raj et al. [3] conducted a study to understand if language consistency between the student and the instructor impacted how students learned programming concepts, and Guo [4] found that non-English-speaking students perceived language barriers when learning how to code, and that they wanted instructional materials to use simplified English without culturally-specific slang.

Referring to language-consistency with block-based tools, Dasgupta & Mako [5] pioneered a study with Scratch, finding that novice users who used the tool in their countries' native languages demonstrated a faster learning rate of programming concepts than those users who worked primarily in English. The authors results are based on users from five non-Hispanic countries. Regardless of the high quality of their results, the authors describe limitations due to the method they followed to validate their hypothesis. The lack of control of their sample population in regards to age, gender, native language (which can be different from the country's language), lead to further research initiatives, as our study, to understand how learners' languages impact learning processes in CS.

From our review, language-consistency has been mainly addressed considering classroom environments (i.e. vernacular medium learning), with limited literature referring it in the context of educational tools intended to teach CS concepts.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

Moreover, Hispanic communities have not been reached for this topic. *How do Hispanic individual experience commonly used block-based programming environments? Is language-consistency between the individual and the tool a factor to be considered and scaffolded in block-based learning environments? How should language-consistency be scaffolded in block-based learning environments?* Questions like these are still open, and with this pilot study we contribute to the discussion and to bring language as a factor to consider when addressing CS for All.

III. STUDY DESCRIPTION

A. Participants

Sixteen individuals participated in the study. We had two groups of participants: a control group of native English speakers (n=7), and an experimental group consisting of Hispanic individuals (n=9) who know English as a Second Language (ESL). All participants reported no prior experience using block-based programming tools or text-based programming languages. We designed the study to be gender-balanced: 43.8% of our participants were female, and 56.3% male.

B. Method and Variables

The study began with an introduction to expectations of participation followed by a 30-minute tutorial, a break period, a 15-minute assessment, and then a survey. We ended the study by providing a final survey, asking them to rate their experience using a Likert scale (1-7) for multiple questions, provide demographic information regarding their gender, age, race, and native language, and to give feedback with open ended questions. To verify question completion, we analyzed the video of the screen captured for each participant's test to determine whether the task was completed properly.

Both, the tutorial and the assessment, requested the participants to complete the functionality of two video game setups. The mechanics of both video games were the same, varying exclusively in the video games' contexts.

Language-consistency, our independent variable, has two levels: English-Speaker & English-Interface (EE) and Spanish-Speaker & English-Interface (SE). Our dependent variables are Effectiveness - measured by the number of tasks completed by the participant in the test, Confidence –measured by Likert scale (1-7) responses regarding the participant's self-perceptions, and Exploration - measured by the time (minutes) the participant took to place the first block onto Scratch's canvas.

The tutorial and assessment were provided in English for the native-English-speakers, and in Spanish for the Hispanic participants. This, looking to reduce any confound regarding the instructions given. Guidelines were revised by native speakers in both languages. Both groups interacted with Scratch featured in English.

IV. PRELIMINARY FINDINGS AND DISCUSSION

Hispanic participants answered 7.63 test questions [Mean = 7.63, SD = 3.46], compared to English speakers, who answered 6.83 questions [Mean = 6.83, SD = 2.48]. However, most of the Hispanic participants agreed that their performance would have improved if Scratch was provided to them in their native language. Also, Hispanic participants took longer to make the first interaction with the Scratch canvas, with an average initial block dragged time of 5.65 minutes [Mean = 5.65, SD = 5.81], as compared to English speakers' average 3.52 minutes [Mean = 3.52, SD = 3.37]. We consider that Hispanic participants took longer to make the first interaction due to possible constraints on understanding or exploring the tool. These, referring to qualitative feedback provided by some of them:

- **Quote 1:** "Having Scratch in my native language would have allowed me to understand better the functions of the blocks and save time.".
- **Quote 2:** "I think [typo: it] would be better to explain the meaning of some english [typo: English] words and that's it".
- **Quote 3:** "I needed to understand the interface, and the assignment better, as well as start memorizing where to search for the correct units."

V. DISCUSSION AND CONCLUSIONS

Based on our findings and results, even though the two groups did not score significantly different, the majority of ESL Learners (i.e. Hispanic participants) thought that they would perform better in their native language. This feeling of inadequacy can impact confidence in learning and overtime grow in those who are trying to learn to code when they are non-native speakers of English. We believe the Hispanic participants may have taken more time on average to make their initial interaction due to compounding effects based on a language barrier to understand how to interact. However, this is only a theory, and further research is required to verify it.

This pilot study contributes showing that even ESL speakers struggle when introduced to blocks programming. If they have a difficult time completing relatively simple exercises, then it stands to reason that individuals who do not speak English at all, may struggle more. Next steps of our research will involve non-US Hispanic population, to evaluate if the total lack of English as a second language may be notorious when introducing learners to block-based environments.

REFERENCES

[1] D. Weintrop and U. Wilensky, "To block or not to block, that is the question," *Proceedings of the 14th International Conference on Interaction Design and Children - IDC 15*, 2015.

[2] N. C. Brown, J. Mönig, A. Bau and D. Weintrop. "Panel: Future directions of block-based programming", *Proceedings of the 2016 ACM SIGCSE Technical Symposium on Computing Science Education – SIGCSE 16*. 2016.

[3] A. G. Soosai Raj, K. Ketsuriyonk, J. M. Patel and R. Halverson. "Does Native Language Play a Role in Learning a Programming Language?", *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*. 2018.

[4] P. J. Guo. "Non-native english speakers learning computer programming: Barriers, desires, and design opportunities", *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 2018.

[5] S. Dasgupta, S. and B. M. Hill. "Learning to code in localized programming languages", *Proceedings of the Fourth (2017) ACM Conference on Learning@ Scale*. 2017.

Meninas.comp Project: Programming for Girls in High School in Brazil

Maristela Holanda
Department of Computer Science
University of Brasilia
Brasilia, Brazil
ORCID: 0000-0002-0883-2579

Aleteia P. F. Araujo
Department of Computer Science
University of Brasilia
Brasilia, Brazil
ORCID: 0000-0003-4645-6700

Maria Emilia Walter
Department of Computer Science
University of Brasilia
Brasilia, Brazil
ORCID: 0000-0001-6822-931X

***Abstract*—The field of computing has not been a popular area of study for young women entering the University of Brasilia (UnB). In 2015, female students comprised a mere 5% of the students seeking to enroll in a Computer Engineering major. In an effort to popularize the field of Computer Science among girls in High School, the Meninas.comp Project (Girls.comp, in English) is being carried out in the public high schools of Brasíla, in Brazil. The project is coordinated by female professors from the Department of Computer Sciences at the UnB. This article reports on one of the activities of this project, presenting the hands-on workshop with programming for public high schools. These programming workshops are attended by students from 10th, 11th and 12th grades. The workshops include game programming, robotics and developing apps for mobile phone.**

***Keywords*—Women, Computing, Education, k-12**

I. Introduction

The Department of Computer Science at the University of Brasília (UnB) currently offers three undergraduate degrees related to Computer Science (CS): Bachelor of Computer Science (since 1987), Teaching Computing (since 1997), and Computer Engineering (since 2009). In 1987, when the Bachelor course began, 32% of the undergraduate students were female. However, this number decreased over time and, by 1997, this percentage had fallen to 10%; by 2013 it was only 6%. The Teaching Computing degree ratio oscillates at around roughly 11%, while Computer Engineering, which had already begun with low numbers, has seen them fall to less than 12% in the past three years. In 2015, young women comprised a mere 5% of the students seeking to enroll in a Computer Engineering major.

In 2010, a group of female professors from the Department of Computer Science created the Meninas.comp Project: Computing is a girls' thing too! (https://www.facebook.com/meninas.comp) with the goal of introducing the field of computing to girls in high school. To popularize CS among girls in high school, the Meninas.comp project is being carried out in the public high schools in Brasília, the Capital of Brazil.

Meninas.comp shows the vital role computer science plays in developing the country and encourages girls in high school to enroll in a CS major in their undergraduate programs. The project is comprised of motivational lectures, hands-on classes and the development of the project for high school female students. In this paper, we will describe the hands-on workshops in public high schools. Programming lessons are not included in the curriculum at government high schools in Brazil. Therefore the Meninas.comp project fills this gap by teaching girls programming in public high schools, mainly in disadvantaged areas.

978-1-7281-7172-2/20/$31.00 © 2020 IEEE

II. hands-on Workshops

Female professors and students from the Department of Computer Science at the University of Brasília have given many lectures in the last nine years of the project. These talks take place at the university or in public schools. We have already visited many local high schools in Brasilia and other surrounding sites.

These activities present what CS professionals do, as well as the essential role computing plays in the development of our country. Female professors, professionals and graduate students in Computer Science deliver these lectures.

The Meninas.comp project develops activities such as hands-on workshops for programming, robotics, and electronics for girls' high schools. The classes carried out in this project take place at the university or in public government schools, preferably in disadvantaged areas. We have already visited many local high schools in Brasilia, and other surrounding sites. The classes are:

- In the programming class, the girls use Kodu software [2] to develop a game. Kodu lets the girls create games via a simple visual programming language. This way, with Kodu, the girls create their game without even knowing a programming language.
- In the robotics class, we use Arduino, where the girls build and program their robots. The girls learn coding. Basic programming and electronic concepts are presented. Girls learn to make electronic circuits with basic components, with LEDs, resistors, jumpers, and others;
- Programming classes with MIT App Inventor [3]. During the lessons, the girls learn to code their apps for Android. In Brazil, Android smartphones are very popular.

III. Result and Discussion

Our first hands-on workshop was with Kodu, in 2011. Kodu is the tool to develop games in a playful way. Figure 1 shows the workshop at the National Conference of Science and Technology in Brazil, in 2011. This one hour workshop was repeated many times a day over the week. This workshop happened, also, in different high school in Brasilia.

The second workshop is ”Girls, let’s develop the first app for your cell phone”. In this class, we used the MIT Inventor App. We developed this workshop in the UnB’ laboratories, it’s an opportunity for girls get to know the biggest university in Brasilia. This workshop has been taught since 2015. Female students in Computer Science and Engineering from our department are teachers of these classes (Figure 3).

The third workshop is robotics with Arduino. During the workshop, high school girls without experience in programming learn about LED, C programming and code the first application to do semaphore. At the beginning of the project, professors taught these classes. Nowadays the former school participants of our first courses, who are currently studying CS majors at UnB, are teaching these classes (Figure 2).

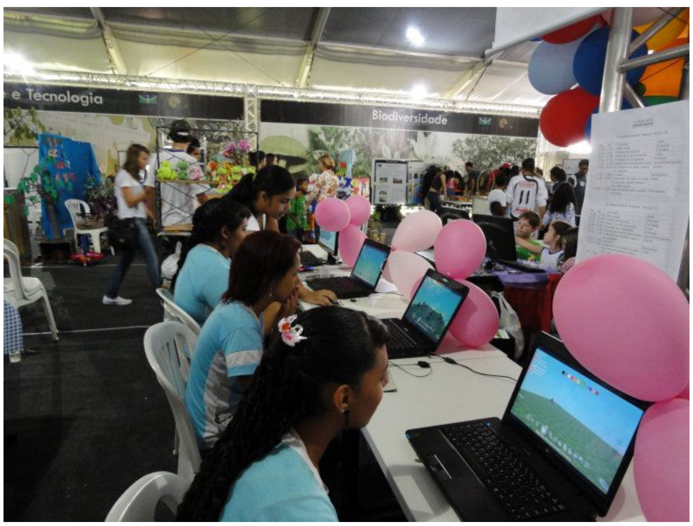


Fig. 1: Kodu Workshop hands-on.

We have developed these workshops many times for nine years, at high school, UnB and events (Campus Party Brasilia, National Conference of Science and Technology in Brazil, and others). We now have six former high school students that they are female students on CS majors at UnB.

IV. Conclusion

The Meninas.comp Project has been operating since 2010 to include girls in Computer Science and Engineering majors at the UnB. Our goal is to empower these girls. Our hands-on workshops have happened, mainly, in the UnB laboratories because that is an opportunity for girls from the disadvantaged areas to get to know the UnB.

It is a challenge to increase diversity in CS majors at UnB. However, in 2018, 23% of the students who enrolled in

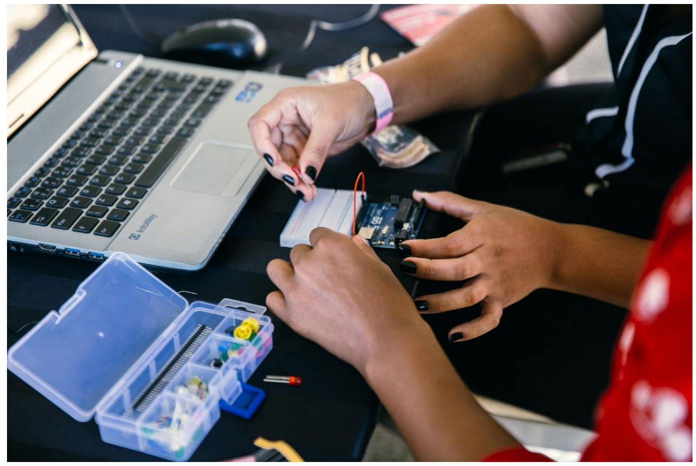


Fig. 2: Arduino Workshop hands-on.

Fig. 3: Android Workshop hands-on.

Computer Engineering are female. This rate is the best since the creation of the major in 2009. Nowadays the teachers of these workshops are, mainly, female undergraduate students of CS majors who did our workshop when they were students in High School.

Acknowledgment

Maristela Holanda thanks Fundação de Apoio a Pesquisa do Distrito Federal (FAP-DF) for supporting this paper, Edital 05/2018 - Bolsa de Pos-doutorado no Exterior, and the Conselho Nacional de Ciência e Tecnologia (CNPq/MCTIC) grants 442789/2018-1 and 440806/2019-4.

References

[1] M. Holanda, A. F. P. Araujo, M, E, Walter. Meninas. comp: Computação também é coisa de Menina. Participacao, vol. A247, pp. 529–551, 2016.
[2] Microsoft Labs. Kodu. Available https://www.kodugamelab.com/.
[3] MIT. App Inventor. Available: https://appinventor.mit.edu/.
[4] M. Holanda, A. P. Favacho, WIT- SBC 2016. Perfil das Alunas no Departamento de Computação da Universidade de Brasília. Women in Information Technology (WIT 2017).

Undergraduate Student Research With Low Faculty Cost

Sindhu Kutty
Division of Computer Science and Engineering
University of Michigan
Ann Arbor, USA
skutty@umich.edu

Mark Guzdial
Division of Computer Science and Engineering
University of Michigan
Ann Arbor, USA
mjguz@umich.edu

***Abstract*—Undergraduates are unlikely to even consider graduate research in Computer Science if they do not know what Computer Science research is. Many programs aimed at introducing undergraduate to research are structured like graduate research programs, with a small number of undergraduates working with a faculty advisor. Further, females, under-represented minorities, and first generation students may be too intimidated or the idea of research may be too amorphous, so that they miss out on these programs. As a consequence, we lose out on opportunities for greater diversity in CS research.**

We have started a pilot program in our department where a larger number of students (close to two dozen) work with a single faculty member as part of a research group focused on Machine Learning and related areas. The goal of this program is not to convince students to pursue a research career but rather to enable them to make a more informed decision about what role they would like research to play in their future.

In order to evaluate our approach, we elicited student experience via two anonymized exit surveys. Students report that they develop a better understanding of what research in Computer Science is. Their interest in research was increased as was their reported confidence in their ability to do research, although not all students wanted to further pursue computer science research opportunities. Given the reported experience of female students, this program can offer a starting point for greater diversity in CS research.

***Keywords*—undergraduate research, research pedagogy, social computing, machine learning**

I. Introduction

Students who have only a second-hand or vague understanding of the Computer Science research process may never seriously consider research as a possible career path. This can hinder engagement from students who are in demographic groups that are under-represented in the field, including women, racial minorities and first generation students.

In this project, we are interested in providing a safe space for students to 'try research on for size'. We aim to provide enough structure to the process so that it is scalable. We hypothesize that we can use this model to target students who may not have had exposure to the idea of research or might have been intimidated by the idea.

978-1-7281-7172-2/20$31.00 ©2020 IEEE

II. Project Description

This project is an educational initiative to introduce undergraduates to research in an environment that is both more scalable and less intimidating than common models of undergraduate research opportunities. Lack of awareness or a self-perceived lack of preparedness may mean that some students miss out on these programs [2]. This program deconstructs the research process via twice-weekly meetings, a guided literature survey and a replication project. Unlike UROP and similar programs, the faculty to student ratio is low (one faculty to 22 students in this offering). Given concerns of high enrollment, this program provides a scalable approach to introduce undergraduates to CS research.

In order to evaluate the effectiveness of our approach, we elicited student experience via two anonymized exit surveys. Students report having a better sense of what is involved in doing CS research despite not having a clear idea previously. They found the level of detail involved in the process challenging but enjoyable.

III. Elements of the Program

This program was advertised to students towards the end of a high enrollment upper-level undergraduate course on Machine Learning taught by one of the authors. The course was run for a duration of 7 weeks with twice-weekly meetings for the first six weeks and a final presentation in the last week. Optionally, students were encouraged to submit a written report of their work. This was an informal course offering: in particular, students received no academic credit or grade for participation in this course.

Elements of this methodology have been used previously in other institutions to engage students with research. Replication projects have been used to teach research in STEM fields, including mathematics, psychology and even computer science (see, for instance, [1]). Reading groups and seminar-style courses typically have assigned readings and presentations. However, we have provided a framework that uses these elements to introduce students to CS research with low per-student faculty cost.

The course focused on recent research results in Machine Learning and Social Computing. A sampling of subtopics were presented in the kick-off meeting. Students then divided into self-selected groups of about 3 each based on topic preferences. If larger groups formed around topics, students were divided into smaller subgroups.

A. Literature Survey Component

To fully immerse students in the field, students do a literature survey of different subareas. The faculty mentor works with each group to pick representative papers for each subtopic, by pointing out some sample results and relevant and reputable conferences. The group that selected the subtopic was responsible for presenting the main results in these papers to the entire cohort. All groups read papers from every subtopic. A template is provided to students to guide them in reading and analyzing the paper, and all groups produce a written summary of papers that they have read that week.

B. Replication Project Component

To engage students in thinking about research contributions, we have students design a replication study. The faculty mentor works with each group to pick an appropriate (set of) result(s) for replication. For instance, students may choose a highly theoretical result and design an experiment to understand the result and test the impact of relaxing the assumptions in the results. The faculty mentor meets with each small group on a weekly basis to discuss their progress and provide feedback on their work. In order to approach this systematically, the tasks are structured so that each week's assignment is of increasing specificity. For instance, one of the first steps may be to delineate the results for replication. In a later week, the task may involve specifying pseudocode to test their hypotheses.

IV. Highlights of Survey Results

There were 22 members of the research group. Two anonymized exit surveys were administered approximately a month and 3 months after the final presentation. We received 19 responses to the first survey and 10 to the second. 3 out of 10 respondents in the second survey were female. As a point of comparison, the general population of female CS undergraduate students at our institution is 22%. We do not have gender data for the first survey.

We elicited students' interest and confidence in doing research via a 5-point Likert scale. Students reported an increased interest and confidence in research. Most students had some exposure to reading research papers but their understanding of what the research process entailed in Computer Science was vague: "*I thought it is involved a lot coding at least and a lot about implementation in real life.*". They were surprised the amount of detail and depth involved in the process: "*The research process focuses a lot more on the thought experiment and ideas behind. The ability of asking interesting question is crucial in research.*". They noted that they had a better understanding of the breadth of applications, likely as a consequence of exposure to interdisciplinary work. They also report having formed a better understanding of the research process: "*Yes, I have a much better idea. Especially after working on a replication project I got a reasonable idea of what CS research looks like.*" and indicate that the course can help other students evaluate whether CS research is right for them: "*Yes I strongly agree that it is helpful regardless of students research status. In previous courses, I feel majority of the time was spent on how to implement the code and following the task instructions. But this reading group really engages me to think about the reasons and broader picture behind it. I enjoy this challenging process.*"

In particular, 2 out of 3 female respondents reported that they definitely saw CS research as part of their future plans. All female respondents also reported having a better sense of what CS research is about due to the program. They reported that the program had helped them decide their plans. All female respondents also report that a student who is not currently interested in research might benefit from such a program: "*If they haven't had that kind of exposure being exposed to research papers and doing these sorts of projects may turn them around if they discover that they enjoy it*"

V. Conclusions and Future Work

After engaging in this program students report that they developed a better understanding of what research in Computer Science is. They reported enjoying the course, indicating a more welcoming environment. Their reported confidence in their ability to do research was increased. Overall, participants also reported having an increased interest in research. All respondents reported that, to varying degrees, it helped inform their post graduation plans. Not all female respondents reported that they necessarily saw CS research as part of their future plans; however, they all reported that the program had helped them decide their plans. All female respondents also reported having a better sense of what CS research is about due to the program and would recommend it to a student who is unsure about CS research. Given the reported experience of female students, this program can offer a starting point for greater diversity in CS research. Ours is an R1 institute with high enrollments in CS. We would like to evaluate the suitability of this approach to different departments with potentially different demographics and cultures. It would also be interesting to explore whether this program can be effectively adapted to other areas of CS than Machine Learning and related subfields.

Acknowledgments

The authors would like to thank Kathryn Cunningham for help with processes related to IRB and the students who participated in the course and provided feedback. The first author gratefully acknowledges the 2019 Course Development Fund, CSE department, University of Michigan.

References

[1] R. Ramanujan. "A.I. as an introduction to research methods in computer science," AAAI '16: Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence. AAAI Press 4128-4129.

[2] M. C. Linn, E. Palmer, A. Baranger, E. Gerard, and E. Stone. "Undergraduate research experiences: Impacts and opportunities," Science. Vol. 347, Issue 6222, 2015.

Evaluating a Cybersecurity Training Program for Non-Computing Major Undergraduate ROTC Students

Naja A. Mack
Computer Science
Morehouse College
Atlanta, GA 30314, USA
naja.mack@morehiouse.edu

Kaylah Mackroy
Psychology
Spelman College
Atlanta, GA 30314, USA
kmackroy@scmail.spelman.edu

Chassidy Cook
Computer Science
Morehouse College
Atlanta, GA 30314, USA
chassidy.cook@morehouse.edu

Robert Cummings
Computer Science
Morehouse College
Atlanta, GA 30314, USA
robert.cummings@morehouse.edu

Tristian Pittman
Computer Science
Morehouse College
Atlanta, GA 30314, USA
tristian.pittman@morehouse.edu

Kinnis Gosha
Computer Science
Morehouse College
Atlanta, GA 30314, USA
kinnis.gosha@morehouse.edu

***Abstract*—There is a rapidly growing demand for individuals in cybersecurity and a deficit of persons able to fill those roles. To help meet this need, students not majoring in computing can be utilized to fulfill this demand by exposing them to data mining, cybersecurity practices, and application of these concepts in the field. This paper presents findings from a twenty-one-week program in which minority undergraduate college students, all members of the Reserve Officer Training Corps (ROTC), were taught computer programming, natural language processing, data visualization, and computer vision fundamentals. Midshipmen and cadets used their newly gained knowledge, teamwork, planning, and communication skills to develop a threat detection prototype using publicly available social media data. Results from pre and post python assessments and post-program interviews that recorded participant attitudes and self-efficacy are reported to highlight the program's effectiveness.**

***Keywords*—cybersecurity, data mining, culturally relevant, non-computing majors, rotc, training program**

I. Introduction

Unlike the first wars that were fought with sticks and stones, modern warfare is a high-tech battlefield where social media has emerged as a surprising — and effective — weapon [1]. From the online recruitment of civilians for terror groups, such as ISIS, to Russian hacking to disrupt the American election; states and nonstates have found a way to weaponize social media as a means to influence the digital population [1]. They now have the power to target people within a society, influence their beliefs and behaviors, and diminish trust in the government and public institutions [2]. To win these unorthodox wars, early threat detection is key; however, with a 2.93 million deficit of cybersecurity professionals, detecting cyber threats early on is unlikely [3]. To fill this growing gap, defend against cyber threats, and strengthen our nation's cyber forces, many institutions have begun to implement cyber education to provide all educated individuals a level of cyber education appropriate for their role in society [4].

II. Program Overview

The program was an intensive twenty-one-week, fall, and spring application of a product-oriented research-and-development program that enabled ROTC midshipmen and cadets to contribute technically to cyber and electronic warfare. The cohort consisted of fifteen ROTC students (seven male and eight female) that were primarily non-computing majors; only one was a Computer Science major. Traditional class sessions were held once a week for 3 hours to ensure the program's progression and the completion of the prototype. The program was facilitated by an African-American female research scientist and three African-American male undergraduate research assistants, all with computing backgrounds. At its core, the program taught fundamental programming concepts and the Python programming language. The program further emphasized cybersecurity and data mining techniques that aided students in developing a prototype tool.

Throughout the program, ROTC students were assigned select lessons from an online Python course to complete. Class time was split into two parts: lecture and working sessions. Lectures were presented via powerpoint slides and included live coding practice exercises where students volunteered or were called upon randomly to solve problems with the assistance of their peers. Working sessions were used to start individual weekly homework assignments, practice concepts covered in class, and clear confusion on Python concepts. After the midshipmen showed that they had mastered the basics, class sessions became strictly working sessions where teams worked together on making their respective parts of the tool deliverable.

978-1-7281-7172-2/20$31.00 ©2020 IEEE

III. Results

To measure the significant difference between the Python pre- and post-assessment, a paired-samples t-test was conducted. Fifteen participants completed the entirety of the pre-test and post-test. There was a significant difference between the pre-assessment (M=56.07, SD=16.99) and post-test (M=83.47, SD=10.55), t(14)=6.555, p=0.001 (uppertail).

A. Post-Program Interviews

After the program ended, all of the ROTC students were asked a series of qualitative questions that would allow them to articulate their experience in the program. The answers collected from the student interviews imply several findings. The first being that students were knowledgeable of the diversity gap in the computer science field, and because of this, they were obliged to have space where they could work alongside other minorities. One midshipman explained how being around other minority ROTC students that were excelling in the program encouraged her to do better. She also mentioned that she had not heard much about cybersecurity prior to this program. Providing an opportunity for an underrepresented group of students to engage with each other in a field that lacks minority representation presented the students with a distinctive experience in the computer science field.

The second finding to be implied was that the program influenced the students' career choices by exposing them to computer science; thus, making them want to pursue careers in cybersecurity. A student spoke about attending a workshop and how it made him realize that tech companies such as Dell are doing their part in trying to diversify the computer science field. By hosting this workshop that allowed the students to meet an African American female former Defense Intelligence Agency CIO/Dell Executive Fellow, reassured the students that even if they did not have a background in computer science, they were not excluded from careers in the field.

Lastly, a common reoccurrence throughout the interviews was the change of the students' attitudes towards computer science. Many of these students gained a newfound respect for the computer science field. Through the program's team project students were able to better understand why the need for cybersecurity is so critical. A student expressed during the interview that initially before being a part of this program he thought computer science was not that serious of a major. Now after designing a tool that centers around cybersecurity he sees the importance of it.

IV. Discussion

Interactive Learning techniques were used throughout the program to ensure knowledge retention. These techniques included pre- and post-assessments, class assignments, homework, group assignments, and quizzes. The program was designed as a multidisciplinary program [5] allowing students to receive computer programming (via Python), cybersecurity, and data mining training through relevant subject matters [5].

To support non-CS majors and underrepresented minority students, the program was developed to be relevant, engaging, original, and vibrant [6]. Students discussed possible careers in cybersecurity and their affinity towards operational security. Students also discussed being more aware of real cyber threat scenarios that could affect them and the military as a profession.

Interactive computer science and cybersecurity programs are suggested to strengthen cybersecurity performance and identity [7]. Cybersecurity and data mining interests and attitudes remained relatively the same from the beginning to the end of the program, though there were a few students who considered taking a computer science course or even minor in computer science. The program was, however, effective at teaching students computer programming. According to the interviews, the program also fostered growth in student initiative and the ability to self-teach.

V. Conclusion

It is important to have initiatives such as the program discussed to expose undergraduate students to cybersecurity and data mining. This program showed promising results in finding cybersecurity and data mining to be important, and for some, a potential career path. The program also improved undergraduate performance in computer programming, where all students but one were not computer science majors. Future programs can explore the impact of their individual activities and projects to further improve the program's effectiveness and pique student interest in cybersecurity. Further research can benefit from these findings in developing programs to introduce and expose computer programming, cybersecurity, and data mining to non-major students as well as to further explore the impact of being a non-major, minority, and military-affiliated in learning computer and data science.

References

[1] P. W. Singer and E. T. Brooking, *LikeWar: The Weaponization of Social Media*. Eamon Dolan Books, 2018.

[2] J. Prier, "Commanding the trend: Social media as information warfare." *Strategic Studies Quarterly*, vol. 11, no. 4, 2017.

[3] "Cybersecurity professionals focus on developing new skills," Feb 2019. [Online]. Available: https://www.isc2.org/-/media/ISC2/Research/2018-ISC2-Cybersecurity-Workforce-Study.ashx?la=enhash=4E09681D0FB51698D9BA6BF13EEAB FA48BD17DB0

[4] E. Sobiesk, J. Blair, G. Conti, M. Lanham, and H. Taylor, "Cyber education: a multi-level, multi-discipline approach," in *Proceedings of the 16th Annual Conference on Information Technology Education*. ACM, 2015, pp. 43–47.

[5] M. E. Locasto, A. K. Ghosh, S. Jajodia, and A. Stavrou, "The ephemeral legion: producing an expert cyber-security work force from thin air," *Communications of the ACM*, vol. 54, no. 1, pp. 129–131, 2011.

[6] Z. J. Wood, J. Clements, Z. Peterson, D. Janzen, H. Smith, M. Haungs, J. Workman, J. Bellardo, and B. DeBruhl, "Mixed approaches to cs0: Exploring topic and pedagogy variance after six years of cs0," in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*. ACM, 2018, pp. 20–25.

[7] M. M. Jethwani, N. Memon, W. Seo, and A. Richer, ""i can actually be a super sleuth": Promising practices for engaging adolescent girls in cybersecurity education - monique m. jethwani, nasir memon, won seo, ariel richer, 2017." [Online]. Available: https://journals.sagepub.com/doi/abs/10.1177/0735633116651971? journalCode=jeca

Does a Computer Science Graduation Requirement Contribute to Increased Enrollment in Advanced Computer Science Coursework?

Steven McGee
The Learning Partnership
Chicago, IL, USA
mcgee@lponline.net

Randi McGee-Tekula
The Learning Partnership
Chicago, IL, USA
Rmcgee@lponline.net

Jennifer Duck
The Learning Partnership
Chicago, IL, USA
jenn@lponline.net

Lucia Dettori
DePaul University
Chicago, IL, USA
lucia@cdm.depaul.edu

Ronald I. Greenberg
Loyola University Chicago
Chicago, IL, USA
rig@cs.luc.edu

Andrew M. Rasmussen
Chicago Public Schools
Chicago, IL, USA
arasmussen@cps.edu

Erica Wheeler
Chicago Public Schools
Chicago, IL, USA
ewheeler6@cps.edu

Adam Shelton
The Learning Partnership
Chicago, IL, USA
aqshelton@lponline.net

***Abstract*—Prior research has shown that students pursuing Exploring Computer Science (ECS) as their first elective course were more likely to pursue another computer science course in high school, as compared to students who took a traditional course as the first course. This study investigated whether the results are consistent when students are pursuing ECS to fulfill the Chicago Public Schools' graduation requirement. ECS is designed to foster deep engagement through equitable inquiry around computer science concepts. It is hypothesized that students who are fulfilling a graduation requirement will pursue additional computer science coursework at rates similar to students who were pursuing ECS as an elective course.**

***Keywords*—Exploring Computer Science, high school computer science, graduation requirement**

I. Introduction

A key strategy for broadening CS participation in the Chicago Public Schools (CPS), where a majority of students are Hispanic or African-American, has been the enactment of a high school CS graduation requirement in 2016 [1]. The Exploring Computer Science (ECS) curriculum and professional development (PD) program [2] serves as a core foundation for supporting enactment of this policy. ECS seeks to contribute to broadening the participation of women and minorities and increasing equity in the field of computer science through activities designed to engage students in computer science inquiry around meaningful problems [2]. The genesis of the work that led to the graduation requirement started four years earlier in 2012 with a teacher-led initiative bringing together CPS teachers, CPS administrators, educational researchers, and university faculty. The partnership, which became known as the Chicago Alliance for Equity in Computer Science (CAFÉCS), brought the ECS curriculum and PD program to Chicago [3]. Implementation of ECS in Chicago started out as a voluntary program. It quickly grew to include around 4600 students in the year before the graduation requirement. Almost half of the students who took ECS as an elective class (43%) went on to take additional high school computer science coursework, compared to one quarter of the students (26%) who started with a different computer science class [4].

While the demographics of students taking ECS reflected the demographics of the district as a whole [5], there was an uneven distribution of schools that were offering the course, due to the voluntary nature of participation. The enactment of the graduation policy had an immediate effect. In the first year of the policy implementation, the number of students taking ECS increased to just over 8000. However, the shift from computer science as an elective course to a graduation requirement changed the nature of who is taking ECS. A significant number of the students are taking ECS because it is a requirement, which could influence their motivation to take additional computer science coursework.

The graduation requirement has also changed the nature of who is teaching ECS. Prior to the graduation requirement, the majority of the ECS teachers had a background or certification in computer science. Starting in the first year of the graduation requirement implementation, the majority of the teachers had a background in other STEM disciplines, such as math or science [6]. While the ECS PD program is designed to accommodate teachers with little computer science background, prior research has not examined the extent to which teachers' backgrounds is related to student success in the ECS course. Our research is guided by the following research questions:

1) Is the rate at which ECS students take additional CS coursework after the graduation requirement consistent with the rate prior to the graduation requirement?
2) To what extent does the teacher's level of CS background

This research was supported by National Science Foundation grant numbers CNS-1738572, CNS-1738776, CNS-1738691, CNS-1738515, DRL-1640215, CNS-1542971, and CNS-1543217.

978-1-7281-7172-2/20$31.00

correlate with the rate at which students take additional coursework?

II. Methods/Data

A. CPS District Data

Through a data sharing agreement with the district, we were provided with data about the students in this sample. The district provided the certification area and experience teaching ECS for teachers who taught ECS, along with students' cumulative GPA for the year they completed ECS, their ECS course grade, grade level, and demographic information about race, gender, and designation as special education, English Language Learner, and/or free or reduced lunch participation. The district also provided information about any subsequent computer science courses students completed in the years after completing ECS. This last variable will be the dependent variable for the study to provide evidence on whether future course taking for students who took ECS as a requirement is consistent with students who took ECS as an elective.

B. Population

This study took place during the 2016–17 through 2018–19 school years. Since the freshman class who entered CPS during the 2016–17 school was the first class to whom the requirement applied, the study focused on students who entered as freshman in 2016–17 or 2017–18 and examined whether they took another CS class in subsequent years. The population was further narrowed to include only those students at neighborhood schools that offered additional CS coursework. In addition, students participating in Career and Technical Education or the International Baccalaureate program were excluded since those students were eligible to waive the requirement. There were 2105 students in the sample. Of the original 2105 observations, 546 were omitted due to missing data. Observations with any missing data were removed and no imputation was performed, leaving 1559 observations for the analysis. Each observation was a unique student who each had one of 30 unique ECS teachers.

III. Results

The overall rate at which students took additional CS coursework during the study period was 13%. Since students were nested within classes, we conducted multilevel linear modeling on the probability of taking another CS course using R version 3.6.2 and version 1.1–21 of the lme4 package. A Generalized Linear Mixed-Effects model was fit using a binomial family probability distribution and a logit link function to predict the log odds of a student taking more than one computer science course. Fixed effects at the student and teacher level with random intercepts by teacher were measured. The results are in Table I. The statistically significant variables are bolded. All of the teacher level fixed effects were insignificant, with student gender and cumulative GPA being the only significant student fixed effects. Students who were female were about half as likely to take a second computer science course as males. Students with a higher GPA were about 7% more likely to take additional CS coursework for each 1 point their GPA was above average.

TABLE I
RESULTS OF LOGISTIC REGRESSION PREDICTING WHETHER STUDENTS TOOK ANOTHER COMPUTER SCIENCE COURSE

Independent Variables	Probability of Taking More CS
Constant	**-1.04***
Teacher Characteristics	
CS Background	-0.73
ECS Teaching Experience	0.13
Achievement	
GPA	**0.33***
Course Grade	0.14
Race	
African American	-0.08
Hispanic	-0.29
Female	**-0.58*****
Special Population	
Special Education	-0.44
ELL	-0.32
Free or Reduced Lunch	-0.28
Attendance	0.13

Significance Levels: 0.05 = *; 0.01 = **; 0.001=***

IV. Conclusions

The results indicate that students subject to the graduation requirement took additional CS coursework at a much lower rate (13%) than students who took ECS as an elective (43%) [4]. However, the total number of students taking ECS has significantly increased, so the total number of students taking additional CS will also continue to increase. As ECS continues to expand in CPS, an increasing number of teachers will be teaching ECS with limited CS background. The background of the teacher did not influence the extent to which students took additional coursework. The results of this research will be directly applicable to informing efforts to use ECS as a means to broaden participation in computer science.

References

[1] L. Dettori, R. I. Greenberg, S. McGee, D. Reed, B. Wilkerson, and D. Yanek, "CS as a graduation requirement: Catalyst for systemic change," in *SIGCSE '18*. Association for Computing Machinery, Feb. 2018, pp. 406–407, Baltimore, MD. https://doi.org/10.1145/3159450.3159646.

[2] J. Goode, J. Margolis, and G. Chapman, "Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model," in *SIGCSE '14*. Association for Computing Machinery, 2014, pp. 493–498.

[3] D. Reed, B. Wilkerson, D. Yanek, L. Dettori, and J. Solin, "How Exploring Computer Science (ECS) came to Chicago," *ACM Inroads*, vol. 6, no. 3, pp. 75–77, Sep. 2015.

[4] S. McGee, R. McGee-Tekula, J. Duck, L. Dettori, D. Yanek, A. Rasmussen, R. I. Greenberg, and D. F. Reed, "Does Exploring Computer Science increase computer science enrollment?" in *American Educational Research Association (AERA) Annual Meeting*, Apr. 2018, New York, NY. https://www.academia.edu/36446926.

[5] S. McGee, R. McGee-Tekula, L. Dettori, A. M. Rasmussen, and R. I. Greenberg, "Research methods for reaching urban students from groups underrepresented in STEM disciplines," in *Navigating Challenges in Qualitative Educational Research: Research, Interrupted*, 1st ed., T. Ruecker and V. Svihla, Eds. Routledge, 2019, ch. 3, pp. 26–38.

[6] S. McGee, L. Dettori, R. I. Greenberg, A. M. Rasmussen, D. F. Reed, and D. Yanek, "The changing profile of ECS teachers," in *SIGCSE '20*. Association for Computing Machinery, Mar. 2020, Portland, OR.

Basic Code Understanding Challenges for Elementary School Children

Olivia M. Nche
School of Computing
Clemson University
oncheey@g.clemson.edu

Raquel Boulware
Business Development
Claflin University
rboulware@claflin.edu

S. Megan Che
College of Education
Clemson University
sche@clemson.edu

Eileen T. Kraemer
School of Computing
Clemson University
etkraem@clemson.edu

Murali Sitaraman
School of Computing
Clemson University
msitara@clemson.edu

Victor B. Zordan
School of Computing
Clemson University
vbz@clemson.edu

***Abstract*— We describe a research study aimed at understanding the basic code reasoning challenges of elementary school children. The research targets third to fifth grade African American students as a step towards making computer science accessible to all children. The study was conducted in a summer camp with 40 students and replicated with 20 new students the following summer. Also participating in the second summer camp were 19 returning students. For data collection, the study uses code-tracing activities involving concepts such as variables, assignments, operators, and sequencing. Performance data is automatically collected in the background as children engage in the activities incorporated in a video game and also through think-aloud sessions. Results include common code understanding challenges for all children.**

Keywords*— *Broadening participation, K-12 education, coding, game, summer camp, coding concepts

I. Introduction and Related Work

Several efforts have been directed towards strengthening the computing pipeline, yet under-representation remains a challenge. As a result, endeavors to include traditionally underrepresented groups play a critical role in broadening participation [1]. In this research, we target African American children not only to include them in the quest to gain computing knowledge, but also to understand how they reason about fundamental CS concepts and what their challenges are. Findings from prior studies indicate that most beginning students struggle with understanding fundamental CS concepts [2]. It has been argued that if students cannot read and understand small fragments of code, it is highly unlikely that they can write comparable pieces of code [3]. Furthermore, if students are grounded in fundamental concepts, they are more likely to succeed even if computing paradigms change [4]. In this study, we explore challenges related to fundamental coding concepts and tracing snippets of pseudo-code.

978-1-5386-5541-2/18/$31.00 ©2020 IEEE

Several studies target broadening participation [1] with the goal of including as many students as possible in computing education. These endeavors range from direct interventions in classrooms to extracurricular settings like summer camps, workshops and roadshows. Studies show that summer camps can be beneficial in engaging underrepresented groups [5]. Kumar [3] conducted a study to investigate whether solving code tracing problems could help improve students' code writing skills. He observed a statistically significant improvement in code writing skills when the students first engaged in code tracing problems. Another study found that practicing line-by-line tracing helped improved tracing skills for students [6]. We incorporate code tracing activities in a game, because games are fun and engaging, and have been shown to be beneficial in learning [7].

II. Research Experiment Summary

In this study, we aim to answer the following question: What are the basic code understanding obstacles that elementary students face?

The study was first done in the summer of 2018 with about 40 students from the lowcountry of coastal South Carolina. The participants were about evenly distributed between males and females. The students were divided into two groups that met twice a week for two hours for a total of four contact hours per week per cohort. In the summer of 2019, another set of 39 students registered to attend the summer camp of whom 19 were returning students. We divided the entire population into two cohorts with all returning students in one group and the new students in another. This was done to help us tailor our curriculum accordingly.

This curriculum was tailored around a detailed taxonomy which we conceived [8], based on the work of Rich, et al., which presents K-8 learning trajectories [9]. The taxonomy identifies individual coding concepts and is rationalized as follows. Code containing a single assignment statement is introduced first. Then the concept of sequencing of assignment statements is presented. After that, arithmetic operators and Boolean operators are introduced.

This study was facilitated by a custom built video game which we designed [10]. Following the lessons in class, students played this video game. There were a total of three modules for both the curriculum and the game. Module 1 was dedicated to assignments, sequence, variables (types) and operators. Module 2 focused on conditionals, and module 3 on loops. This study reports results based on the data from the first module only. Each module in the game contained 5 levels and each level had 5 questions that focused on the specific concepts. The questions were designed to focus on the specific concept that each level targets. The questions per level were variations the same concept.

The think-alouds were different from standard think-alouds in that the students were prompted to explain the reasoning behind their answer choices as they played a version of the game. This game version had only five questions which combined multiple concepts.

III. Results

A. Quantitative analysis of basic coding challenges

Analysis of the game data revealed different mean scores for different concepts. Sequencing of assignments and operators were the concepts with the lowest mean scores.

B. Qualitative analysis of basic coding challenges

The think-aloud studies also revealed that students struggled with operators and sequence of assignments. We illustrate their reasoning with examples:

Correct thought process (about a sequence of assignments). Amongst the students who answered the sequence question correctly, some explained that "the second statement is the only (one) to consider." This shows that these students have grasped the concept of order to some extent. Others explained that "when you put a value in, if you put a different one in, the first one is gone."

Incorrect thought process. Some students who did not understand sequencing of assignments solved a nonexistent problem, for example, by assuming that the "assignment statements are cumulative." For the question shown below, a student just added or subtracted everything in both assignments in some order, and picked an answer.

book_box $\longleftarrow 6 + 2$;

book_box $\longleftarrow 5 - 1$;

How many books are in the book_box?

A. 8 B. 5 C. 6 D. 4 E. Don't know

Another student used the process of elimination of choices and mentioned "round." When a wrong answer choice which a student expected was not available, the student decided to find a choice that was close to their expected answer.

Correct thought process, wrong answer. Some students thought about the problem correctly, stating that the second sequence statement is the correct one to focus but choose a wrong answer. The problem had to do with arithmetic mistakes, but not with understanding a sequence of assignments. For example, for the above question, they picked 6 as an answer choice because they evaluated 5 - 1 incorrectly as 5 + 1. We noticed this trend in later conditional questions where the student evaluates the condition correctly but pick the wrong answer because of arithmetic mistakes.

Finally, in the think-alouds, students also had difficulty with relational operators and Boolean operators.

IV. Conclusions and Future Directions

This research focused on understanding basic code reasoning challenges for elementary African American school children by engaging them in fundamental concepts in a lecture format and providing an avenue for practice and assessment via a video game. A key goal in the study was to pinpoint potential challenges that children might face. We found that students struggled with sequencing of assignments and all operators. A continuation of this work will be to carry out similar studies to pinpoint challenges that middle and high school students might face with computing concepts.

Acknowledgments

This work was funded in part by a grant from Boeing SC and by NSF grant 1738760.

References

[1] J. Margolis, J. J. Ryoo, C. D. Sandoval, C. Lee, J. Goode, and G. Chapman, "Beyond access: Broadening participation in high school computer science," *ACM Inroads*, vol. 3, no. 4, pp. 72–78, 2012.

[2] M. Piteira and C. Costa, "Learning computer programming: study of difficulties in learning programming," in *Proceedings of the 2013 International Conference on Information Systems and Design of Communication*, pp. 75–80, ACM, 2013.

[3] A. N. Kumar, "A study of the influence of code-tracing problems on code-writing skills," in *Proceedings of the 18th ACM conference on Innovation and technology in computer science education*, pp. 183–188, ACM, 2013.

[4] A. Schwill *et al.*, "Fundamental ideas of computer science," *Bulletin-European Association for Theoretical Computer Science*, vol. 53, pp. 274–274, 1994.

[5] K. Sung, K. Gourd, A. McMahon, K. Mansoor, and R. Gaggero, "A collaborative course for learning how to teach summer java coding camps," in *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, pp. 515–520, ACM, 2018.

[6] S. Erete, N. Pinkard, C. K. Martin, and J. Sandherr, "Exploring the use of interactive narratives to engage inner-city girls in computational activities," in *2016 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*, pp. 1–4, IEEE, 2016.

[7] D. R. Michael and S. L. Chen, *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade, 2005.

[8] O. M. Nche, E. Colbert-Busch, M. Sitaraman, and V. B. Zordan, "Presenting cs concepts through multiple representations to engage african-american elementary school children,"

[9] K. M. Rich, C. Strickland, T. A. Binkowski, C. Moran, and D. Franklin, "K-8 learning trajectories derived from research literature: Sequence, repetition, conditionals," in *Proceedings of the 2017 ACM conference on international computing education research*, pp. 182–190, ACM, 2017.

[10] O. M. Nche, J. Welter, S. M. Che, E. T. Kraemer, M. Sitaraman, and V. B. Zordan, "Codetracesure: Combining gaming, cs concepts, and pedagogy," in *RESPECT 2019*, IEEE, 2019.

Educational Initiatives to Retain Hispanic/Latinx Students in Computing: A Systematic Literature Mapping

Keishla D. Ortiz-Lopez
Texas A&M University
College Station, TX, USA
keishla.ortiz4@tamu.edu

Maristela Holanda
Texas A&M University
College Station, TX, USA
mholanda@tamu.edu

Richard Furuta
Texas A&M University
College Station, TX, USA
furuta@tamu.edu

Dilma Da Silva
Texas A&M University
College Station, TX, USA
dilma@tamu.edu

***Abstract*—Diversity in Computer Science and Engineering (CSE) majors has been a challenge in the US. Women, Hispanic/Latinx, Black/African American, and Native American students are minorities in CSE majors. Most universities and organizations have worked on outreach activities to these underrepresented minorities (URM). In this context, this paper presents a systematic literature mapping on educational initiatives in higher education for retention of Hispanic/Latinx students in CSE majors reported in the last ten years (2009-2018). The methodology was based on a systematic literature review protocol using four academic databases: Scopus, Web of Science, ACM Digital Library and IEEE Xplore. We found 76 papers about educational initiatives in CSE majors to retain URM students that include Hispanic/Latinx students. We classify the papers to get relevant information about institutions, type of educational initiatives, main conferences, and present these findings in this paper.**

***Keywords*—computer science education, underrepresented minorities, diversity, hispanic, latinx, literature mapping, educational initiatives, retention**

I. Introduction

Despite all the efforts made to recruit and retain people from underrepresented groups in Computer Science and Engineering (CSE) majors in the US, it is still a challenge. Women, Hispanic/Latinx, Black/African Americans and Native Americans are part of the larger groups of underrepresented minority groups (URM) in CSE majors. According to the CRA Taulbee survey from 2018 [1], 11.1% of the students enrolled in 2017 in a Bachelors program in CSE are Hispanic/Latinx, but only 8.4% of Bachelor degrees in CSE were awarded in that year to students belonging to this URM group.

In this context, we present a systematic literature mapping about educational initiatives in higher education implemented or proposed in CSE majors and reported in the last ten years (2009 to 2018, inclusive) focusing on or including Hispanic/Latinx students, the largest ethnic minority group in the US [2].

978-1-7281-7172-2/20/$31.00

II. Methodology

We used a systematic literature review protocol following the guidelines presented in [3] with four academic digital libraries indexing conferences in CSE Education: Scopus, Web of Science (WoS), IEEE Xplore, and ACM Digital Library. We chose 76 papers using the search string shown in Figure 1 and the following inclusion criteria: full papers, US only papers written in English, higher education level interventions, and papers including Hispanic/Latinx students.

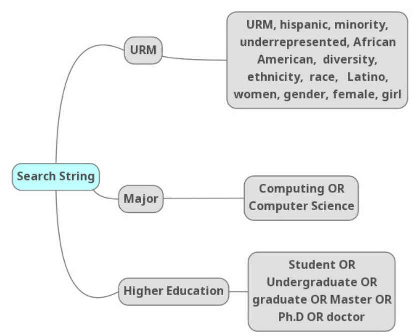


Fig. 1. Search string components.

III. Initial Results

In this section, we present and discuss the results obtained from the 76 papers that focus on educational initiatives to retain Hispanic/Latinx students. Table I lists all the conference names with their abbreviations.

Figure 2 illustrates the frequency of the papers found by conferences and year (2009-2018), where the colors represent the years. The top five conference sources are: ASEE, SIGCSE, FIE, ITiCSE, and SIGITE. 76.92% (50 papers) of the conference papers are from ASEE, SIGCSE, and FIE, which provide opportunities to professors in CSE Education to document interventions at their institutions to retain specific groups of students, including URM groups.

Figure 3 shows the number of papers per state. The figure does not include the US territory Puerto Rico (PR), but we

TABLE I
CONFERENCES NAMES WITH THEIR ABBREVIATIONS.

Abbreviation	Name
ASEE	American Society for Engineering Education
CSEET	Conference on Software Engineering Education and Training
FIE	Frontiers in Education Conference
ICCSE	International Conference on Computer Science and Education
ICER	International Computing Education Research
INTED	International Technology, Education and Development Conference
ITiCSE	Innovation and Technology in Computer Science Education
RESPECT	Research in Equity and Sustained Participation in Engineering, Computing, and Technology
SIGCSE	Special Interest Group on Computer Science Education
SIGITE	Special Interest Group of Information Technology Education
TAPIA	Richard Tapia Celebration of Diversity in Computing

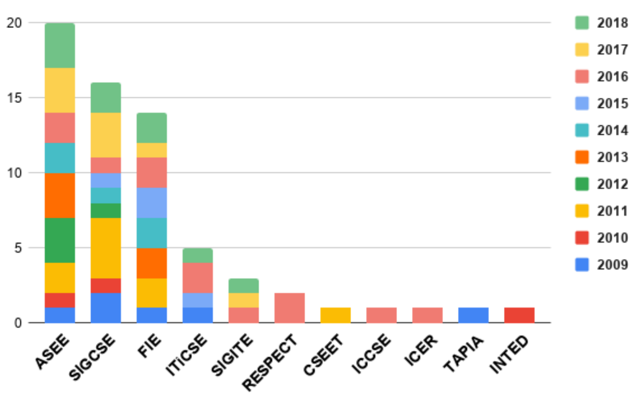


Fig. 2. Number of papers found by conference and year.

found two papers with educational initiatives implemented in PR [4, 5]. This is important to mention since in PR 98.9% of the population identifies as Hispanic/Latinx[6]. We can see in Figure 3 that these interventions have been implemented or proposed in states with the highest number of people that identify as Hispanic/Latinx [2]. In total, 85 institutions implemented or proposed these educational initiatives, of these 27 (31.76%) are in the top 100 institutions in CSE [7].

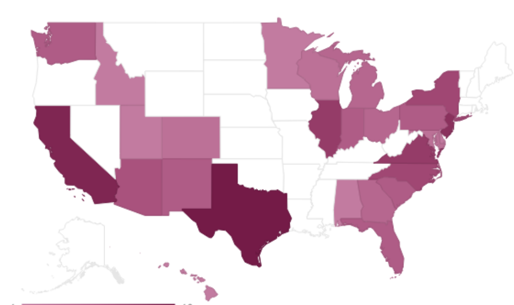


Fig. 3. Number of papers per state (all states, except US territories).

Another result worth mentioning is that 15.58% of the papers focused only in Hispanic/Latinx and the rest of the papers included all URM groups (i.e., Hispanic/Latinx, Native Americans and Black/African Americans). However, 23.28% of the papers did not specify which URM groups they are referring to. Recall that URM groups, not only include people from certain race/ethnicity, but also may include people with disabilities or from the LGBT community. Those papers instead referred to URM groups using general terms, e.g., underrepresented, minorities, non-Caucasian, non-White, non-traditional CSE students, and other related terms.

Lastly, there are more institutions working on retention of URM students (possibly including Hispanic/Latinx) that do not document their interventions in conferences. We believe it is important to always document any possible intervention so researchers in CSE Education can be aware of these results.

IV. DISCUSSION

In this paper, we present a literature mapping aiming to provide an overview about educational initiatives implemented or proposed to retain Hispanic/Latinx students in CSE majors. We show that there is recent evidence of these interventions in states with the highest number of Hispanic/Latinx populations in conferences in CSE Education. We also identified papers that did not specify which URM groups they targeted, but since Hispanic/Latinx are the largest ethnic minority group in the US [2], we did not exclude them from the results presented in this paper.

Future work include improving our search string such that all URM groups are specified and to broader our analysis to incorporate other URM groups. In particular, we want to broader the evaluation of interventions to determine if they were limited based on race/ethnicity or if they also were focused on any other variable(s) such as gender, socioeconomic status, etc.

ACKNOWLEDGMENT

Maristela Holanda thanks the FAPDF, Brazil, for the post-doctoral grant. Edital UnB/DPG 05/2018.

REFERENCES

[1] S. Zweben and B. Bizot, "2018 Taulbee Survey," Computing Research Association, 2019, referenced on 10/10/2019. [Online]. Available: https://cra.org/resources/taulbee-survey/

[2] R. Hernández-Nieto and M. C. Gutiérrez, "Hispanic Map of the United States 2017," *Informes del Observatorio / Observatorio Reports*, Nov. 2017.

[3] B. Kitchenham and S. Charters, "Guidelines for Performing Systematic Literature Reviews in Software Engineering," Keele University and Durham University, Tech. Rep. EBSE 2007-001, 2007.

[4] A. Q. Gates *et al.*, "The Computing Alliance of Hispanic-Serving Institutions: Supporting Hispanics at Critical Transition Points," *ACM Transactions on Computing Education*, vol. 11, no. 3, pp. 1–21, Oct. 2011.

[5] L. Delgado Vazquez *et al.*, "Integrated educational research and technical experiences to draw females students into the energy systems area: The UPRM experience," in *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*. Madrid, Spain: IEEE, Oct. 2014, pp. 1–6.

[6] "Census Bureau," referenced on 10/10/2019. [Online]. Available: https://www.census.gov/quickfacts/PR

[7] "Top Universities," Quacquarelli Symonds Limited, referenced on 10/10/2019. [Online]. Available: https://www.topuniversities.com/

Exploring Issues of Gender Equity in Girls' Out-of-School Time STEM Engagement

Pooja Upadhyay
Technology for Social Good
DePaul University
Chicago, IL
poojaupadhyay92@gmail.com

Mikaela Coleman
Technology for Social Good
DePaul University
Chicago, IL
mcolem31@mail.depaul.edu

Anna Bethune
Digital Youth Network
Northwestern University
Chicago, IL
AnnaBethune2018@u.northwestern.edu

Denise Nacu
Technology for Social Good
DePaul University
Chicago, IL
dnacu@cdm.depaul.edu

Sheena Erete
Technology for Social Good
DePaul University
Chicago, IL
serete@cdm.depaul.edu

Nichole Pinkard
Digital Youth Network
Northwestern University
Chicago, IL
npinkard@digitalyouthnetwork.org

***Abstract*- Inequitable STEM participation among minoritized girls is a current and critical problem. Prior research has highlighted the importance of the middle-school age years as an important time for youth for interest identity development in science and math. Middle-school is often the stage at which youth begin their journey towards STEM careers. However, girls' STEM participation can be thwarted by gender discrimination, lack of external support, and socio-economic factors. Out-of-school-time (OST) activities are often designed to overcome these barriers. While the research on the barriers and challenges to participation are clear, less is known about how program designers and researchers can act on these insights to design individual programs as well as the overall ecosystem. This paper highlights key findings from current research on barriers to broadening participation in STEM among minorized girls and explores key insights from research for engaging program designers and researchers in designing OST experiences that are affirming and inclusive for minoritized girls.**

Keywords- Out-of-school-time, equitable participation in STEM, STEM engagement, minorities in science, broadening participation

I. Introduction

Out-of-School Time (OST) programs, defined as informal learning programs that do not take place during school hours, are part of a complex learning ecosystem consisting of formal school settings, home, and community experiences [1]. Various OST providers across the country are intentionally focused on increasing middle-school aged girls' participation in STEM [1,2]. Despite girls achieving better grades in science and math, and higher scores in standardized tests [19,36], these achievements do not necessarily translate to persistence along STEM pathways and women continue to be underrepresented in mathematically intensive fields in STEM [3,34]. Many cultural and sociological barriers prevent girls from engaging in STEM, with patterns of disengagement starting to show as early as middle school (self-reports of confidence in science and math, course-taking behavior, STEM intent) [3, 4]. Girls of color face greater challenges as racial and gender biases intersect [6,16,35]. Science identities, confidence and interest formed in middle school years are crucial to future pathways [24,33]. OST providers are in a key position to: (a) help minoritized girls who are disengaged from science and math gain confidence and interest in STEM, and (b) build a social support system to encourage caring adults' and community members' active engagement in decision-making around STEM [1,2]. In this paper, we sought to understand: (a) what socio-technical barriers may affect middle school girls' STEM engagement, and how, and (b) how might OST programs address these barriers towards girls' increased engagement. This paper focuses on insights that may apply to the design of OST STEM program offerings.

We highlight key findings from current research on barriers to broadening participation in STEM among minorized girls, and share key insights from studies that examine programs targeting minoritized girls. Using an integrative literature review methodology, we explored research in education, sociology, psychology, and learning sciences to form themes based on overlapping findings. To explore barriers to learning, we used keywords such as "equity in education", "gender differences in learning", "gender barriers", "STEM participation", "racial, ethnic inequities", "discrimination in science education", "Intersectionality in STEM", "women in STEM", "STEM careers, pathways", "girls of color", "gender gap in education", "minorities in science", "perceived barriers". We explored equity interventions using terms such as "OST gender equity", "equitable science learning", "after school", "informal learning", "science identity", "agency in STEM", "minorities in science", "STEM interest", and "strategies for STEM motivation".

II. Barriers to Girls' STEM Engagement

The research literature highlights multiple barriers that may affect girls' STEM learning, engagement and interest in different ways. We organize these barriers into broad themes:

A. *Effects of stereotyping and discrimination*

Stereotypes suggest that women lack science abilities [7] and perceive STEM and engineering as masculine [8]. Assuming gender roles leads to seemingly subtle but denigrating

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

invalidations and false assumptions of power [9]. Stereotyping has negative psychological effects, and affects learner's confidence and perceived support [10]. Furthermore, there is risk of conforming to stereotypes, or stereotype threat [11].

B. *Not acknowledging discrimination*

Invalidating behavior affects peers views due to the social learning embedded [9]. In one study, many students reported no perceived racial or gender barriers in their peers' experiences [9]. Educational values like "objectivity and rationalism" suggest learning accommodations to be equitable, and it is falsely assumed that these values are heeded more than stereotypical issues [12]. Assumptions about disinterest in science among gender and racial minorities are unfounded with no evidence of lack STEM aspiration yet affect learners' academic intent and outcome [3,13].

C. *Lack of external support*

Adolescents' level of STEM engagement is part of a larger process of career exploration influenced by external sources such as social support [14,32]. Parental styles and expectations may be different for girls and boys [15,19], which may discourage girls' interest. Black and Latino students tend to report lower perceived support to pursue science than whites [10]. Additionally, lack of social interaction with peers leads to cultural isolation [16], leading to loss of social support [6,14,17]. Lack of historical examples of success also discourage decision-making in a highly social environment where minoritized girls may perceive a lack of fit [16,25].

D. *Socioeconomic factors*

Students of color may have less access to highly resourced schools that may motivate science and math interests, and there may be lack of exposure to science outside the classroom [16,18].

E. *Learning and teaching styles*

Education theorist Kolb suggests that students tend to move towards fields that fit their learning styles best. STEM courses are exceedingly competitive and fail to accommodate all learning styles [21]. Women may adapt to an "expert" or "authoritative role" common in STEM teaching, but tend to perform better when educators facilitate learning [20].

III. Opportunities to Address Barriers in the Design of OST Program Offerings

Various design and research efforts are underway to raise awareness about gender and racial biases towards more equitable STEM learning ecosystems [5]. In this section, we present opportunities in research towards addressing barriers discussed in the previous section.

A. *Equip stakeholders to address inequity and disengagement*

Many equity-centered design initiatives explore innovative ways of engaging stakeholders (eg: Stanford's d.school, Creative Reaction Lab, Civic Creatives). Educators and mentors should be equipped to (a) recognize stereotypical behavior among youth; e.g. assumptions in the use of everyday language, and (b) identify and deal with disengaged youth [22]. Some efforts explore training mentors and facilitators to observe how learners engage, and conduct debriefs after programs [31]. Research has found that girls who learned about gender discrimination and famous female scientists who faced discrimination demonstrated increased confidence [23]. Mentors, usually young women learning science, act as role models [24,25]. Mentors can dispel girls' negative stereotypes about science by showing that they have interesting lives outside their work environments [25]. A study has shown success with facilitators using stories and narratives from personal contexts and relating them to science learning [24].

B. *Towards continued science learning in the home*

Research has highlighted the importance of engagement in STEM across settings to sustain interest [5]. Programs could equip parents and caring adults to engage youth in everyday science learning by suggesting activities at home related to their learning [22]. Programs can also equip parents with resources to facilitate science conversations at home. One study reports different ways in which parents communicated with youth; ones with formal education in science engaged youth in knowledge acquisition and concepts, while others used story-telling and personal narratives in conversations about STEM [26]. Providing a set of tools and resources to youth, and adults, easily accessible at home contexts, may help increase level of engagement for those who may not have access to technology at home [31].

C. *Making STEM learning relevant to community's priorities*

While career readiness is a worthy goal, it is also important to address measures grounded in community perspectives [31]. Cultural norms and practices of families from non-dominant groups may vary [29]. Informal learning opportunities can leverage knowledge about their communities' interests (e.g. addressing health disparities, climate change) to help direct communities' and learners' interest in science learning [26].

D. *Facilitating learning in ways that may not be as formal as school contexts*

OST program GET (Green Energy Technology) city explored building agency by having girls play the role of science experts in their community [27]. Collaborative learning can be facilitated by encouraging peer to peer interaction through team projects [28]. Learning experiences should highlight forms of participation in science that are familiar to non-scientist learners, such as asking questions and drawing analogies [22]. In order to garner youth interest, facilitators need to maintain a balance between what is "cool/fun" and what is "scientific" in discourse [24]. Exploring facilitation of concepts through currently relevant topics (e.g. recycling) has been reported to increase interest [24]. Research shows that prescriptive and informal feedback encourages learning and interest [32].

IV. Conclusion

OST initiatives and research-practice partnerships [30] are in a unique position to engage girls of color in current and future STEM opportunities. Research points to the need for exploring revised metrics of program success in the out-of-school space [2], focusing the efforts towards increasing minority engagement. This review is aimed at a call for action for further research to use OST programs' context in the learning ecosystem to build resources, tools, and practices towards more equitable outcomes.

References

[1] N. Pinkard, "Freedom of movement: defining, researching, and designing the components of a healthy learning ecosystem." Human Development 62, no. 1-2, 2019, pp. 40-65.

[2] K. Chun, E. Harris, "STEM Out-of-School Time programs for girls. Highlights from the Out-of-School Time database. Research update, no. 5." Harvard Family Research Project, 2011.

[3] C. Riegle-Crumb, B. and King, “Questioning a white male advantage in STEM: Examining disparities in college major by gender and race/ethnicity”, Educational Researcher, 39(9), 2010, pp.656-664.

[4] F. Pajares, "Gender differences in mathematics self-efficacy beliefs." Gender differences in mathematics: An integrative psychological approach , 2005, pp. 294-315.

[5] W.R. Penuel, T. Lee, B. Bevan, “Designing and building infrastructures to support equitable STEM learning across settings”. Research + Practice Collaboratory Research Synthesis. San Francisco: The exploratorium , 2014.

[6] S. Erete, Sheena, A. Israni, T. Dillahunt, "An intersectional approach to designing in the margins." interactions 25, no. 3, 2018, pp. 66-69.

[7] C. Leaper, C.S. Brown, "Perceived experiences with sexism among adolescent girls." Child development 79, no. 3, 2008, pp. 685-704.

[8] M. Crowley, "Gender, the labor process and dignity at work." Social Forces 91, no. 4, 2013, pp. 1209-1238.

[9] D.W. Sue, “Microaggressions in everyday life: Race, gender, and sexual orientation.” John Wiley & Sons, 2010.

[10] J.M. Grossman, M.V. Porche. "Perceived gender and racial/ethnic barriers to STEM success." Urban Education 49, no. 6, 2014, pp. 698-727.

[11] J.R. Shapiro, A.M. Williams, "The role of stereotype threats in undermining girls’ and women’s performance and interest in STEM fields." Sex Roles 66, no. 3-4 , 2012, pp. 175-183.

[12] M.F. Belenky, C.M. Blythe, N.R. Goldberger, J.M. Tarule, “Women's ways of knowing: The development of self, voice, and mind.” Vol. 15. New York: Basic books, 1986.

[13] M. Bonous-Hammarth, "Promoting student participation in science, technology, engineering and mathematics careers." In Higher education in a global society: Achieving diversity, equity and excellence, pp. 269-282. Emerald Group Publishing Limited, 2005.

[14] L. Hotchkiss, H. Borow. "Sociological perspective on work and career development." Career choice and development 3, 1996, pp. 281-334.

[15] D.L. Stevenson, D.P. Baker. "The family-school relation and the child's school performance." Child development, 1987.

[16] L. Charleston, R. Adserias, N. Lang, and J. Jackson. "Intersectionality and STEM: The role of race and gender in the academic pursuits of African American women in STEM." Journal of Progressive Policy & Practice 2, no. 3, 2014, pp. 273-293.

[17] K.I. Maton, "Making a difference: The social ecology of social transformation." American Journal of Community Psychology 28, no. 1, 2000, pp. 25-57.

[18] W.J. Jacob, D.B. Holsinger, "Inequality in education: A critical analysis." In Inequality in education, pp. 1-33. Springer, Dordrecht, 2008.

[19] C. Buchmann, T.A. DiPrete, A. McDaniel. "Gender inequalities in education." Annu. Rev. Sociol 34, 2008, pp. 319-337.

[20] V.J. Ma, X. Ma, "A comparative analysis of the relationship between learning styles and mathematics performance." International Journal of STEM Education 1, no. 1, 2014, p. 3.

[21] S. Kulturel-Konak, M.L. D'Allegro, S. Dickinson. "Review of gender differences in learning styles: Suggestions for stem education." Contemporary Issues in Education Research 4, no. 3, 2011, pp. 9-18.

[22] National Research Council, “Learning science in informal environments: People, places, and pursuits”. National Academies Press, 2009.

[23] E.S. Weisgram, R.S. Bigler, "Effects of learning about gender discrimination on adolescent girls' attitudes toward and interest in science." Psychology of Women Quarterly 31, no. 3, 2007, pp. 262-269.

[24] H.S. Mosatche, S. Matloff-Nieves, L. Kekelis, E. K. Lawner. "Effective STEM programs for adolescent girls: Three approaches and many lessons learned." Afterschool matters 17, 2013, pp. 17-25.

[25] L. Kekelis, J. Wei, "Role models matter: Promoting career exploration in after-school programs: Or, if it’s worth doing, it’s worth doing right.", 2010.

[26] C. Garibay, R.M. Teasdale, "Equity and evaluation in informal STEM education." New Directions for Evaluation 2019, no. 161, 2019, pp. 87-106.

[27] A.C. Barton, E. Tan, "We be burnin'! Agency, identity, and science learning." The Journal of the Learning Sciences 19, no. 2, 2010, pp. 187-229.

[28] R.L. DeHaan, "Teaching creative science thinking." Science 334, no. 6062, 2011, pp. 1499-1500.

[29] T.M. Philip, F.S. Azevedo, "Everyday science learning and equity: Mapping the contested terrain." Science Education 101, no. 4, 2017, pp. 526-532.

[30] C.E. Coburn, W.R. Penuel, “Research–practice partnerships in education: Outcomes, dynamics, and open questions” Educational Researcher 45, no. 1, 2016, pp. 48-54.

[31] W.R. Penuel, T.L. Clark, B. Bevan, “Infrastructures to Support Equitable STEM Learning across Settings”, Afterschool Matters, 24, 2016, pp.12-20.

[32] D.F. Halpern, C.P. Benbow, D.C. Geary, R.C. Gur, J.S. Hyde, M.A. Gernsbacher, “The science of sex differences in science and mathematics”, Psychological science in the public interest, 8(1), 2007, pp.1-51.

[33] R. Christensen, G. Knezek, “Relationship of middle school student STEM interest to career intent”, Journal of education in science environment and health, 3(1), 2017, pp. 1-13.

[34] M.T. Wang, J.L. Degol, “Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions”, Educational psychology review, 29(1), 2017, pp.119-140.

[35] L.T. O'Brien, D.M. Garcia, A. Blodorn, G. Adams, E. Hammer, C. Gravelin, “An educational intervention to improve women’s academic STEM outcomes: Divergent effects on well-represented vs. underrepresented minority women”, Cultural Diversity and Ethnic Minority Psychology, 2019.

[36] C. Hill, C. Corbett, A. St Rose, “Why so few? Women in science, technology, engineering, and mathematics”, American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036, 2010.

Computer Science is about Problem Solving: Highlights from a 6th Grade Computing Camp

Bushra Anjum, Ph.D.
Doximity
San Francisco, USA
bushra.anjum@gmail.com

Greg Wilcox
Los Osos Middle School
Los Osos, USA
gwilcox@slcusd.org

***Abstract*—Dr. Bushra Anjum and Mr. Greg Wilcox organized a computing camp for 6th graders at the Los Osos Middle School in California during the summer of 2019. Though the school has a computer lab, it lacks a computing curriculum along with CS-trained faculty. Dr. Anjum led the camp--- consisting of 5 highly interactive training sessions--- to introduce various exciting computing concepts to the students. The sessions were conducted with the help of the school's STEAM (science, technology, engineering, arts, mathematics) faculty and included videos, active discussion, and hands-on activities introducing new skills. This effort was aimed to inspire young people to step up and contribute to the future of technology.**

In this paper, the authors share some of the lessons and insights gained from this experience. They also discuss those strategies that worked and those that didn't while sharing some recommendations for students and faculty interested in conducting such outreach.

Keywords— K-12 education, equity, problem solving

I. Introduction

Data driven decisions in education at the site level include thinking outside the box. One such approach featured in this experience paper identifies the process and outcomes of a computing camp, a pilot program to encourage and engage 6th grade students in the study of computer science.

Gender inequity in the computer science field has been a well-known issue in the tech world. The number of women enrolled in computer science at secondary schools, universities, and employed in the workplace reflects a disparity in our current population. According to the United States Bureau of Labor Statistics, in 2018, computer occupations employing women ranged from 37.5 % for computer systems analysts to 10.3 percent for computer network architects[1]. Clearly, the United States Census Bureau 2018 numbers do not mirror the female population, 50.8 %[2].

Organizations and programs have historically sought to level the playing field for women in computer science. Girls Who Code, since 2012 have continued to build the numbers of women working in the computer science area. In 1995, 37% of computer scientists were women. Today, it's only 24%. If we do nothing, in 10 years, the number of women in computing will decrease to just 22% [3] [4].

The focus of this computing camp was to increase female interest in underrepresented computer science fields.

Equity specifically in underserved minorities and women employed in technology fields by companies, big and small, are posited as the rationale for the computing camp collaboration with Mr. Wilcox and Dr. Anjum. The journey to a computing camp section of a 6th grade STEAM course being co-taught by an expert in the field of computer science, Dr. Bushra Anjum, a data analytics program manager, currently with Doximity begins with a visit to Amazon in San Luis Obispo, California.

II. Computing Camp at Los Osos Middle School

Los Osos Middle School is located on the Central Coast of California, about halfway between Los Angeles and San Francisco. The 6-8 middle school, had 599 students in the 2017-2018 school year, (published 2018-19) per the most recent California Department of Education, School Accountability Report Card. 61.1 percent of the student population is White (not Hispanic), and 49.74 percent are considered socioeconomically disadvantaged. There were 184 6th graders in attendance during the 2017-18 school year [5]. However, according to the Los Osos Middle School registrar, Anne-Marie Hoffman, in 2018-19, there were 555 students, 297 males (53.51 %) and 258 females (46.49 %). The STEAM class when the computing camp session was introduced had a total of 32 students, 20 males, and 12 females. The course enrollees were scheduled based on a rotational wheel that included 4 other STEAM classes; robotics, video production, aerodynamics, and transportation.

The school has a 1:1 ratio of computers to students, yet computer science is not a formal part of the course choices. The majority of computers are Chromebooks with 2 labs of desktops. A degree of computer programming is embedded in the 6th grade when all 6th graders learn to use Scratch. Last year one class of 8th grade students learned how to create interactive 3D images using Unity and GIMP. Some 8th grade history students created augmented reality presentations triggered by QR codes on a student-created poster. In 2018, Los Osos Middle School received a national honor being designated as a "Schools to watch," one 22 middle schools in the state of California [6].

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

A. The Industry-School Partnersihp

Initially, Mr. Wilcox brought 27 students from Los Osos Middle School to visit a variety of local businesses as part of career exploration, including Amazon. Dr. Anjum reached out to Mr. Wilcox, offering to teach a unit on computer science. Later in the school year, Wilcox contacted Dr. Anjum, who had moved up to a start-up, Doximity, headquartered in San Francisco. She telecommuted from San Luis Obispo County and still wanted to teach 6th grade students about computer science. Our initial meeting at Los Osos Middle School included 3 other STEAM teachers.

The partnership between an industry expert and the local teaching staff has been critical to the success of the camp. It is essential to recognize that while the industry expert may know their technical craft, it is the teachers that know their students. The teachers have been working with these students for months, in some cases years, and can advise best on the complexity of the content, delivery and presentation style, and identifying and following up with the most and least interested students.

B. Lesson Plans and Execution

Dr. Anjum decided to make the camp not focused on programming, but "problem solving". The primary goal was to introduce the field of computer science to the students and the immense potential for good it holds. The secondary goal was to inform that programming is just a small part of computer science. The bulk of the work that computer scientists do is figuring out the right solution, which requires creativity, critical thinking and collaboration.

The first session was focused on what computer science is, a brief history of how it came about, and the applicability of computer science in every field today, ranging from medical to entertainment to agriculture to historic restoration, etc. We were able to convert the then recent tragedy of the fire related destruction of Notre Dame de Paris cathedral into a teaching moment. We highlighted the work of late art historian and computer enthusiast Andrew Tallon, who meticulously mapped Notre Dame in three-dimensions using laser scanners. Using his digital maps, the reconstruction of Notre Dame will be possible with an accuracy of 5 millimeters [7]. Students responded to this story with awe and delight as they saw how "loosing a historic site by a disaster" was a problem and computing provided a solution. The students also responded well to the computing research and innovation in robotics that provide assistance for the disabled, and veterans who have lost limbs in the line of duty.

The second session was focused on the internet and how an army project started in the era of the cold war ended up as the biggest communication revolution in the history of mankind. The students enjoyed the story immensely, on how the army's intention to create a "resilient **<u>inter</u>**connected **<u>net</u>**work" became the "**<u>internet</u>**". Many boosted that they are going to tell their parents and friends that "internet" is not really a word, or at least it wasn't a few decades ago.

Another session was focused on security, where various aspects of wired and wireless networks were discussed. The notion that "it is easy to bury a wire or lock it in a building, but it is impossible to control the air" led to interesting follow-up discussions. This led to discussing the Frequency Hopping Spread Spectrum work as a means to secure radio communication. We also discussed securing the message via encryption, and the students were introduced to Caesar Cipher. We did a few exercises in the class where students were given encrypted messages and a key and were asked to decrypt the message. It was one of our highly engaging exercises. We also recognized the potential and converted it into a mid-session feedback opportunity. More details on it are shared in the next section.

Finally, we had a session dedicated to the Binary encoding. We sparked the students' interest by asking, "Why do we count in 10s? Why not 6 or 12?". It led to a fun discussion where students finally narrowed down and tied decimal to 10 fingers. We segued into computers at this point and asked, "But poor computer have no fingers to count on. What does it have?". We got various answers, circuits, wires, electrons, electricity, power! And from there, making the connection from electricity to the binary state was straight forward. In that session, students also learned to convert decimal numbers to binary using repeated divisions and were successfully able to convert 6 digit decimal numbers. This actually came as a surprise to the instructor as she was expecting the students to convert 3 and 4 digit numbers easily and struggle with 6 digits. The class, however, aced it. A student later shared he is not a big fan of math, but he enjoyed doing this exercise as *"collecting 0s and 1s is fun and funny"*.

C. Creative Mid-Session Feedback

Students were thoroughly engaged in converting encrypted messages, given to them by the teachers, to unencrypted ones using Caesar Cipher. We recognized the potential here and turned it into a mid-session feedback opportunity. We asked the students to write an encrypted message to Dr. Anjum and give her the decryption key. She will decrypt it later. The message could be anything related to the computing camp, what are they learning, what are they liking or not linking. Students were given the option of not writing their names on the paper so that they may express themselves freely.

Though we were skeptical about the messages we may receive, the overall feedback was increasingly positive and encouraging. We are sharing a few of the notes below.

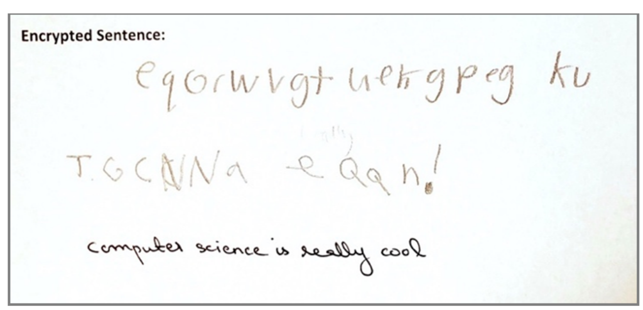


Fig. 1. Encryption based feedback 1

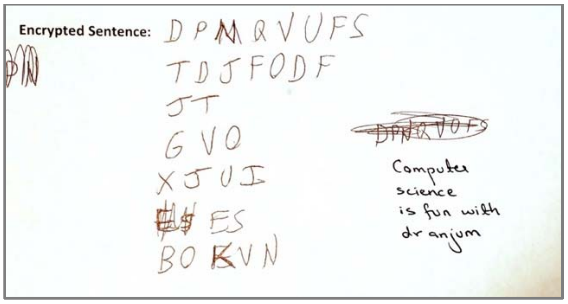


Fig. 2. Encryption based feedback 2

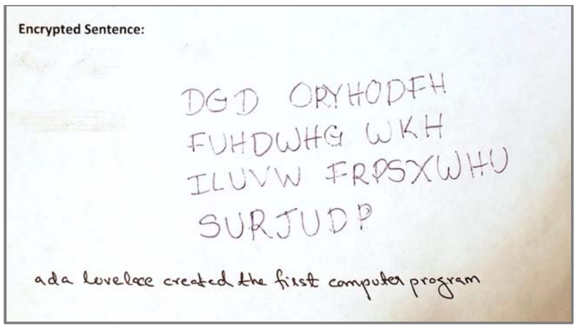


Fig. 3. Encryption based feedback 3

III. Reflections and Recommendations

One lesson we learned early on is that while numbers, such as pay or open job postings, may be of primary importance to teens and adults, they matter little to the students of this age group (ages 10 to 12). We started the camp by sharing the statistic" By 2026, there will be an estimated 3.5 million jobs related to computing open in the U.S." and "The average salary of a software engineer is $120,000". These statements were met with neither understanding nor appreciation by the students.

We quickly revised our strategy and started focusing on the impact computer scientists make. They have the potential to do what heroes do, act in service of others who are in need, whether for an individual, a group, or a community. The idea of heroism struck a chord with the student audience.

Our end of session student evaluations showed that the students responded in a positive way to the lessons leading to solving problems similar to those of computer scientists. One question asked of all students was: "How did it feel about learning about some of the problems real computer scientists face today?" The following are a few of the characteristic responses: *"It was fun to learn about it from a woman's point of view. I like the secret code where they used it in the army." "I felt reassured because although they [computer scientists] run into problems, they find a way to fix them." "I remember Dr. Anjum teaching us how to code and decode."*

Below we share some of the handwritten notes received as the end of session feedback.

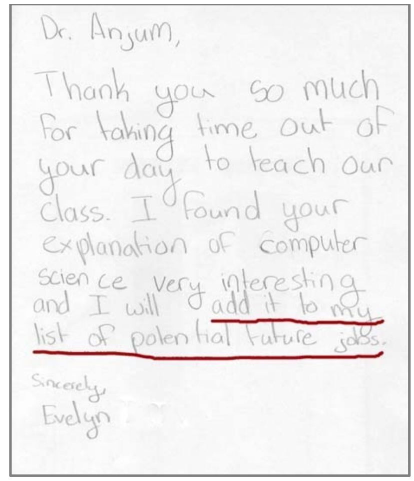


Fig. 4. End of session feedback 1

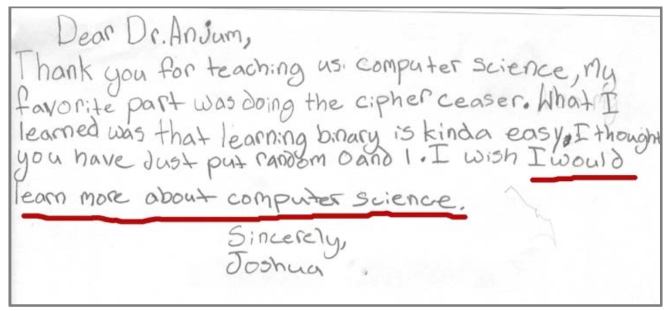


Fig. 5. End of session feedback 2

It is interesting to note that not all students related to open-ended problem solving. According to Jean Piaget's cognitive theory, students ages 7 to 11 are in the "concrete operational stage [8]." Students are not all alike when it comes to their development, both physical and mental. Hence a good mixture of open-ended problems and rules-based, if/then types of scenarios would have increased the overall students' interest and engagement.

IV. Subtle Nudge and Encouragement to Female Students

We created flyers to advertise the camp to students. In the flyer, special attention was paid to the language, content, and imagery to provide subtle nudges to encourage female student participation. The image used for the flyer was of a female computer scientist guiding with a young female student keenly looking at her computer screen. The language used the construct "young women and men" to highlight the participation of women (Fig. 6). Also, throughout the sessions, the construct "she or he" was used in equal proportions to "he or she" to enforce the subconscious cues of equality.

*Dr. Bushra Anjum will lead the camp, consisting of 5 highly interactive training sessions, to introduce various exciting computing concepts to the students. The sessions will include videos, active discussion, and hands-on activities to learn new skills that will **help young women and men** to lead the future of technology.*

Dr. Anjum is originally from Pakistan and has taught and mentored internationally. She is currently working remotely for a San Francisco based startup as a Data Scientist.

Fig. 6. Text used for flyer

In each lesson, the examples of prominent figures were carefully chosen to highlight the contribution of one female and one male individual. For example, while discussing the history of computers and computer science, *Ada Lovelace* was mentioned alongside Charles Babbage. For the topic of internet and communication, *Radia Perlman's* spanning tree was referred to alongside Vint Cerf internet architecture. When the topic of security was discussed, the contributions of *Hedy Lamarr* for Frequency Hopping were examined along with the Caesar cipher by Julius Caesar.

It is paramount that female students identify with the pioneers of the field and see that women have been contributing to computer science since its inception. We conducted a survey 3 months after the camp to access the impact of these efforts. The results are in the next section.

A. Anectodal Evidence

The 12 girls were interviewed 3 months after the computing camp was offered. Mr. Wilcox utilized a qualitative questionnaire to analyze the aspect of interest effectiveness of the computing camp. A conceptual approach to understanding computer science was selected based on the rationale that understanding variables, expressions, and loops are foremost to most computer science careers [9].

Figure 7 contains the quotes from the girls in reference to the question: Do you think it made a difference having a woman computer scientist teaching Computer Camp? If so, how?

Overall, 6th grade student females responded positively to having a woman data scientist teach computer science.

CONCLUSIONS

The primary goal of the computing camp was to introduce the field of computer science to the students and the immense potential for good it holds. The secondary goal was to inform that programming is just a small part of computer science. The bulk of the work that computer scientists do is figuring out the right solution, which requires creativity, critical thinking and collaboration. We were able to achieve both these goals using interactive sessions, active discussions and hands on exercises. Further, we were able to spark female students' interest and curiosity about computer science by carefully choosing language, woman pioneer examples, and in person discussions.

We are also happy to report that a coding class is now incorporated in the 6th grade, in part due to the introduction to computer science via the computing camp. The new course introduces, and is built on, Scratch.

- *"Yes, 'cause it was more inspiring."*
- *"Yes because she would tell us that girls could also do anything, so yes."*
- *"Yes, so that more women will want to do that."*
- *"Yes, it showed women empowerment."*
- *"It showed the females in the group that they could have very important jobs."*
- *"Yes because she showed it from a different view point."*
- *"I think it made a difference having a woman computer scientist teach me because she showed her side on working in computer science. She also encouraged girls that computer science is a great field to work in. She shared experiences she has had."*

Fig. 7. Student feedback

REFERENCES

[1] United States Department of Labor, Bureau of Labor Statistics, [Online]. Available https://www.bls.gov/cps/cpsaat11.htm.

[2] United States Census Bureau, [Online]. Available https://www.census.gov/quickfacts/fact/table/US/PST045218.

[3] Girls Who Code [Online]. Available. https://girlswhocode.com/

[4] R. Saujani, "Turn and Talk/ Reshma Saujani on getting girls into computer science," Educational Leadership, vol. 26, no. 5, Feb. 2019.

[5] California Department of Education. School Accountability Report Card. 2017-18. Los Osos Middle School. http://sarconline.org/SarcPdfs/10/40688096097349.pdf

[6] California Department of Education. State Schools Chief Torlakson Congratulates High-Performing Middle Schools Selected as 'Schools to Watch,' [Online]. Available. https://www.cde.ca.gov/nr/ne/yr18/yr18rel06.asp

[7] "How One Man's Legacy Could Help Rebuild Notre-Dame Cathedral", https://architizer.com/blog/practice/tools/andrew-tallon-notre-dame-cathedral/

[8] B. Hofer and P. Pintrich, The Development of Epistemological Theories: Beliefs About Knowledge and Knowing and Their Relation to Learning, Review of Educational Research,

[9] S. Grover, N. Jackw and P. Lundh, "Concepts before coding: non-programming interactives to advance learning of introductory programming concepts in middle school," Journal Computer Science Education, vol. 29, 2019, 06 Feb. 2019.

Creating a School-wide CS/CT-focused STEM Ecosystem to Address Access Barriers

Danielle Boulden
NC State University
Raleigh, NC, USA
dmboulde@ncsu.edu

Callie Edwards
NC State University
Raleigh, NC, USA
callie_edwards@ncsu.edu

Veronica Cateté
NC State University
Raleigh, NC, USA
vmcatete@ncsu.edu

Nick Lytle
NC State University
Raleigh, NC, USA
nalytle@ncsu.edu

Tiffany Barnes
NC State University
Raleigh, NC, USA
tmbarnes@ncsu.edu

Eric N. Wiebe
NC State University
Raleigh, NC, USA
wiebe@ncsu.edu

Dave Frye
NC State University
Raleigh, NC, USA
dafrye@ncsu.edu

***Abstract*—STEM ecosystem is an emerging model for identifying the barriers and support structures that students have in their learning trajectories in STEM. In this paper our university-based research team presents a CS/CT-focused STEM ecosystem strategy designed to address underrepresentation in computing fields. W e d escribe o ur c urrent a nd f uture w ork w ithin our school-level research-practice partnership (RPP) with a local middle school, used to guide the creation of this ecosystem.**

Keywords*—*Research-Practice Partnership, K-12, STEM Ecosystem

I. Introduction

Large segments of the U.S. population (e.g., women, African-Americans, Hispanic/Latinx), have been historically marginalized from participation in computationally-intensive STEM professions and in the higher education degree programs that prepare them for those careers [1]. Efforts to broaden participation in these fields a re a c ritical strategy to expand and diversify the talent pool to meet the waxing demand for STEM-trained professionals.

Policy makers have recently charged organizations who play an important role in preK-12 STEM education with addressing this issue by both helping to better understand its root causes and developing innovative strategies to address it [2]. Informed by these concerns we are establishing a computer science and computational thinking (CS/CT) focused STEM ecosystem that is cultivated and sustained through an existing Research-Practice Partnership (RPP) at a middle school with high racial/ethnic diversity to address and research the challenge of broadening participation in CS focused academic programs.

The STEM ecosystem framework has emerged as a powerful strategy for addressing STEM literacy and education [3]. It is founded upon the understanding that building student capacity and interest in STEM-focused academic activities needs to be addressed in a systematic and coordinated fashion over time and place [4]. At the core of a STEM ecosystem, are multiple opportunities for learners to engage in a variety of activities across diverse settings that enable them to develop knowledge, interest, and skills in STEM disciplines over the course of their youth [5], [6]. Students interact with other individuals (e.g., peers, mentors, teachers, parents) throughout these experiences subsequently influencing their academic and career trajectories in, hopefully, positive ways [5]. Learning can occur across multiple settings including the formal school environment as well as out-of-school learning opportunities such as after school clubs, summer camps, and informal home experiences [6]. When strategically aligned and coordinated, these opportunities become intentionally designed pathways to support equitable STEM learning experiences for all students. Universities, schools, businesses, and community organizations are all integral stakeholders as they provide critical resources for authentic STEM learning [7].

II. EcoCS: Building a CS/CT-focused Ecosystem through a School-level RPP

Our team views the STEM ecosystem as a robust framework for addressing the barriers and necessary support structures that students encounter within their learning trajectories in STEM areas, including CS/CT. Therefore, we posit that a CS/CT-focused STEM ecosystem can be a viable strategy to broaden the participation of student populations that have been historically denied access to meaningful CS/CT learning opportunities and to position them for success along such a CS/CT learning trajectory.

Our model recognizes that effective CS/CT learning requires coordinated efforts amongst school leadership, teachers, parents, and other key external constituencies as they work to design and support computationally-rich educational pathways for all students. Current research and policy initiatives recognize that computationally rich experiences can occur not only across formal STEM subject areas, but also in non-STEM coursework, elective courses, and informal educational activities [8]. Outcomes of this coordinated effort will produce

This work has been funded in part by NSF Grant No 1837439

978-1-7281-7172-2/20$31.00

teacher and student resources, robust CS/CT learning opportunities, and adequate training that prepares all stakeholders to broker opportunities directly and indirectly as students grow their capacity and interest.

Our strategy incorporates a breadth and depth approach in which breadth refers to exposing the entire, diverse student body to culturally responsive CS/CT learning experiences through introductory CS/CT-related activities in core academic classes (e.g., mathematics, science). Additionally, this broad exposure to CS/CT, starting in 6th grade, means building a critical mass of experiences that students can share with their school peers and build motivation and expertise, accelerating student preparation for later CS/CT opportunities. Furthermore, intentional outreach to students' homes and community are provided by the school to expose parents, guardians, and siblings to CS/CT activities and help bolster support for student interest outside of school. Breadth is then coupled with opportunities for students to deepen their interest through additional learning endeavors that build their capacity for success in high school and beyond.

To help realize the potential value of a CS/CT ecosystem, our research team partnered with practitioner leaders at a local middle school with a digital sciences magnet theme to operationalize this model. Using an RPP approach, research and practitioners collectively identified a problem of practice, namely how do we broaden participation of underrepresented populations in CS/CT through its integration into various elements of the academic enterprise. Then, RPP team members developed and iteratively refined strategies to address this challenge.

III. Progress to date and future directions

Since the inception of this RPP, university researchers and practitioner leaders from the local middle school have engaged in several collective efforts to infuse CT practices into the school culture. The first major initiative was the establishment of a digital sciences team (DST) during the 2018-2019 academic year. The DST is tasked with leading efforts to integrate digital sciences and CT throughout the school. The team is comprised of researchers, school leaders, and a representative from each subject area. The team reviews and plans programs and activities for students and parents.

Researchers also collaborated with the school's leadership to assemble a teacher leader cohort charged with leading CT and CS integration efforts including school-wide professional development (PD). To become teacher leaders, these individuals were required to attend a weeklong summer training on infusing computing. In order to build the content and pedagogical knowledge of other teachers within the school, the cohort holds monthly PD sessions during their subject-area planning times. The teachers then offer follow-up support to their peers as needed.

University researchers also provide direct support to teachers as they co-develop curricular units and implement them within their classrooms. To date, all students have engaged in CS practices within their science classrooms to learn important content standards through computational modeling. Last year, the research team collaborated with all science teachers to develop and implement curricular units that provided students with achievable and relevant opportunities to use, modify, and create their own computational models to simulate scientific concepts.

Importantly, effective communication and trusting relationships facilitate the development and maintenance of productive RPPs. As such, researchers have dedicated considerable time and resources to designing systems that foster regular communication and rapport building with school leadership and staff in an effort to increase buy-in and knowledge about creating a school-wide CS/CT-focused ecosystem. Members of the RPP team engage in bi-weekly meetings to review and resolve teacher issues, and research-practitioner duos attend professional meetings to deepened their understanding about navigating a RPP. Notably, the team also hosted a research-practice partnership kick off meeting to inform all school staff of the current and future work at the beginning of the 2019-20 academic year. Through this deep and consistent dialogue, the team builds a common understanding of vision, problems of practice, and metrics of success. Finally, the ecosystem work also extends to families and parents as the RPP team co-plans and supports several outreach events and activities such as curriculum showcase nights, school-wide magnet fairs, and a family code night at the school.

Now that we have established the trust and respect of school leadership, we are planning more intensive and focused data collection and analysis. These efforts will enable us to study barriers to developing an ecosystem that supports CS/CT for every student, factors or interventions needed to support that development, indicators of success, and an understanding of how the ecosystem prepares and engages all students for future CS/CT work beyond middle school. Data collection and analysis will be iterative as new insights emerge about new factors pertinent to the ecosystem. Our overarching goal is to generate new knowledge about how to grow STEM ecosystems that support CS/CT learning for ***all*** students.

References

[1] J. Margolis, R. Estrella, J. Goode, J. J. Holme, and K. Nao, *Stuck in the shallow end: Education, race, and computing*. Cambridge, MA: MIT Press, 2008.

[2] A. Powell, N. Nielsen, M. Butler, M., C. Buxton, C., O. Johnson, L. Ketterlin-Geller, and C. McCulloch, *Creating Inclusive PreK–12 STEM Learning Environments*. Waltham, MA: EDC, 2018.

[3] STEM Funders Network, "STEM Learning Ecosystems," *STEM Funders Network*, 2018. [Online]. Available: http://stemecosystems.org. [Accessed September 14, 2019].

[4] W. R. Penuel, T. L. Clark, and B. Bevan, B., "Infrastructures to Support Equitable STEM learning across settings," *Afterschool Matters*, vol. 24, pp. 12-20, 2016.

[5] National Research Council, *Identifying and supporting productive STEM programs in out-of-school settings*. Washington, D.C.: The National Academies Press, 2015.

[6] K. Traphagen, and S. Traill, *How cross-sector collaborations are advancing STEM learning*. Los Altos, CA: Noyce Foundation, 2014.

[7] A. J. Levy, E. Fields, J. DeLisi, L. Winfield, J. Louie, and G. Fitzhugh, "Office of Science and Technology Policy–State-Federal STEM Summit," Education Development Center, June, 2018.

[8] Y. B. Kafai, and Q. Burke, "Computer Programming Goes Back to School," *Phi Delta Kappan*, vol. 95 no. 1, pp. 61–65, 2013.

Motivating STEM+C Learning with Social Impact of Cybersecurity and Digital Forensics

Eoghan Casey
Cyber Sleuth Science Lab
Baltimore, US
ORCID: 0000-0001-7219-317X

Karen Peterson
National Girls Collaborative Project
Seattle, US
kpeterson@ngcproject.org

Daryl Pfeif
Cyber Sleuth Science Lab
New Orleans, US
daryl@cybersleuthlab.org

Cassy Soden
Cyber Sleuth Science Lab
New Orleans, US
cassy@cybersleuthlab.org

***Abstract*—This work describes the design, development, implementation and research of the Cyber Sleuth Science Lab (CSSL), an innovative educational program and supporting virtual learning environment created to provide young women and men from traditionally underserved populations (grades 9-12) with digital forensic knowledge, skills and career pathways. CSSL combines online and in-person classroom elements that challenge students to become cyber sleuths learning to use real-world digital forensic methods and tools to solve goal-based investigative scenarios, and to explore complex social issues related to technology. Classroom activities provide additional support and role model engagement to encourage youth to consider STEM+C related careers while improving their cyber street smarts. This research uses a quasi-experimental, comparison group design combining qualitative and quantitative methods.**

Keywords*—*Equity, problem-based learning, career pathways, cybersecurity, digital forensics

I. Introduction

Cybersecurity and cybercrime are growing rapidly and present real-world challenges related to technology. In addition, there is a major shortage of qualified candidates in Cybersecurity and Digital Forensics. Notably, relatively few women enter this dynamic workforce sector, which is in stark contrast to other forensic science disciplines which attract many more women than men. The primary research questions in this work relate to effectiveness of instructional methods and career pathway pursuit. Specifically, we are studying the effectiveness of the CSSL for teaching digital forensic proficiency that is directly applicable in the workplace, and for inspiring young women and other underrepresented youth to pursue STEM+C related careers. An overarching question in this work is whether young women show interest in digital forensics and cybersecurity in specific, and computer science education in general, and related technical skill development when it is situated within a learning environment that explores the complex issues associated with cybercrime, such as criminal justice, legal considerations, and information privacy.

This work is supported by the NSF STEM+Computing Partnership (Grant No. 1640107).

II. Scientific-inquiry-based Pedagogical Framework

The Cyber Sleuth Science Lab (CSSL) combines a sophisticated virtual learning environment hosted in the cloud with rich goal-based scenarios and supporting educational resources to fuel in-classroom instructional activities and career pathway exploration. Investigative scenarios in the CSSL are constructed with input from youth dealing with issues that are directly relevant to their lives, including cyberbullying, privacy, account hijacking, identity theft, anonymous harassment, unauthorized sharing of personal photographs. Computational thinking is codified with the CSSL interface and instructional activities. For students, learning support resources are embedded with the CSSL platform. Educators and students are supported by facilitators who circulate in classrooms to address technical issues and student questions. A Teacher Dashboard allows educators to track student progress. Each student is also able to view personal progress completing activities through their individual Dashboard.

III. Program Development

The CSSL program has a flexible modular design that is adaptable to different contexts in school and out of school. Development started in 2017 and pilots were run in Baltimore, New Orleans and Washington State, summarized in “Table I”. Embedded assessments, in-person surveys, and automated data gathering are combined to gain insights into experiences and outcomes for students and educators and facilitators.

TABLE I: PILOT OVERVIEW

Venue	Details			
	Students	*Duration*	*Hrs/day*	*Total hrs (est.)*
Baltimore 2017	12	1 day	6	6
NOLA 2017	30 (4+26)	1-2 days	6	6
Baltimore 2018	79	4 days	6	24
NOLA 2019	17	1 week	6	30
Everett 2019	12	3 weeks	6	78
Baltimore 2019	32	5 weeks	1	24

Initial focus groups and pilots of the CSSL helped determine the needs of youth and educators in the target environments. The initial pilots were structured as a focus group of 12 young women in Baltimore City schools, and two groups of female students in New Orleans (4 for 1 day, 26 for 2days), all grades 8-12 (most with prior computing education). A pilot in 2018 was conducted simultaneously in four classrooms, as part of a larger summer program supporting Baltimore City Schools. The 79 students (40% female, 58% male from traditionally underserved populations) ranged from grades 9 through post-graduation with the majority in grades 10-12. These students completed two investigative missions over three days, answered formative and summative questions, wrote final reports, some of which were presented in front of the class orally. An extra Industry Day brought students from all four classrooms together with expert practitioners who discussed their career pathways and then divided into smaller groups for questions and answers. A final convention of all students was held to wrap-up the program, announce achievement awards, and encourage continued pursuit of STEM+C.

In 2019 multiple pilots were held in Baltimore, New Orleans (71% female, 29% male) and the Everett (50% female, 50% male), supported by Washington Network for Innovative Careers (WANIC). The Everett pilot was the most extensive, requiring the educator and CSSL team to work closely together to create a complete program for 78 total hours. Students were able to complete all investigative scenarios, present their work in class, have structured reflection sessions, and interactions with multiple guest speakers (practitioner role models). In addition, a mock trial was held between the second and third investigative missions, dividing the class into three teams (prosecution, defense, forensic expert witnesses) to present evidence-based arguments, with communication focusing on forensic findings rather than theories of guilt/innocence. The facilitator was from a local community college enrolled in a cybersecurity and digital forensics program, and she had opportunities to present new topics to the students and work with them on content related matters.

IV. Outcomes and Lessons Learned

Across all pilots, the young women and men who participated in the CSSL program were inspired and engaged by their experiences, and developed an increased knowledge and interest in Digital Forensics and Cybersecurity. Students particularly benefited from playing the role of investigators and getting hands-on experience with real-world digital forensic tools to help someone recover deleted data or deal with cyberbullying. The majority of students indicated that the program provided them with enough educational supports, and that they learned skills that are useful for a career, and expressed increased interest in and knowledge of digital forensics and cybersecurity.

After the CSSL program, students expressed surprise about how easy it is to access and recover information from digital technology, and had a heightened awareness of risks associated with technology use. In addition, many students had a broader view of careers related to cybersecurity and digital forensics and the experiences of professionals in these career, and wanted to learn more about pathways into these careers. Overall, across both 2018 and 2019 pilots, young women developed a slightly higher interest in Digital Forensics and Cybersecurity than young men. Interestingly, during the 2019 pilots, young women expressed a significantly larger change in appreciation and interest than young men.

A summary of primary lessons learned through implementation of the CSSL:

- *In-classroom Activities*: students benefit from in-classroom activities, not just online instructional activities.
- *Supporting Girls*: girls benefit from special support in co-ed learning environments.
- *Career Quest*: youth benefit from a structured approach to exploring career pathways.
- *Super Cyber Sleuths*: some students complete investigative missions more quickly and need additional learning activities.
- *Classroom Management*: teachers benefit from an enhanced Teacher Dashboard to help them manage classroom activities, track student progress and performance more flexibly and effectively. An added benefit of this tracking mechanism is that educators had students view their own individual progress and see what they still needed to complete.
- *More Time*: exploration takes time, and cannot always occur within an hour of classroom time.
- *Professional Development*: educators benefit from more supports, guidance and time to become familiar with the CSSL before bringing it into the classroom.

V. Conclusions

The CSSL program provides a rich multidisciplinary learning experience, combining STEM+C with social issues. Young women and young men are motivated to learn more about cybersecurity and digital forensics, but perhaps with a different focus. Young women appear to be more motivated by social issues such as safety and privacy, whereas young men seem to be more motivated by career choices. Although students enjoy learning in the digital platform through investigative missions, they benefit from "outside of the computer" activities such as structured in-classroom discussions, mock trials, and in-person interactions with practitioner role models. Young women favor such in-classroom activities relative to young men who tend to prefer seeking supports in the digital platform.

Acknowledgment

Thanks to the educators and staff in Baltimore, New Orleans and Everett, Jill Denner for guidance on research, Jennifer Jocz and Jessica Brett at EDC, Brad Smith and the HotPepper development team, and Stephanie Burns for her inspiration with the Career Quest.

Bridge to Computing: An outreach program for at-risk young men

Veronica Catetė, NC State University, Raleigh, NC, USA, vmcatete@ncsu.edu
Dave Bell, NC State University, Raleigh, NC, USA, dbell5@ncsu.edu
Amy Isvik, NC State University, Raleigh, NC, USA, aaisvik@ncsu.edu
Nicholas Lytle, NC State University, Raleigh, NC, USA, nalytle@ncsu.edu
Yihuan Dong, NC State University, Raleigh, NC, USA, ydong2@ncsu.edu
Tiffany Barnes, NC State University, Raleigh, NC, USA, tmbarnes@ncsu.edu

***Abstract*—In 2017, our police department and the Give Back Organization (GBO), a local non-profit, contacted our university about hosting a game development summer camp. The camp was proposed to keep boys ages 12-15 living in a community with high levels of gang enrollment off the streets while providing an opportunity to learn about college and computing careers. The police also wanted to improve officer-youth relations. Our lab provided camp counselors, space, and content for the camp. Each camp supported a total of twelve African-American boys. Over three years, we refactored the curricula and organization of the camp and present our lessons learned from the experience.**

***Keywords*—at-risk youth, K-12 outreach, computer science education, computational thinking, community**

I. Introduction and Background

As computer science (CS) education becomes increasingly important for *every* student, programs to introduce CS to more students at the K-12 level are hoping to broaden participation by closing the achievement gap. This gap starts early in the education pipeline as lower-income and minority students receive, on average, far less STEM educational support than other students [1]. General purpose K-12 CS programs do not sufficiently close the achievement gap [2]; therefore, specific and targeted after-school programs must also be considered.

Research into designing CS outreach programs for at-risk youth is scarce [3]–[5]. Lower socioeconomic status predicts that at-risk youth have less access to CS courses and receive less encouragement by educators or their parents to study CS [6]. This is unfortunate as CS jobs can provide students with an opportunity for upward economic mobility.

Resnick & Burt developed a model for categorizing adolescent risk, factoring in environmental antecedents such as poverty, neighborhood, and family dysfunction, as well as early markers like poor school performance and interactions with child services. Potential risk outcomes and behaviors include drug and alcohol abuse, crime/imprisonment, school dropout and other serious issues. Many children ages 10-15 do not yet show risk outcomes, but could be classified as high risk if they share a combination of factors [7].

Studies have demonstrated that programs focusing on mentoring and teaching at-risk kids new skills tend to have positive outcomes [3], [5]. Programs like KLICK! [4] and Launch-It [5] provide at-risk kids access to creative computing activities such as web development, robotics, flash animations and games. They also feature mentoring components such as working with university students and listening to guest lectures and exploring career paths through industry field trips. Students in these programs showed increases in school value perception and computing ability [4] and positive perceptions of computer use [5]. As we develop programs for marginalized communities, it is important to understand what factors are important to students and communities. Below, we discuss the evolution of Bridge to Computing, a game design camp for youth at-risk for gang involvement.

II. Bridge to Computing

Year 1 The police and Give Back Organization (GBO) proposed game development as the focus of the camp as it is effective for engagement. Utilizing curricula from the STARS Computing Corps [8], two graduate students alternated leading the 8-hour day, 3-week camp, with 1-2 undergraduate volunteers taking shifts to support them. Additionally, an armed police officer in uniform was present in the on-campus camp to develop relationships with the campers and assist with possible behavioral incidents.

The project-based curriculum included four projects, one each in Scratch, Weebly, and JavaScript, and a final project in any language. Campers learned to code games in Scratch, then made a Weebly website advertising their games. We planned for campers to learn JavaScript through CodeAcademy exercises, and create a JavaScript game by the 4th week. The last two weeks were spent on final project. Each week campers *learned* how to use the relevant tool through an instructor guided example project. The campers formed pairs to *pitch* and *develop* a game idea, getting feedback from the class. Finally, campers would *present* their projects, providing a demonstration and describing what they learned. Requirements for final projects were developed with GBO: create a game that provides players with a sense of the realities of gang life and demonstrates the campers' aspirations to escape gang influence. The final game was to be presented in an expo attended by faculty, officers, family and friends.

To reduce monotony, project time was interspersed with free-time as well as other learning and outdoor activities. We invited various speakers including faculty, researchers, professional game developers, and college athletes. Speakers

Funding provided by Cisco and the Give Back Organization

shared personal experiences, their path to higher education, and advice. The goal was to introduce role models and increase interest in higher education. We included field trips to science labs and local businesses to develop student interest in academics and STEM careers.

Unfortunately, we did not have a prior understanding of the campers' levels of digital literacy. Most campers had limited access to traditional computers and keyboards, thus having underdeveloped typing skills. To mitigate this, campers played typing games and we revised the coding curriculum to use block-based environments, including introductory lessons from the online BJC curriculum [9]. In the final week, campers used the online story-telling tool Twine to make interactive autobiographies about their communities and personal lives.

Year 2 In spring 2018, we hired a graduate student with prior outreach experience to develop and teach a modular, cohesive curriculum. We also hired two Black recent high school graduates to act as full-time near-peer mentors, who were from an at-risk neighborhood and had positive experiences using Snap*!*, to provide more consistent role models for campers. Officers wore plain clothes to be more approachable and had official police training in youth interaction.

The goal of the 2018 curriculum was to better scaffold campers as they transition from block-based development into JavaScript and HTML while also allowing for inconsistent attendance. Based on 2017, we predicted most campers would miss a few lessons, therefore we created independent modular assignments that would allow campers to succeed despite absences. Morning warm-ups for campers were logic puzzles to facilitate computational thinking. We interspersed programming with other activities including learning to type, creating presentations, and content from other STEM fields. We continued inviting guest speakers from industry and the police department as students were typically more engaged in hearing from industry professionals rather than faculty.

During the last three weeks of camp, the lead counselor introduced campers to classic computer science problems, including checking for whether Euler paths are possible in graphs and developing solutions to the travelling salesman problem. Counselors emphasized that university students were also learning about these classic CS problems, helping campers to see themselves as being capable of succeeding in college.

Year 3 For year three, we hosted two three-week camps, doubling the participation of students and increasing the end of program retention rates. We also changed the venue of each camp, as the previously used Linux-based machines required high digital literacy and campers struggled typing in generic usernames and complex passwords to login. The first of the two camps occurred in a collaboration classroom equipped with Chromebooks. This allowed the students more freedom to move around. The second session occurred in a computer lab using new Windows machines.

Four camp counselors were hired from a local historically Black university. One returned from the prior year and recruited three additional counselors. We greatly diminished officer presence as their involvement was not as fruitful as we hoped. Campers persistently challenged directives from the officers. Officers were only present for one in-class activity a week to lead discussions on soft skills for personal development or participate in recreational activities.

Working with Snap!, campers completed online introductory lessons in BJC and developed projects in pairs. The new curriculum emphasized soft skills more than programming. Students practiced conflict resolution and would talk as a group about problems facing them and their communities. For a more meaningful experience with industry tours, both sets of campers attended full-day field trips to the primary sponsors' location. The company's Blacks in Technology group organized activities and provided campers with the opportunity to share their personal experiences and talk to a panel of diverse employees at the company.

III. Discussion & Conclusions

Generally, our program worked to effectively keep at-risk youth off the streets and we made large steps towards teaching CS while developing officer-youth relations. We believe the transition of the officer's role from disciplinarians to facilitators of leadership training and outdoor activities improved their engagement with campers by utilizing their strengths. As the nature of the police officer's role has changed, so has our administration of these camps. We realized that having an individual with shared, relatable experiences was also necessary, so our HBCU student staff were critical in creating meaningful bonds and developing relatable and engaging lessons.

Finally, we have also shifted perceptions of educational outcomes as the years have progressed. By having too many elements in Year 1 that were perceived as being "school" to the kids (such as having faculty guest lectures or having multi-day assignments that are "due" at the end of the week), campers engaged less with the material. As such, our focus has shifted towards providing engaging, meaningful, and impactful activities that inspire students and increase their intrinsic desire to continue to attend and pursue STEM in school.

References

[1] J. Margolis, *Stuck in the shallow end: Education, race, and computing*. MIT Press, 2010.

[2] W. L. Bainbridge and T. J. Lasley, "Demographics, diversity, and k-12 accountability: The challenge of closing the achievement gap," *Education and Urban Society*, vol. 34, no. 4, pp. 422–437, 2002.

[3] I. Blau and N. Benolol, "Can designing self-representations through creative computing promote an incremental view of intelligence and enhance creativity among at-risk youth?" *Interdisciplinary J. of E-Skills and Lifelong Learning (IJELL)*, vol. 12, pp. 267–278, 2016.

[4] M. Girod, J. Martineau, and Y. Zhao, "After-school computer clubhouses and at-risk teens," *American Secondary Education*, pp. 63–76, 2004.

[5] G. D. Blank and H. U. Odi, "Launch-it," 2008.

[6] J. Goode, "Increasing diversity in k-12 computer science: Strategies from the field," in *ACM SIGCSE Bulletin*, vol. 40, no. 1. ACM, 2008, pp. 362–366.

[7] G. Resnick and M. R. Burt, "Youth at risk: Definitions and implications for service delivery," *Amer. J. of Orthopsychiatry*, vol. 66, no. 2, pp. 172–188, 1996.

[8] V. Cateté, K. Wassell, and T. Barnes, "Use and development of entertainment technologies in after school stem program," in *Proc. of the 45th ACM tech symp. on CS education*. ACM, 2014, pp. 163–168.

[9] D. Garcia, B. Harvey, and T. Barnes, "The beauty and joy of computing," *ACM Inroads*, vol. 6, no. 4, pp. 71–79, 2015.

Using Research to Ensure Equity in a Cybersecurity Education Pathway

Jill Denner
ETR
Scotts Valley, CA, USA
jill.denner@etr.org

Emily Green
ETR
Scotts Valley, CA, USA
emily.green@etr.org

Julie Edwards
Pajaro Valley Unified School District
Watsonville, CA, USA
julie_edwards@pvusd.net

***Abstract*—This poster describes how we are using research to inform the development of a cybersecurity education pathway to attract and retain students from groups that are underrepresented in computing fields. The partners include a non-profit research organization, a community-based tech workforce center, a community college, and a K-12 school district that serves predominantly Latinx students. The poster describes our goals, activities, the data we have collected, and how they are being used to create a sustainable pathway from high school to college that attracts a diversity of students. We describe our stages of research utilization, as well as the challenges that we are facing related to using research to ensure equity in the cybersecurity education pathway.**

Keywords—equity, cybersecurity education, K-12 community college, research-practice partnerships

I. Introduction

Cybersecurity education is a growing area of computer and information science. However, there is a global shortage of professionals in information security, and companies are not staffed by a population that represents the diversity in the US (CyberVentures, 2019; Reed & Acosta-Rubio, 2018). Career-themed pathways that integrate college preparatory academics, rigorous technical training, work-based learning, and support services can help students get and stay on track (Caspary & Warner, 2016). But creating sustainable pathways to attract and retain students from groups that are underrepresented in computing fields is a challenge.

This poster describes how we are using research to ensure that pathway development and implementation follow an equitable and inclusive approach to computing education. We are building a cybersecurity-focused computer information systems (CIS) pathway from high school (HS) to college in a majority-Latinx district. Our cross-institutional partnership includes non-profit researchers, a large school district, a community-based technology center and a community college.

Data are being used to understand who enters the pathway, to monitor student participation in on-ramps and their movement along the pathway, and to understand what services are needed to recruit and sustain participation as well as the structural and cross-organization challenges to providing them. The interpretation of local data is guided by empirical and theoretical research in the field of computer science education, including research on equitable approaches to computing education (Margolis et al., 2012). Our work is driven by a Research-Practice Partnership that aims to ensure that the research addresses both local needs and critical research questions (Coburn & Penuel, 2016).

Funding for this research was provided by NSF grant no. 187655.

Our process for using research to inform practice is based on a multi-stage conceptual framework of research utilization: 1) identify available and needed knowledge (acquisition), 2) create processes and routines to incorporate it into practice (assimilation) or new solutions (transformation), and 3) apply the knowledge to new problems (exploitation) (Cohen & Levinthal 1990; Zahra & George 2002). In this poster, we describe our accomplishments to date and how our collaboration moves through the stages of research utilization. We also highlight the challenges we face with generating and using research to ensure that our work maintains an equity lens throughout pathway development and implementation.

II. Pathway Development

A major focus of our work is on building the pathway. A team of teachers, faculty, counselors, and staff from the college, school district, and community-based organization are working to delineate a series of on-ramp programs after school and during the summer, offer high school classes with student outreach strategies, build a system of articulation from high school to college, provide student supports, coordinate implementation across sites, align the pathway with district initiatives, and monitor student participation. At the end of Year 1, we established key onramps and the first pathway class, where enrollment increased from 63 students in 2018-19 to 149 students in 2019-20. In the next sections, we describe the stages of research utilization that are informing pathway development..

III. Identify Available and Needed Knowledge

An early step was to create a database of relevant research and summaries of existing data. For example, the team used publications on Linked Learning pathways (ConnectEd, 2013) and Aligning Systems for Equity (SRI, 2019) to identify steps for building a path that includes rigorous academics as well as real-world technical skills and personalized supports. Summaries of existing data from student transcripts were used to identify needs, including existing gender imbalances in CIS on-ramps and classes at both the high school and college level. These data are being used to inform the development of recruitment and retention strategies.

IV. Collect and Analyze Data

Additional data are being collected to understand students' motivations for entering the pathway, who persists, and what kinds of supports, services and systems can help. These include interviews with students, school district and college administrators, teachers, and counselors. The findings are informing student recruitment and class implementation. For example, the CIS classes attract students that like math, science or technology. They enjoy the hands-on activities, learning things they can readily apply outside of class, and working with other students. The data show that CIS classes

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

attract a range of students when they highlight the hands-on and creative nature of the class, give details about what they will learn, and help students see that they have the skills to succeed in the class.

Data from the school administrator interviews are informing pathway development and system alignment. They are helping the team build on school and district priorities for career technical education, including certification, dual enrollment, and work-related experiences, and connect to other subject areas and college and career support systems. The data are also being used to identify structural factors that will need to be addressed in order to support and sustain the pathway. These include helping school staff understand the different areas of computing and how they connect to specific college majors or careers and addressing both the lack of teachers with tech industry experience and inequitable internet access.

V. Create Processes and Routines to Utilize Research

Our team is utilizing both external and local data to ensure an equitable pathway. To make external research accessible, we summarized key articles on a specific topic in a “what to read” document to provide quick answers to questions and share a “research minute” at team meetings. Strategies for making local data “actionable” include data visualizations that summarize student participation and motivation, and thematic summaries about how students have been impacted, with illustrative quotes. The Superintendent has asked for regular data summaries (what she calls “tidbits”) that she can share with various stakeholders. We are also creating longitudinal case studies of students to show patterns of course enrollment and grades that led them to take CIS classes or on-ramps, as well as their current goals and interests. These data are being used to identify what services and supports are needed to keep them on the pathway.

Team discussions explore the application and limitations of data. For example, when we found that two thirds of students in the first pathway class knew nothing about the topic before enrollment, these data were used to show the need for the class. Similarly, longitudinal case studies of students’ course enrollment and grades led to a conversation about which students to target for the on-ramp classes. And our summary of course enrollment data led to a consideration of whether the next class in the pathway should be dual enrollment when we found that most students were just in 9th grade and not prepared for college-level work.

VI. Apply Knowledge

Collecting data is much easier than applying it. One challenge is that when new data are collected, analyzed, and summarized, they are not always actionable. For example, while our data show that the classes and camps attract more male students, they do not provide insight into why this is happening or what strategies would be effective to address this disparity. A second challenge is that institutional data is not designed to answer questions about systems or students’ goals and motivations. For example, the district’s college and career readiness platform produces data to inform the student, their family and their counselor. The platform was not designed to help researchers track changes in their goals and interests. A third challenge is that there is limited external research on how to build a coordinated, cross-institutional pathway in cybersecurity education that focuses on equity. In particular, there is very little research on how to engage and support thigh school Latinx students in computing fields.

VII. Conclusion

This poster describes how a collaborative of four organizations is working together to design and implement a cybersecurity education pathway in a majority Latinx community. The goal is to recruit and retain a diverse group of students from high school into college in a field of study that has a growing workforce. The partners have identified “research” as an important component to ensure the success of a pathway that maintains a lens of equity and inclusion. In this poster, we described the accomplishments to date and the stages of research utilization that the collaborative is going through. We also described some of the challenges to using research knowledge as we build an education pathway..

Acknowledgment

The authors wish to acknowledge the contributions of Steve Bean and Gerlinde Brady to the Research Practice Partnership, and the dedication of the high school teachers Sarah Blanchette and Heidi Holland.

References

[1] G. Reed and J. Acosta-Rubio, “Innovation through inclusion: The multicultural cybersecurity workforce,” 2018.

[2] CyberVentures, “Representation Of women in the cybersecurity workforce is recalculated to 20 percent,” 2019.

[3] K. Caspary and M. Warner, “What it takes to create Linked Learning,” 2016.

[4] C. E. Coburn and W. R. Penuel, “Research–practice partnerships in education: Outcomes, dynamics, and open questions.” Educational Researcher, 2016, vol 45, pp. 48-54.

[5] J. Margolis, J. .J Ryoo, C. D. Sandoval, C. Lee, J. Goode, and G. Chapman, “Beyond access: Broadening participation in high school computer science.” ACM Inroads, 2012, vol 3, pp. 72.

[6] W. M. Cohen and D. A. Levinthal, “Absorptive capacity: A new perspective on learning and innovation,” Administrative science quarterly, 1990, pp. 128-152.

[7] S. A. Zahra and G. George, “Absorptive capacity: A review, reconceptualization, and extension.” Academy of management review, 2002, vol 27, pp. 185-203.

[8] ConnectEd, “Building a linked learning pathway: A guide for transforming high schools for college and career success,” 2013.

[9] SRI, “Aligning systems for equity,” 2019, Mt View California.

Engaging 4th and 5th Grade Students with Cultural Pedagogy in Introductory Programming

Joseph Isaac, Jr.
Dept. of Comp. & Info. Sci. & Engineering
University of Florida
Gainesville, FL 32611
jisaacjr@ufl.edu

Yerika Jimenez
Dept. of Comp. & Info. Sci. & Engineering
University of Florida
Gainesville, FL 32611
jimenyer@ufl.edu

Christina Gardner-McCune
Dept. of Comp. & Info. Sci. & Engineering
University of Florida
Gainesville, FL 32611
gmccune@ufl.edu

***Abstract*—The computing education community has explored multiple strategies to address the problem of underrepresentation of African American and Latino students. Recently, the community has started to explore culturally relevant pedagogy (CRP) to increase the effectiveness of curricula and programs designed to increase participation in underrepresented groups. CRP suggests that the use of culture can benefit students by providing them with opportunities to bring their culture into learning. In this poster paper, we explore the use of CRP to introduce 4th and 5th grade African American students to computer science in an 8-week summer camp through the context of social justice.**

Keywords*—computer science education, culturally relevant pedagogy, broadening participation in computing

I. Introduction

Although the enrollment numbers of African American and Latino students are low, 5.1% and 11.1%, respectively, they continue to grow in undergraduate CS courses [1]. To further increase the effectiveness of curricula and programs designed to increase the participation of these groups, the Broadening Participation in Computing (BPC) community has explored using Culturally Relevant Pedagogy (CRP) over the past 8 years. In this poster paper, we explore the use of CRP to introduce 4th and 5th grade African American students to computing in an 8-week summer camp through the context of social justice. We also reflect on our experiences implementing this CRP curriculum.

We adopted Gloria Ladson-Billings' culturally relevant pedagogy (CRP) to guide our incorporation of social justice into the computing curriculum and pedagogy [2]. Culturally relevant pedagogy is a pedagogy that addresses student achievement and helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities in society [2]. CRP uses three criteria: academic achievement, cultural competence, and sociopolitical consciousness to guide teachers into providing more culturally rich and engaging student learning.

However, K-12 computing curricula often prioritize the inclusion of students' interests and culture, but not many consider the sociopolitical consciousness criteria. For example, Ron Eglash's curricula on Cornrow Curves and the Virtual Bead Loom focused on the academic achievement and cultural competence criteria of CRP by using math and computing to simulate cornrow braid patterns and Native American bead loom art [3][4]. However, neither tool is used to bring awareness to issues in students' own communities.

II. Curriculum Design

Using CRP in our summer camp, we aimed to provide opportunities for 4th and 5th grade African American students to learn computer science concepts (academic achievement), share their own cultural knowledge in lessons and activities (cultural competence), learn from the varying cultural knowledge shared by their peers and instructors (cultural competence), and develop a coding project that brings awareness to a social justice issue that matters to them (sociopolitical consciousness).

Students spent the first 5 weeks learning sequences, loops, conditionals, variables, operators, and how to plan, code, test, and debug their code in Scratch (see Table 1). The last 3 weeks were spent creating an animation on a social justice issue of their choice in their communities.

TABLE I. Summer Camp Curriculum

Weeks	Lessons	Cultural Example(s)
1	Intro to Scratch + What is CS?	About Me Slide, Robotics, Black Panther movie
2	Problem Solving and Sequences	*Problem Solving*: Restaurants for a friend with gluten allergies. Sequences: Morning routine
3	Loops & Conditionals	*Loops*: Drill, laundromat dryer, blender, repetition in music. *Conditionals*: Logic playing Uno
4	Coding Process: Plan, Code, Test, & Debug	N/A
5	Variable and Operators	*Variable*: Values in a video game (score, points, health, time, etc.) *Operators*: Comparing money (US bills and coins)
6	Reviews Lessons	N/A
7	Social Justice Project	Immigration, gun violence, bullying, discrimination
8	Social Justice Project	N/A

III. Participant Demographics

All participants in the summer camp identified as African American. They were recruited by the summer camp, which typically targets people of color communities. We taught 49 students, but only 26 students' parents signed the IRB consent forms to participate in the study (Table 2).

TABLE II. SUMMER CAMP DEMOGRAPHICS

Demographic	**Statistics**
Gender	16 females and 10 males
Ethnicity	26 African Americans
Grade	12 (4th Grade) and 14 (5th Grade)
Prior Programming Experience	11 (No), 10 (yes), 5 (No response)

IV. SOCIAL JUSTICE FINAL PROJECTS

The social justice final project operationalized everything taught in the camp. To help guide this process, resources (worksheets, information handouts, etc.) were provided for the following steps: (1) identifying the social justice issue, (2) brainstorming an animation story, (3) programming planning, (4) coding, (5) testing & debugging code, and (6) presenting and demonstrating the project to the class. The instructors provided scaffolding and one-on-one assistance for students throughout the process.

The students selected social justice topics that were near to their hearts and concerns for their communities. The social justice topics students chose focused on: racism (n=7), gun violence (n=6), littering (n=3), women's rights (n=2), equal pay (n=2), gangs (n=1), theft (n=1), and bullying (n=1). Fig. 1 shows a gun violence protest animation created by a 5th grade student.

Fig. 1. Gun Violence Social Justice Project Example

V. TEACHING EXPERIENCE & LESSONS LEARNED

A. Male African American Teacher Perspectives

As an African American male, I anticipated being able to connect with students because I came from a similar culture as them and I understood many of the cultural references the students used during our class sessions. These references included rappers, singers, athletes, movie references, video games, dance trends, and slang. In addition, I intentionally tried to make connections to students by dressing in casual clothing similar to them. Many of them noticed the sneakers I wore, knew the brands (e.g., Nike, Jordan, Adidas, and Vans), and complimented me on my sneakers throughout the summer. However, our cultural similarities alone were not enough to have an instant rapport with students, and it did not prevent behavioral issues. Thus, I had to take a personal interest in students and their work to build rapport. Overall, I found implementing culturally relevant pedagogy (CRP) into a computer science curriculum for the first time both challenging and rewarding. I acknowledged the *importance of leveraging existing cultural competence while intentionally building connections with students.*

B. Female Latina Teacher Perspectives

As a Latina woman, I have always had an easy time connecting with underrepresented minorities, especially female students. However, in implementing CRP, I learned that cultural competence requires that teachers understand their own cultural backgrounds and actively learn about those of their students.

During Week 3, a male student calmly asked me, "Miss Jimenez, where are you from?" I replied back "I am from a Caribbean island, do you know the Dominican Republic?", the student responded, "Oh you are going to get deported". At the moment, I was in shock because at 9 to 11 years old, I was not politically or socially aware of events that were happening around me. Instead of getting upset by his comment, I replied back, "No, I cannot get deported. Naturalized American citizens cannot get deported." I continued to explain to the class that naturalization is a legal process that immigrants do to become US citizens. After this discussion, students felt more comfortable and open to talking to me about incidents that were happening around them and expressed their thoughts aloud. Such examples included school shootings, gun violence, and racism. Having a medium for students to express their thoughts and worries is crucial at this point in time.

Overall, we found that integrating elements of sociopolitical consciousness and cultural competence with technology mediums such as Scratch helped students not only understand difficult topics, but also use the computer science concepts learned in class to build their own social justice animations that they were passionate about. Thus, having CRP in our implementation of the curriculum provided invaluable experiences to help us shape future curricula and our approach to teaching diverse students.

REFERENCES

[1] S. Zweben and B. Bizot, "2017 CRA Taulbee Survey," Comput. Res. News, vol. 30, no. 5, pp. 1–47, 2018.

[2] G. Ladson-Billings, "Toward a Theory of Culturally Relevant Pedagogy," Am. Educ. Res. J., vol. 32, no. 3, pp. 465–491, 1995.

[3] R. Eglash and A. Bennett, "Teaching with Hidden Capital: Agency in Children's Computational Explorations of Cornrow Hairstyles," Child. Youth Environ., vol. 19, no. 1, pp. 58–73, 2009.

[4] A. Boyce, K. Doran, A. Campbell, S. Pickford, D. Culler, and T. Barnes, "BeadLoom Game," Proc. 6th Int. Conf. Found. Digit. Games - FDG '11, no. March, pp. 139–146, 2011.

Rural Research-to-Practice Partnerships Integrating Computer Science K-8

Ruth Kermish-Allen, PhD.
Maine Mathematics and Science Alliance
Augusta, ME USA
rkermishallen@mmsa.org

Pamela Buffingston, PhD.
Educational Development Center
Boston, MA USA
pbuffington@edc.org

Scott Byrd, PhD.
Maine Mathematics and Science Alliance
Augusta, ME USA
sbyrd@mmsa.org

Brittney Nickerson
Maine Mathematics and Science Alliance
Augusta, ME USA
bnickerson@mmsa.org

Rhonda Tate
Maine Mathematics and Science Alliance
Augusta, ME USA
rtate@mmsa.org

***Abstract*—This report highlights evidence from a research to practice partnership (RPP) designed to examine computer science (CS) integration in rural K-8 schools. The project implements a design approach that encourages collaboration between educators, tech integrators, and administrators. They act as co-researchers in identifying and examining connections between barriers to integration.**

***Keywords*—computer science, computational thinking, problems of practice**

I. Introduction

Rural communities across the country are hungry for highly engaging learning experiences that integrate computer science (CS) across disciplines as more jobs require CS skills and new computer science standards come into place. However, existing and emerging barriers make integration difficult, particularly in rural Maine, where staffing and resources are already strained.

The Integrate to Innovate (i2i) project has been using a design research framework to co-design a research to practice partnership (RPP) to answer the question: What are the key elements needed to support rural K-8 educators' integration of CS into math and science instruction? This began with identifying barriers, or problems of practice, in integrating CS within a rural Maine setting.

II. Methods

We have built a rural framework from the design-research models and practices developed in the Middle-school Mathematics and the Institutional Setting of Teaching project [1] to advance providing equitable learning opportunities in computer science to all students. Our model is place-based, generates long term relationships with one or a small number of districts, has a focus on informing research and practice, emphasizes co-design, and fosters collaboration among all members at every stage of the process [2]. We have partnered with 25 current K-8 educators, administrators in three rural Maine districts, along with STEM business partners to ensure the problems of practice identified and potential solutions developed meet the needs of the essential stakeholders.

At a series of on site visits in the schools of the participating rural Maine districts, RPP members were trained by researchers to make classroom observations to document CS integration experiences, including barriers, within the classroom. They later organized in focus groups to analyze the data.

Using a combination of survey data and semi-structured interviews with all RPP participants, we were able to focus on identifying potential problems of practice, followed by applying a social network analysis. We examined network measures of brokerage [3] between the problems of practice and represented these connections in a network graph. Brokerage, here represented as betweenness centrality, is an indicator of how any one practice or barrier might be related to other barriers through their bridging of "structural holes" in a network. Betweenness centrality and the mapping of these connections not just represents the connectivity between barriers but also surfaces underlying practices that could represent opportunities for training and programming. We used Gephi software to store, code, and analyze network analytic data.

III. Results

The following graphs represent both the culmination of data from i2i interviews, survey data, summer retreat artifacts (posters), the summer retreat transcripts, and the connections between problems of practice (PoP) that were tracked during those interviews and events where administration, tech integrators, and teachers were present. A "connection" is produced by either a person mentioning two problems of practice being related or leading to one another (in an interview or focus group transcript), or if they were represented as being related in an artifact. The nodes or points on the graph are sized according to the number of ties connected to that practice (larger = more ties). The thickness of a tie or link is based on the number of ties between those two problems (more links = thicker).

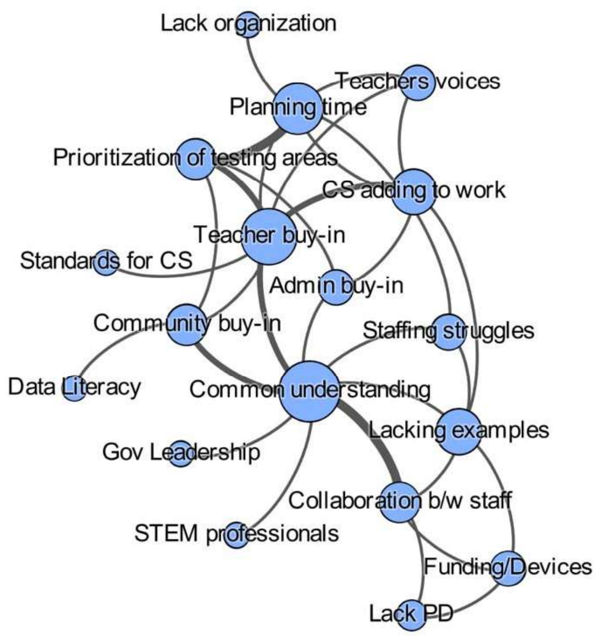


Fig. 1. PoP Network Analysis

TABLE I. Measures of PoP Betweennes Centrality

Label	**Betweenness Centrality**
Common understanding	60.53
Teacher buy-in	33.75
Planning time	20.82
Lacking examples	18.37
Community buy-in	18.01
Collaboration b/w staff	16.47
CS adding to work	12.23
Staffing struggles	7.24
Prioritization of testing areas	4.67

Our top three "problems" in our survey rankings were planning time (lack of), common understanding (lack of), and lacking examples. While common understanding is still important in this graph the other two are not as prominent. "Planning time" is related primarily to testing areas and work management/organization, and "lacking examples" is a subset of more structural barriers related to collaboration between staff, funding, professional development and work/staffing struggles. Other problems that seem more prominent in this graph, that were not previously highly ranked shed light on more specific areas of rural problems: teacher buy-in, CS adding to work, collaboration between teachers and tech integrators, and community buy-in.

IV. Conclusion

At a gathering of the full RPP in late October 2019, participants dug into the data presented here and began formulating initial research questions that would help the RPP better understand the nuance of each problem set and aid in the next steps of designing professional development strategies and integration materials to address them.

Next research steps include investigating how a rural school culture comes to value CS and CT (specifically through common understanding of the CS and CT definitions and buy-in), what the key components of a CS integration support and coaching model would be in order to establish and sustain CS integration in rural K-8 classrooms, and what design principles of instructional materials are needed to design activities aligned with other STEM practices and learning progressions.

In May 2020, i2i will hold a symposium to reach Maine educators, policy-makers, and business leaders to communicate these findings and essential next steps in addressing rural CS integration problems.

Acknowledgment

This project is funded by the CS4All Program at the National Science Foundation – Award # 183726

References

[1] P. Cobb, et al, "Design research with educational systems: Investigating and supporting improvements in the quality of mathematics teaching and learning at scale." *National Society for the Study of Education Yearbook, 112*(2), 320-349. 2013.

[2] C. Coburn, W. Penuel, and K. Gail, K, *Research-practice partnerships: A strategy for leveraging research for educational improvement in school districts*. New York, NY: William T. Grant Foundation, 2013.

[3] S. Wasserman and K. Faust, *Social network analysis: Methods and applications* (Vol. 8). Cambridge university press, 1994.

Add-on Computer Science Endorsements: A Community Effort

Donna Shea, Ph.D.
College of Education
Mississippi State University
Starkville, Mississippi, USA
dshea@colled.msstate.edu

Shelly Hollis
Center for Cyber Education
Research and Curriculum Unit
Mississippi State University
Starkville, Mississippi, USA
shelly.hollis@rcu.msstate.edu

Leanne Long, Ph.D.
Research and Curriculum Unit
Mississippi State University
Starkville, Mississippi, USA
leanne.long@rcu.msstate.edu

***Abstract*—In this experience paper we will share the process we used within our NSF CSForAll Research Practitioner Partnership Network Improvement Community (NIC) to inform the creation of two add-on computer science endorsements for teachers in Mississippi. These additions to a standard teaching license, a K-8 endorsement and a 7-12 endorsement, are available for pre-service teachers to obtain prior to graduation, as well as for in-service teachers to obtain through an online program. There can be many barriers to developing endorsements in this relatively new K-12 education space. Through the work of our NIC we learned that time, cost, location, and relevance were all important aspects that teachers were concerned with, while the university departments were more focused on capacity, enrollment, rigor, and funding. We will describe how working through a NIC smoothed the way to creating endorsements that are recognized by teachers as valuable and accessible and by the university as rigorous and relevant.**

***Keywords*—network improvement community, computer science, education, teaching license, endorsements**

I. Introduction

In 2017, through the CSForAll program, the National Science Foundation (NSF) funded the Mississippi State University (MSU) Research and Curriculum Unit (RCU) project, CS4MS NIC: Growing Teacher Competency and Capacity, which focuses on growing teacher competency and capacity in computer science education. While the first goal of the project centers around professional development for a specific high school computer science course, the second goal of this project is to work with MSU College of Education (COE), the Department of Computer Science and Engineering (CSE), and the Mississippi Department of Education (MDE) to develop appropriate licensure and endorsement pathways for computer science teachers. This goal led to the collaboration between the newly formed RCU Center for Cyber Education (CCE) and faculty and administration from both the COE and the Department of CSE at MSU to lay the foundation for the creation of courses for computer science endorsements. The grant project's NIC played an integral part in providing feedback which would impact the ultimate set of courses and time commitment required for the endorsement. Collaboration between practicing teachers, post-secondary computer science faculty, and COE administrators is a critical component to creating an add-on endorsement for both pre-service and in-service teachers that is rigorous but achievable both in terms of cost and time commitment.

II. Community Collaboration

Upon being awarded the NSF grant, the COE math and technology faculty along with COE administrators and CSE faculty and administrators worked with the members of the RCU-CCE at MSU to determine how best to approach the task of determining appropriate courses for an endorsement in computer science. The group looked at the blueprint for the Praxis Subject-Area Assessment for Computer Science, College Board standards associated with the newly created Advanced Placement Computer Science Principles course, and the Mississippi College and Career Readiness Standards (MCCRS) for Computer Science to begin considering what content was most appropriate for K-12 teachers. Once content objectives were narrowed down, the CSE group looked at courses within the computer science curriculum and the COE group looked at their courses to identify which, if any, could be used to meet the those objectives and best prepare teachers to cover the competencies within the K-12 MCCRS for Computer Science.

Ultimately, it was determined that two endorsements would be necessary to meet the needs of teachers from kindergarten through high school. The group decided that elementary teachers would not need the same level of coursework that high school teachers may need in order to be sufficiently qualified to teach the state-approved computer science standards. Therefore, a K-8 endorsement and a 7-12 endorsement were determined most appropriate. The group came back together over several sessions to decide upon the best courses for each endorsement.

III. Identification of Courses

It was determined that a course needed to be developed for the K-8 endorsement to cover the gap in material that was found within the COE courses. Also, there was a course that was co-taught between COE math faculty and CSE faculty which was determined appropriate for the K-8 endorsement. It quickly became evident that CSE courses were necessary to cover the content of the 7-12, particularly 9-12, MCCRS and thus those courses were identified.

This work was supported by the National Science Foundation under Grant #1738377

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

The course syllabi for the two sets of courses, along with the blueprint of the Praxis Subject Area Assessment for Computer Science and the MCCRS for Computer Science, were shared with the NIC. Time was given within a break-out session for each group to study the materials to determine whether they agreed that the courses adequately covered the content. The group found an apparent gap in the strand of networking which was taken back to the COE/CSE group. It was then determined that the material needed to be placed within the newly developed course and that the course also needed to be required for the 7-12 endorsement as well as the K-8 endorsement.

IV. Approval of Endorsements

Once all agreed to the 12 hours that would be required for the K-8 endorsement and the 20 hours for the 7-12 endorsement, the COE worked to write the proposal to be carried before the Certification Commission. When that day came, Donna Shea, Ph.D., NSF grant co-principal investigator and Director of Clinical/Field-Based Instruction, Licensure, and Outreach, presented the proposal to the Certification Commission and it was approved. The proposal was for the K-8 and 7-12 courses for each endorsement, but it was also to ask the Certification Commission to add Computer Science as another area of initial licensure for the COE's Master of Arts in Teaching (alternate route) program. The Certification Commission approved the proposal and it was sent to the Mississippi State Board of Education and approved shortly thereafter.

The following courses were identified as covering the content and pedagogy necessary to teach the K-12 Computer Science Standards for each endorsement:

A. *K-8 Endorsement*

- TKT 4763/6763 Digital Tools for 21st Century Teaching and Learning
- TKT 4583/6583 Graphics and Web Design
- TKT 4333/6333 Introduction to Computer Science Education
- TKB 4543/6543 Advanced Information Processing

B. *7-12 Endorsement*

- CSE/EDS 4990/6990 Computing and Cybersecurity Classroom Integration
- CSE 1284 Introduction to Computer Programming
- CSE 1384 Intermediate Computer Programming
- CSE 2383 Data Structures and Algorithms; CSE 2813 Discrete Math
- TKT 4333/6333 Introduction to Computer Science Education

V. Methods of Course Delivery

The courses for the K-8 endorsements are all split-level courses, some of which could potentially be used as electives within a master's degree. The courses for the 7-12 endorsement are all undergraduate courses and would likely only be taken by those outside of CSE majors to add on this endorsement. All courses will be offered online, so it would be convenient for teachers to take the courses from anywhere in Mississippi. We anticipate that some MSU COE teacher candidates will take the necessary courses to graduate with the additional endorsements to supplement their initial area of licensure. Since the courses are offered online, we also anticipate that practicing teachers will take the courses to add the additional computer science endorsements to their standard Mississippi Educator License.

VI. Continuing the Alignment of Courses and Endorsements

The next step in this process will be working with MDE to identify which endorsement is appropriate for each of the current computer science courses within their approved course manual and to develop a procedure for properly applying the correct endorsement to any new courses that may be developed. We will work with the NIC team make a recommendation to MDE on which endorsement should apply to which courses. In most cases it will be obvious simply based on the grade level of the course in question. However, for courses offered at the middle school level there will need to be some consideration given to the competencies and objectives of the course to determine the appropriate level of experience for the teacher, since the endorsements overlap at the middle school grades.

VII. Conclusion

Overall, we have learned through this process that collaboration is the key to building effective CS endorsements. The COE and the Department of CSE must work together to develop courses with the appropriate level of rigorous computer science content balanced with the pedagogical strategies unique to teaching the problem-solving and inquiry skills associated with computer science. Practitioners need to be included in the process to ensure what is created is relevant to their classroom and practical to achieve in terms of their time and financial commitment. The state department of education needs to be involved to make certain that the endorsements are allowable and associated with the appropriate K-12 courses. This project has demonstrated what can be accomplished when a community of stakeholders work together for improvement.

Broadening Participation in Computing through a Biology Summer Research Experience for Undergraduates

Patricia Ordóñez
Computer Science Department
University of Puerto Rico Río Piedras
San Juan, Puerto Rico
patricia.ordonez@upr.edu

Humberto Ortiz-Zuazaga
Computer Science Department
University of Puerto Rico Río Piedras
San Juan, Puerto Rico
humberto.ortiz@upr.edu

Juan S. Ramírez-Lugo
Biology Department
University of Puerto Rico Río Piedras
San Juan, Puerto Rico
juan.ramirez3@upr.edu

***Abstract*—Representation of Hispanics, and in particular Hispanic women, is notoriously low in computer science programs in higher education and in the tech industry. The engagement of undergraduate students in research, often and early in their path towards degree completion, has been championed as one of the principal reforms necessary to increase the number of capable professionals in Science, Technology, Engineering, and Mathematics (STEM). The benefits attributed to undergraduate research experiences have been reported to disproportionately benefit individuals from groups that have been historically underrepresented in STEM. The Interdisciplinary and Quantitative Biology Research Experience for Undergraduates (IQ-Bio-REU) summer program was created to engage ten (10) underrepresented undergraduate students in authentic research experiences in emerging fields of biology which integrate quantitative and computational approaches to projects ranging from molecular biosciences to bioinformatics to ecology to bridge the digital and data divide for underrepresented Hispanics and women in computing. Our poster speaks to our observations of our students, faculty, and trainers after participating in our NSF funded summer REU at a Hispanic Serving Institution in a predominantly Hispanic, low socio-economic neighborhood in Puerto Rico.**

***Keywords*—interdisciplinary, data science, broadening participation in computing, computational biology**

I. Introduction

To increase the participation of underrepresented minority (URM) students in computational sciences, we created a summer research experience for undergraduates (REU) at a Hispanic-Serving Institution (HSI) for students from STEM disciplines to participate in projects that involve the application of computational analysis to biological research. Herein we describe the program and the computational and professional skill development workshops and other training activities that provided support for participants to successfully navigate their incursion into computational research.

According to the National Center for Women in Technology 2019 Scorecard of the women working in the United States in technology in 2017, 12.9% were African American, 19.7% were Asian/Pacific Islanders, and only 5.4% of them were Latina. Seeing as women occupied 26% of the occupations in Computer and Mathematical Occupations, we estimate Latinas occupy about 1% of them [1]. In the high-tech sector, numbers for URMs are even more disproportionate [2].

The University of Puerto Rico Río Piedras (UPRRP) is a top research institution, categorized as a doctoral university with high research activity by The Carnegie Classification of Higher Institutions [3]. It is also one of the top producers of Hispanic PhDs in Science and Engineering in the US [4], yet it lags behind in computational science. In the College of Natural Sciences at UPRRP, over 60% of the undergraduate students in Biology are women and in Computer Science it hovers around 15%. The college's population is 98% Hispanic.

Undergraduate research experiences (UREs) have long been considered one of the principal reforms that are necessary to meet the workforce demands of the 21st century [5,6]. UREs have been reported to disproportionately benefit URMs in science, a growing segment of the population whose enrollment in STEM programs is increasing, but that abandons STEM degrees at a high rate [7,8].

II. Program Description

The IQ-Bio-REU was created to engage 10 undergraduate URMs (see Table 1) in authentic research experiences in emerging fields of biology integrating quantitative and computational approaches to projects ranging from molecular biosciences to ecology. Throughout the course of a nine-week period students were immersed in a mentored research project including a wide array of high-impact practices such as experimental design, data collection, troubleshooting, data analysis, working group discussions and the communication of their results to peers.

Participants also received training and practice for fluency in computational skills and data analysis and opportunities for professional development. Ultimately, our program aims to channel more students into careers at the vanguard of science and achieve the goal of promoting participation by URMs in computing within scientific disciplines, thus enhancing diversity in STEM.

One workshop presented by members of a Harvard BD2K center focused on the development of statistical tools that helped students better interpret their data. In the Replicathon, students were presented with two different conclusions from one dataset and they replicated several statistical analyses to present and defend their conclusions to the judges. Another

This research is funded by NSF grant #1852259

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

workshop was offered by the Center for Brain, Minds and Machines at MIT. Postdoctoral and graduate students prepared two days of workshops to expose participants to the fields of neuroscience, statistical modeling, and machine learning in computational neuroscience.

TABLE I. PARTICIPANT CHARACTERISTICS

Demographic Characteristics of 2019 Cohort		
Total =10	***Participant Characteristics***	***Number***
	Non-CS Major	8
	Hispanic/Latinx	7
	African American	1
	Native American	1
	Female	6
	Rising Junior or earlier	5
	No prior research experience	4
	Non-traditional returning students	2

At the end of the summer we organized a mini-hackathon to help REU students solidify their understanding of the research carried out throughout the summer. REU members lead interdisciplinary teams, received feedback from the local community of mentors and our collaborators of the REU and presented their research to other scientists in the community.

III. PROGRAM OUTCOMES

The Software Carpentry workshop included a pre- and post-workshop surveys to see participants attitudes and self-reported skill levels. The surveys indicated that participants gained confidence in their data analysis skills. In response to "I can write a small program/script/macro to solve a problem in my own work" the pre-workshop survey results showed 46% of learners strongly disagreed with that statement, 23% agreed, and 0% strongly agreed. Post-workshop numbers changed to 14% strongly disagree, 43% agree, and 29% strongly agree.

The Undergraduate Research Student Self-Assessment (URSSA) is a self-report survey instrument that is widely used for the evaluation of research experiences [10]. It is intended as a retrospective self-report of perceived gains in understanding, skills and shifts in attitudes of students after participating in a research experience. The survey instrument was administered to participants on the final day of the REU experience. Participants perceived that they had significant gains in computational research skills after the program. Notably when asked to gauge their skills in “analysing data from patterns” on a 5 point scale, where 1=no gain and 5=great gain, the median score (M) was 4 (Standard Deviation [SD]=1.12). For “Understanding the connections among scientific disciplines”, M=4.9 (SD=0.32) with 90% of participants reporting “great gain”. With regards to gaining skills “working with computers”, M=4.4 (SD=0.84, 60% great gain). Taken together, these results suggest that students embraced the interdisciplinary nature of the program and perceived that the program had been useful for the development of computational research skills in an interdisciplinary setting.

The experiences of IQ-Bio-REU triggered changes in attitudes beyond skill acquisition. In an unsolicited email months after the REU had concluded, one of our participants from the US stated that “Puerto Rico was honestly such a transformative experience, I left so prideful of being Latino. Really really proud! ...I may not be Puerto Rican, but we share so much in common! I think that's what's getting my through the hard times here is that I'm not just pursuing my goals for myself, but for my family and wider community.”

The most unexpected outcome was the bond that the trainers that came from our collaborators on the mainland made with our students and program. Several were moved to return for the Hackathon and others were determined to help the university after seeing the lack of computational science on campus to the point of writing a proposal to develop curriculum for the university. It was clear that it had been an eye-opening experience for them to witnessing the digital and data divide that exists between our university and their own.

IV. CONCLUSIONS

The project demonstrated the importance of bringing URMs from different disciplines together at an HSI to build their confidence, and their computational and research skills. We expect that computer scientists from the program will persevere in their field and others will integrate computation into their future careers in STEM. By opening up our activities to the local community in future iterations, we strive to engage more URMs in computational science.

REFERENCES

[1] DuBow, W. & Pruitt, A.S. (2019 Update) NCWIT Scorecard: The Status of Women in Technology. Boulder, CO: NCWIT, www.ncwit.org/scorecard.

[2] Rayome, A.D. 5 Eye-opening statistics about Minorities in Tech, https://www.techrepublic.com/article/5-eye-opening-statistics-about-minorities-in-tech/.

[3] The Carnegie Classification of Institutions of Higher Education (n.d.). About Carnegie Classification. Retrieved from http://carnegieclassifications.iu.edu/.

[4] Top 20 doctorate-granting institutions ranked by number of minority U.S. citizen and permanent resident doctorate recipients, by ethnicity and race of recipient: 5-year total, 2013–17, NSF Science and Engineering Doctorate Awards https://ncses.nsf.gov/pubs/nsf19301/data Table 9.

[5] Linn, M. C., E. Palmer, A. Baranger, E. Gerard, and E. Stone. 2015. “Undergraduate Research Experiences: Impacts and Opportunities.” Science 347 (6222): 1261757–1261757. https://doi.org/10.1126/science.1261757.

[6] Gentile, James, Kerry Brenner, Amy Stephens, and Life Studies. 2017. “Undergraduate Research Experiences for STEM Students.” Edited by James Gentile, Kerry Brenner, Amy Stephens, and Life Studies. Washington, DC. https://doi.org/10.17226/24622.

[7] NSB, National Science Board Science and Engineering Indicators, 2014, National Science Foundation.

[8] NSF, Women, Minorities, and Persons with Disabilities in Science and Engineering. 2013, National Science Foundation.

[9] Wilson G. Software Carpentry: lessons learned [version 2; peer review: 3 approved]. F1000 Research 2016, 3 : 62 https://doi.org/10.12688/f1000research.3-62.v2.

[10] Weston TJ, Laursen SL. 2015. The Undergraduate Research Student Self-Assessment (URSSA): Validation for Use in Program Evaluation. CBE Life Sci Educ 14:1–10.

Through the Looking-Glass: Barriers, Motivations, and Desires of Non-Traditional Students Learning Programming in an Online CS1 Course

Farzana Rahman
Department of EECS
Syracuse University
Syracuse, NY, USA
fraham02@syr.edu

***Abstract*— Student demographics have been changing on college campuses for many years, and to reflect the most efficient methods of teaching the current target population, many institutions are offering online introductory programming courses (CS1). Additionally, due to the increasing number of computing jobs and national demands, we are seeing a surge of non-traditional students (aged over 25), entering the online CS1 courses. We are at a large metropolitan public research university, Florida International University (FIU), where 30% of the students are non-traditional students. However, the online CS1 course usually consists of 70-75% of non-traditional students. We carried out a study in that course for the last 5 semesters where we interviewed non-traditional students to better understand their characteristics and how those are related to their learning goals and performance. This paper is just an attempt to identify the unique characteristics of non-traditional students that can help Computing-ED researchers and admins to design online CS1 courses with appropriate pedagogy, so a better learning experience can be provided to them and retention rates can be increased. Hence, in this paper, we report our preliminary findings on characteristics of non-traditional students who enroll in CS1 course, what their goals and expectations are-how that may differ based on their major (CS majors and non-majors), pre-CS1 programming experience, gender, and race/ethnicity.**

Keywords*— *non-traditional; CS1; online course; diversity

I. Introduction

The demographics on college campuses throughout the nation have been changing over the last decade, finding a more diverse group of students. Modern-day students look for academic programs that meet their needs with very full lives, time-dependent jobs, and family responsibilities. Many students cannot afford to take time away from their jobs or supporting their family to go to a brick and mortar classroom [1]. Online programs offer the flexibility that students are looking for while maintaining universities' academic commitment. Like many other STEM disciplines, computing programs throughout the nation have started to offer courses in online format [2].

Recently there is a surge in online introductory programming courses, also known as CS1 courses, where we see a surge of non-traditional students (aged over 25), who already have a degree in a different discipline and work either full-time or part-time, enter the CS1 course. We are at a large metropolitan public research university where we have a large number of non-traditional students, who prefer an option for a more flexible learning environment and schedule (e.g. online classes) than traditional students, and hence they tend to enroll in online CS1 course at large [2]. For non-traditional students, going back to school requires more planning and lifestyle reassessment and they may have families, full-time jobs, and/or mortgages they are responsible for. Similarly, when they enroll in the CS1 course, with or without the intention of getting a computing degree, we hypothesize that they tend to have differing goals, motivations, as well as expectations. Due to age differences, varying life experiences and constancy in an academic environment, we also hypothesize that traditional and non-traditional students have varying cognitive levels upon entering the online CS1 course. Finally, our observation finds that non-traditional students are more likely to leave school due to conflicting responsibilities (work, parenting, caring for an elderly parent), are less likely to complete their degree, and have lower retention rates compared to traditional students.

As online learning continues to see significant growth in computing fields, identifying the characteristics of these students will have important implications in diversity efforts. Computing departments are struggling to provide a good experience with limited resources and very little knowledge about these set of students. As departments seek to manage increasing enrollments in computing courses through online CS1 courses, as well as continue to attract and retain diverse students to the field, scholars and administrators will need to understand the unique characteristics of these students to deliver a better learning experience to them. To find answers to these questions, we conducted a study at a large metropolitan public research university classified as a Hispanic Serving Institution (HSI), where 30% of the students are non-traditional students. However, the online CS1 course, which took part in our study, usually consists of (70-75) % of non-traditional students with very low retention (less than 10%) and academic success rate.

This paper is just an attempt to identify the unique characteristics of non-traditional students that can help Computing-ED researchers and admins to design online CS1 courses with appropriate pedagogy, so a better learning experience can be provided to them and their retention rates can be increased. Hence, in this paper, we report our preliminary findings on characteristics of non-traditional students who enroll in CS1 course, why they enroll in CS1 course, what their goals and expectations are-how that may differ based on their major (CS majors and non-majors), pre-CS1 programming experience, gender, and race/ethnicity.

978-1-7281-7172-2/20/$31.00 ©2020 IEEE

II. The Study

A. Research questions

This paper presents preliminary findings from a study conducted at FIU, on an online CS1 course largely taken by non-traditional students for 5 semesters. In total, 282 students (traditional and non-traditional combined) participated in this study, out of which 209 (i.e. 74%) were non-traditional students. This paper will explore the background, demographic characteristics, pre-course experiences, motivation, objective and mindset of non-traditional students who enrolled in the online CS1 courses between Spring 2018 and Summer 2019 semester (5 semesters including summer '18 and '19). The questions guiding the contribution of this paper are:

RQ1. *What are the characteristics of non-traditional students enrolled in online introductory programming or CS1 courses?*

RQ2. *How do these characteristics differ between female and male students?*

RQ3. *How do these characteristics differ between CS majors and non-majors?*

B. Preliminary Results and Discussion

In this section, we present a preliminary analysis of our study on what characteristics are unique for non-traditional students.

Gender: Even though female makes up close to 28% of the online CS1 course, non-traditional female students represent a much smaller share in online CS1 courses (12%). There is an even smaller representation of non-traditional female students among CS majors (21% female) than among those who are CS non-majors (51 % female).

Race/Ethnicity: Close to half (49%) of the students in the online CS1 course are Hispanic/Latino/Latino American, followed by 27% White/Caucasian, 11% Asian/Asian American, 7% Black/African American, 4% Multiracial, and 2% Other. Racial/ethnic diversity is greater among male students taking online CS1 relative to their female counterparts.

The academic and professional background of parents: A large portion of non-traditional students in CS1 courses reports that they are first-generation college students (62%). 28% of female students and 41% of male students had parents who went to college. However, as many as 8% of females and 18% of males report that at least one parent has a tech job.

Major: Contrary to our hypothesis, we found that only 18% of students enrolled in the online CS1 course were CS majors, and that varied significantly by gender. Only 8% of non-traditional females were CS majors and the rest were from very different academic majors ranging from education to IT. We found that males and females are equally likely to represent majors in engineering, business, and the physical sciences, math but female are more likely than men to report majors in biology, social sciences, and education.

Lack of belonging and community: These students report to often have multiple responsibilities that prevent the possibility of full-time enrollment and as a result, they (91%) reported a lack of belonging in academic circles and also lacking a sense of community with their peers. They can spend very little time on campus, which decreases their opportunities to seek support and build relationships with instructors and peers. Finally, enrollment status affects financial aid eligibility which can become a financial burden for the part-time student when compared to their full-time traditional counterparts.

Mindset: Our analysis indicates that non-traditional students who enroll in CS1 have more of an "outcome centered" mindset. Almost 64.6% of them expected to get into a better job with higher pay once they finish their CS major or minor requirements. 13.5% of them reported already working in IT or software developer position and they enrolled in the CS1 course to perform better in their current job.

Prior programming experience: Our study found that more than half of the non-traditional students enrolled in online CS1 already have little to moderate prior programming background. Many of them were already working part-time in development, IT, computer maintenance jobs, which required them to know programming or some computing logic. 41% students reported never taking a STEM course in college before.

Technology usage: A large population (close to 75%) of students expressed their comfort with computer usage as very high. However, in contrast, a large population (close to 45%) of students expressed they never installed software on their own. In a course like CS1, where students were required to set up JDK and an IDE, many students seemed to struggle with it even though they reported otherwise.

Reason for enrollment in an online CS1 course: Non-traditional students of online CS1 provide a range of reasons for enrolling in the class, with the most common reason being that it was convenient for them considering their lifestyle. More than half of the students reported they took the course out of curiosity or to make a career change. Only 32% of students reported that they took the course because it fulfilled their course requirement (close to 18% being CS major and a few others from engineering major). Few, 4.2% reported taking the class because they were encouraged by an advisor or a peer.

Environmental factor: Many (72%) students report that stress resulting from environmental factors poses one of the biggest challenges to success in the CS1 course. These factors include finances, domestic responsibilities, housing, childcare, family stability, employment demands, and transferring from a 2 to 4-year college. Close to 60% reported that despite putting required hours every week, online CS1 course, being a very technical and intensive programming course, required mental peace, time and dedication, self-study efforts from students' end, which resulted in more stress. Many (over 80%) reported that despite being dedicated, the pressure of balancing work, family responsibilities, and other circumstances adds a great deal of emotional strain to their daily life, that do not allow them to put enough effort to succeed.

References

[1] Conrad, R.; Donaldson, J. Engaging the Online Learner: Activities and Resources for Creative Instruction. John Wiley & Sons, Inc; 2004.

[2] Bowl, M. Experiencing the barriers: non-traditional students entering higher education, Research Papers in Education, 2001, 16:2, 141-160.

Promoting Diversity in CS via Code as a Liberal Art

Ursula Wolz
Culture & Media, Lang College
The New School
New York, US
wolzu@newschool.edu

Todd Anderson
Culture & Media, Lang College
The New School
New York, US
andersts@newschool.edu

Jennifer Wilson
Nat. Science and Mathematics, Lang College
The New School
New York, US
wilsonj@newschool.edu

***Abstract*—We discuss how a minor in Code as a Liberal Art was established through novel approaches to curriculum and pedagogy at a liberal arts college with a strong commitment to progressive interdisciplinary education. Working groups of com-mitted faculty from a range of disciplines, outside of computer science, identified a set of core learning objectives for coding in the liberal arts. Multiple course offerings were developed by faculty with diverse expertise ranging from theater to machine learning to address the core learning objectives within the context of their discipline. This approach suggests a new avenue for broadening participation and increasing equity in computing, especially at institutions without programs in computer science, by addressing well-known challenges such as student prepared-ness and lack of sufficient faculty with appropriate expertise. More importantly, it demonstrates how, by explicitly avoiding a 'one size fits all' model, students from diverse backgrounds can become confident and successful coders within a liberal arts context.**

Keywords—liberal arts computer science, Interdisciplinary computer science, computer science minor

I. Introduction

Reports from the Computer Research Association (CRA) [1] and the National Academies (NA) [2] on broadening participation in computing implicitly focus on institutions with existing programs in computer science (CS) for majors and non-majors. A broadening initiative started at Lang College in Spring 2020 is outside the scope of these reports because the institution lacked a formal program in computing. Lang is representative of other institutions in which access to any computing is severely limited. This report is a road map for implementing a highly interdisciplinary model that respects the significant contributions of faculty outside of CS who both designed and are implementing this program through the application of integrated, cross-disciplinary learning objectives.

II. WHO HAS ACCESS TO COMPUTING

The Code as Liberal Art initiative casts a wide net without one-size fits all requirements. Both CRA and NA reports highlight two recent phenomena that impede progress toward diversifying access to computing education. (1) While significant gains have been made in increasing under-represented groups into CS, classroom demographics remain significantly different from those of the undergraduate population at large; and (2) there is a crisis of resources, particularly of faculty, as overall demand for computing courses has ballooned in the past decade. The reports note distinctions between major and non-major offerings; however the analysis assumes that credentialed CS faculty teach (or co-teach) courses, and that offerings for non-majors and majors are distinct, with the former providing breadth rather than depth.

Small liberal arts colleges, historically black colleges, or associate degree providers are barely represented in the analysis, yet suffer acutely from these problems. They are increasingly the gateway to higher education for under-represented groups and those with insufficient mathematics background [3], [4]. Of equal concern is evidence that for-profit institutions that do not provide a liberal education that includes ethical and social impact of computing make a significant contribution to the recent increased enrollment of students of color, especially women [5]. One solution to proposed by the CRA and NA reports is to promote interdisciplinarity. The challenges are well known, requiring significant changes in academic culture [6], [5] from silos to collaboration by faculty across disciplines.

III. CODE AS A LIBERAL ART

Our new minor was established by a multidisciplinary group of faculty to deepen students' understanding of code and computational thinking in relation to access, equity and social justice. Lang College has a tradition of curricular innovation with strengths in the Arts, Writing, Media Studies and Social Sciences. It does not offer majors in CS or mathematics. It employs an open curriculum (with a single first year general education requirement in writing), and emphasizes interdisciplinary seminars. In 2018, a task force drawn from Culture and Media, the Arts, Anthropology, Philosophy, Music, and Mathematics was charged: "to increase coding literacy, and to foster a new form of civic education in response to the increasing presence of computational systems in contemporary life. "

The Task Force sponsored courses across disciplines. The courses embedded coding experiences into disciplinary courses, demonstrating how code is increasingly integrated into research methodologies of academic practice and techniques for artistic expression. The task force sponsored roundtables to develop explicit goals for a minor program and build interest among faculty at Lang, and the larger university. Code as a Liberal Art received a substantial financial gift to support new curriculum development and now offers courses in Culture and Media Studies, Writing, Natural Science and Mathematics, Politics, and the Arts. Funding enables non CS-trained faculty to incorporate coding modules or assignments in their classes by pairing them with experienced part time faculty to develop curriculum and lab experiences for the classroom. The new minor launched in Spring 2020.

IV. STANDARD LEARNING OBJECTIVES

In four semesters (Fall 2018 - Spring 2020), 14 new minor courses in six disciplines, each met most, if not all, of a common set of learning objectives:

- Use computation as a tool to enhance liberal arts education, to better analyze, communicate, create and learn
- Engage in project-based and collaborative learning utilizing computational/algorithmic thinking
- Gain a broader understanding of the historical and social factors leading to the increasing presence of computing.
- Work through the social and political implications of/embedded within computational technologies and develop an accompanying ethical framework.
- Appreciate the challenges of equity and access posed by increased reliance on computing as well as their potential to reinforce existing inequalities in society.
- Think critically about the ways one interacts with computation including understanding its limits from philosophical, logical, mathematical and public policy perspectives.
- Understand the intrinsic relationship between the physical world, analog environments and digital experiences

The depth of coverage of the objectives, and the breadth of disciplines represented suggests that we are successfully providing increased interdisciplinary computing opportunities.

The exercise of defining these objectives provides guidance both for future curricular planning and to help students learn to code within their educational focus or to broaden their experiences coding. The collaborative articulation of common learning objectives across disciplines helps faculty integrate coding into their offerings, and simultaneously shapes the minor within the liberal arts. Faculty have opportunities to share expertise, leading to pedagogical development, over time.

V. STUDENT ACTIVITIES TO MEET OBJECTIVES

Two courses are summarized briefly to illustrate how a common thread is the balanced inclusion of key concepts computing and the complementary discipline.

Digital Creative Writing is a second year level elective with no coding prerequisite. It is a broad survey of how coding and digital tools can be applied to the written word, from generative text and twitterbots, to memes, interactive fiction and narrative games. Each week students explore a new area of digital written culture, with new coding techniques introduced to create new work. Coding skills are introduced primarily through examples. Students begin by adapting that code, eventually dramatically restructuring programs to achieve their creative goals. In the final project students integrate new techniques into their existing writing practice, to build an ongoing digital writing practice for future work.

Do Machines Learn? is an elective in Culture and Media that introduces students to theories of human learning and contrasts it with artificial intelligence, including knowledge representation, logic systems, heuristic search, agent theory, and neural-net based machine learning. Students code a small simulation in which their intelligent avatar navigates a world model without human intervention. Through their coding research on human learning, each student answers the question ‘do machine learn?’. (Their answers were all ’NO!’)

VI. CONCLUSIONS AND RECOMMENDATIONS

Student assessment and course evaluations provide preliminary evidence that learning objectives are being met. Equally significant is that faculty across disciplines are collaborating to share expertise, identify common and consistent approaches and identify resources to expand individual expertise. Next steps and upcoming challenges include: (1) Providing academic support outside the classroom (coding tutors, facilities, equipment) (2) developing a detailed curriculum map that includes identifying specific computing skills and language choice (3) developing advanced courses (4) support for students and faculty to integrate new coding skills beyond the minor’s course offerings.

The Code as a Liberal Art approach presents one avenue for broadening participation in computing by overcoming the shortage of computer science faculty – a challenge facing many institutions including those with existing CS programs. Key to its success is the interdisciplinary and collaborative faculty engagement to determine core learning objectives and develop curriculum in computing as well as its social, ethical and intellectual implications.

ACKNOWLEDGMENT

Sincere thank you to Sara Schupf for her generous financial support of the Code as a Liberal Art initiative.

REFERENCES

[1] C. R. Association. (2017) Generation CS: Computer Science Undergraduate Enrollments Surge Since 2006. [Online]. Available: http://cra.org/data/Generation-CS/

[2] National Academies of Sciences, *Engineering, and Medicine, Assessing and Responding to the Growth of Computer Science Undergraduate Enrollment*. Washington, DC: The National Acadamies Press, 2018.

[3] D. Borzelleca, “The Male-Female Ratio in College,” *Forbes*, Feb. 2012. [Online]. Available: https://www.forbes.com/sites/ccap/2012/02/16/the-male-female-ratio-in-college/#39d0d2effa52

[4] J. Marcus, “Universities and colleges struggle to stem big drops in enrollment,” *The Hechinger Report*, Jun. 2017. [Online]. Available: https://hechingerreport.org/universities-colleges-struggle-stem-big-drops-enrollment/

[5] E. Shein, “The CS teacher shortage,” *Communications of the ACM*, vol. 62, no. 10, pp. 17-18, 2019.

[6] U. Wolz and L. Cassel, “The Role of Interdisciplinary Computing in Higher Education, Research and Industry,” *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*. New York: ACM, 2012.