Including Disability in Diversity

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***Abstract*— For over a decade, AccessComputing has worked to increase the participation of people with disabilities in computing fields. A key component of this work is to influence institutional change in educational institutions, computing organizations, government labs, and industry companies. This paper considers lessons learned in working with these partners in ensuring that disability is included in larger conversations around diversity.**

Keywords—disability, broadening participation, institutional change

I. Introduction

For over a decade, *AccessComputing* has worked to increase the participation of people with disabilities in computing fields. Through National Science Foundation (NSF) funding, *AccessComputing* has helped students with disabilities successfully pursue degrees and employment in computing fields and worked to increase the capacity of postsecondary institutions, employers, and other organizations to fully include individuals with disabilities in computing education and careers. We've previously documented lessons learned in engaging computing students with disabilities [1]. This article considers lessons AccessComputing has learned in work with organizations including educational institutions, computing organizations, government labs, and industry.

Demand for computing professionals is outpacing supply. The underrepresentation of women, racial/ethnic minorities, and people with disabilities [2]–[6] contributes to the current shortage. Individuals with disabilities are less likely than their nondisabled peers to succeed in careers [5]–[8]; complete degrees [5]–[10]; and pursue science, technology, engineering, and mathematics fields [11], [12].

To be successful in a computing career, individuals with disabilities must overcome barriers imposed by inaccessible facilities, curricula, and information technology; inadequate academic supports; and lack of encouragement and role models. Students with disabilities in computing fields report issues including difficulty navigating technical interviews, inaccessible programming environments and hardware, disability disclosure in the classroom and the work environment, and additional complications related to relocation for internships or employment [1].

AccessComputing began in 2006 as a joint effort between the Allen School of Computer Science and Engineering and the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center at the University of Washington (UW) as a multi-objective national project with the goal of increasing the number and success of people with disabilities in computing fields. The objectives included direct interventions for students, institutional change for organizations, and creation and curation of resources for individuals and organizations. In the process we have engaged over fifty academic and organizational partners who share our goals and commitments. In 2015, the UW Information School joined the effort and our objectives were expanded to include promoting the teaching of accessibility and working with computing industry to help them become more equipped to recruit and retain more people with disabilities as interns and permanent employees. Evaluation results of *AccessComputing* activities suggest that computing departments, professional organizations, and employment opportunities have become more welcoming and accessible as a result of engagement with *AccessComputing* [13].

II. Impact on Educational Institutions

AccessComputing has impacted computing education both at the K-12 level and the postsecondary level. At the K-12 level, this includes development of a Web Design and Development course (WebD2) by our information technology accessibility specialist Terrill Thompson in collaboration with K-12 teachers [14]. WebD2 integrates accessibility and universal design (UD) principles and methods throughout the curriculum, thereby increasing accessibility awareness, knowledge, and skills among future computing professionals. The curriculum has been used extensively—over six thousand users worldwide have created instructor accounts and over one thousand individuals have subscribed to a discussion list created to support teachers with the curriculum.

In 2014, we received a complementary grant from NSF, *AccessCS10k* to increase the participation of students with disabilities in computing education at the K-12 level. It is

This material is based in part upon work supported by the National Science Foundation under Grant Number 1539179. 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.

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important to ensure that students with disabilities are included in the current movement to bring computing education into K-12 schools [15]. In collaboration with Andreas Stefik at the University of Nevada, Las Vegas, this project has taken a two-pronged approach. Because many popular tools used in K-12 computing are inaccessible to students who are blind or have mobility impairments, this project develops and promotes the Quorum programming language, an accessible alternative [16]. The project also provides professional development for individuals who develop trainings for K-12 teachers. This professional development includes information about accessible tools as well as information about how universal design of learning (UDL) can make a classroom more welcoming and accessible to students with a variety of disabilities [17]. Starting in 2018, through an additional grant, *AccessCSforAll*, we will hold professional development workshops for teachers of students who are blind, deaf, or have learning disabilities so that they can offer an accessible Advanced Placement Computer Science Principles (CSP) course. *AccessCSforAll* will develop an accessible CSP curriculum that employs the Quorum language and emphasizes the impact of accessible technology on society.

At the postsecondary level, *AccessComputing* works with a nationwide network of computing departments at thirty-five colleges and universities each represented by a committed individual partner. These partners engage with each other via phone meetings, online communities of practice (CoPs), and in-person capacity building institutes (CBIs) and commit to taking steps that will make computing courses, resources, programs, and/or project activities more welcoming and accessible to individuals with disabilities. Several of these partners have disabilities, others have research interests related to accessibility, and some are interested more generally in broadening participation in computing.

Through project activities, *AccessComputing* helps partners identify steps they can take to increase the participation of people with disabilities in computing. As a result, partners have recruited student team members, hosted interns with disabilities, included students with disabilities in outreach activities, and made their websites more accessible and welcoming. Several of our partner institutions, including Carnegie Mellon University, Georgia Tech, New Mexico State, and Landmark College have worked with *AccessComputing* to host CBIs at their institutions. These collaborative meetings include a variety of stakeholders and focus on actionable steps their institution can take to more fully include people with disabilities in computing fields, make resources accessible, and incorporate disability-related content in courses. In addition, *AccessComputing* has developed and disseminated a large collection of online resources that educators can use to make their courses, departments, and schools more welcoming and accessible to students with disabilities [18]. This includes publications related to UDL, accessibility of computing labs, and information technology as well as videos on related topics.

Since 2015, *AccessComputing* has been working to increase the inclusion of information related to accessibility and disability in postsecondary computing courses. Tech companies report that they need more employees with an understanding of accessibility [19], [20]. Additionally, acknowledging disability in the curriculum may serve to make computing more welcoming and accessibility to individuals with disability and other diverse backgrounds. When people with disabilities are involved with the development of technology, it can help to ensure that technology is accessible from its inception [21]. Many, though certainly not all, individuals with disabilities are interested in accessibility and may be more interested in careers in technology when exposed to this content [22], [23]. In CBIs and other presentations, we have promoted the inclusion of accessibility in computing courses and offered strategies for doing so. We have also partnered with Teach Access in a variety of activities with similar goals. Teach Access is an initiative of tech companies and educational institutions interested in expanding what undergraduates are taught about accessibility in computing fields [20]. At the UW, *AccessComputing* co-PI Andrew Ko has worked with instructors in the Information School to integrate information about accessibility into existing courses. As a result, large groups of UW undergraduates are learning about the topic. As of Fall 2017, accessibility is officially part of the curriculum in the Information School. All sections of INFO 200 (Intellectual Foundations of Informatics) now include at least one day of accessibility content in the 10-week quarter, reaching 900 students per year.

III. Impact on Organizations

In addition to postsecondary partners, *AccessComputing* also works with a network of organizational partners that include computing associations, broadening participation groups, and groups focused on disability. Through this work, we have seen several groups make changes that have had a positive effect on individuals with disabilities in computing fields. At the inception of the Center for Minorities and People with Disabilities in Information Technology (CMD-IT), *AccessComputing* PI Richard Ladner advocated for the inclusion of people with disabilities along with other underrepresented groups to be part of its mission. Ladner is a founding member of the Board of Directors of CMD-IT. For the past several years, the Tapia Celebration of Diversity in Computing has been presented by CMD-IT. Because of this and *AccessComputing*'s involvement, there has been an increased focus on disability at the event. Recent years have seen multiple keynotes from individuals with disabilities including Annie Anton of Georgia Tech, Chieko Asakawa of IBM, Shaun Kane of the University of Colorado, and Daniel Sonnenfeld of Salesforce. Disability has had an increased presence at the conference in terms of attendees and program content.

AccessComputing has impacted other conferences as well. We have worked with the Grace Hopper Celebration's Women from Underrepresented Groups committee to ensure that women with disabilities are represented in their tracks, and we send students to the conference annually. In conjunction with Jonathan Lazar from Towson University, we have worked extensively with the Association for Computing Machinery (ACM) Special Interest Group on Computer-Human Interaction (SIGCHI) to make their conference more accessible. We worked with the ACM Special Interest Group on Computer Science Education (SIGCSE) to implement an accessibility chair at their conference and presented multiple sessions in recent years related to disability.

AccessComputing plays an important role with the ACM Special Interest Group on Accessible Computing (SIGACCESS). We have supported people with disabilities attending ASSETS, their conference. Over the past ten years, the number of people with disabilities attending ASSETS has increased remarkably, with many of them being *AccessComputing* partners or student participants.

Each summer *AccessComputing* funds research experiences for undergraduates (REUs) for about five students wtih disabilities per year. Most often, these students work with faculty members at their home institutions and are not part of a larger REU site. We partner with the Computing Research Association Distributed REU (DREU) program to track and provide structure for these students. Through these REUs students with disabilities gain research experience and faculty members gain experience working with students with disabilities.

Since 2010 *AccessComputing* has worked with CMD-IT, the Computing Alliance for Hispanic-Serving Institutions (CAHSI), and the Coalition to Diversify Computing to coordinate the Academic Careers Workshop, which brings together senior graduate students and young faculty members in computing from underrepresented groups with senior mentors. Every year, students and faculty members with disabilities attend to learn about networking, grant writing, and the tenure and promotion process.

AccessComputing has worked with a variety of other computing organizations to help them include accurate information about disabilities in their own resources or to make their resources more accessible. Examples include csteachingtips.org, NCWIT (the National Center for Women in Information Technology, ncwit.org), and the ACM (acm.org).

IV. Impact on Industry

Since 2015, *AccessComputing* has begun working more directly with industry via our partnership with Teach Access mentioned above, as well as by creating strategies to increase the participation of people with disabilities in the computing workforce. We work with a network of industry partners interested in recruiting, onboarding, and retaining employees with disabilities. Partners include Lawrence Livermore National Labs, Microsoft, Salesforce, and Oath. In June of 2016, we held a CBI for our partners. Proceedings are available online [23]. Industry partners engage with *AccessComputing* staff and partners via regular telephone conferences; work towards creating a welcoming and accessible environment for interns and employees with disabilities; have access to a resume database of computing students who have disabilities for potential internships and permanent employment; and explore opportunities for *AccessComputing* students to test products for accessibility.

Interactions with industry partners have varied. Salesforce has organized recruiting events for students with disabilities and partnered with *AccessComputing* to recruit interns and employees with disabilities. We have worked closely with Microsoft and Oath on initatives related to increasing the amount of accessibility content in the computing curriculum, such as designing and holding a workshop for faculty at the UW. Teach Access has replicated this workshop in other settings.

V. Lessons Learned

Based on our experiences with *AccessComputing*, we offer the following lessons learned:

Disability is a part of diversity. People with disabilities encounter many of the same barriers as other underrepresented groups, including women and racial and ethnic minorities. Including disability in diversity conversations enriches our understanding of broadening participation.

Meet partners and collaborators where they are. Different partners and collaborators have different needs, which means that we engage with each of our partners differently. Determining what a partner might be interested in doing and working with them on that can lead to effective change rather than approaching all partners in a cookie cutter approach.

Develop a strong infrastructure to expand your impact. The administrative and staffing infrastructure that the DO-IT Center has developed has allowed us to apply for related grants, namely *AccessCSforAll* and *AccessEngineering*, to expand our impact on the representation of people with disabilities in K-12 computing and engineering, respectively.

Be persistent. Some organizations can be slow to change and require continued effort. Once change has been made, persistence is necessary to ensure that organizations don’t revert, particularly as leadership changes.

Adapt to stakeholder shifts over time. Over time, we have added new partners to our network, allowing us to reach new schools and organizations and expand our work into industry. In addition, we’ve seen individual partners increase or decrease their involvement based on myriad factors. Regardless, the overall work and efforts to change move forward.

Leverage existing networks. Many of our partners were existing contacts within our PIs’ networks, including collaborators, students, and others who work in similar research areas. Many of them joined our efforts because of these existing relationships.

Engage diverse communities to promote change. Within our project, we work with computer scientists, social scientists, industry engineers, disability service professionals, and others. This diversity allows participants to learn from one another and leads to rich conversations and change.

Build community through different interactions. We engage with partners at our CBIs, at national conferences, in phone meetings, and via our CoPs. Each interaction is a chance to build community, have conversation, and find ways to collaborate and make change. Different partners are more active in different arenas depending on their own preferences.

AccessComputing has also learned from challenges that we have encountered.

Be mindful of small numbers. When we formed targeted CoPs that included individuals interested in specific disabilities, we found that the communities never took off. The groups were small and segmented our community too much. Our CoPs have been more effective with a larger yet more diverse group.

Engaging in a common activity with diverse partners may be difficult. We hoped to engage with our university partners to collect data on students with disabilities on their campus. Not all partners wanted to participate. Others were unable to obtain the data. Data that we did obtain varied across institutions.

Take time to learn about new groups. We have tried to engage with veterans with disabilities over time with mixed results. Many veterans have disabilities related to their service and yet many veterans are reticent to identify as an individual with a disability. Learning more about military culture has been critical to engaging with veterans.

Over the last decade, *AccessComputing* has been changing the conversation about diversity in computing by working to ensure that disability is included through our work with a variety of stakeholders including individuals with disabilities, educators, computing organizations, and industry. We look forward to continuing to do this work and seeing disability become a more prominent part of the conversation about broadening participation in computing.

We encourage others who are interested in increasing the participation of individuals with disabilities in computing to get involved. Faculty members can refer computing students with disabilities, join our online mentoring community as a mentor, or host an intern in their lab. Educators can find ways to make change within their departments by becoming a partner, joining one of our online CoPs to engage in online conversations, including information about accessibility in their courses, and utilizing our online resources to find ways to make their departments and schools more welcoming and accessible to individuals with disabilities. Industry professionals can also become partners and utilize our resume database of students with disabilities in computing to recruit interns and employees to their organizations.

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Not Just Black and Not Just a Woman: Black Women Belonging in Computing

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***Abstract*—A sense of belonging is key to pursuing and persisting in computing. It is also one of the reasons for the low representation of women and Black people in computing. Research has attempted to understand why these underrepresented groups feel like they do not belong in computing. These initiatives tend to analyze race and gender separately as if people experience these aspects of identity separately. For Black women who are seeking to belong in computing, these sorts of analyses are problematic. Black women are not just "women plus color, or Black plus gender" [1]. Intersections of their race and gender yield unique experiences for them. Thus, analyses that only focus on women's experiences or Blacks' experiences leaves out the many nuances that result from one being both a woman and Black. This paper is an exploration of "what it means to belong" in computing. By analyzing Black womens multiple identities through an intersectional lens, we show that most research for Black people or women is not inclusive of Black womens unique perspectives. We make visible a gap in computing education research that does not address intersectionality.**

***Index Terms*—Black women, Computing, Broadening Participation, Belonging, Intersectionality, Identity**

I. Introduction

"Do I belong?" This is one of the questions people ask themselves when deciding to enter, continue, or abandon the pursuit of computing fields [2]. Ong et al. back this claim with findings that social identity and belonging, and not lack of interest, is key in pursuing and persisting in computer science (CS) [3]. It is no wonder then that many efforts to increase participation of Blacks and women attempt to provide guidelines on how to help these underrepresented communities feel like they belong [4], [5], [6].

These initiatives tend to analyze race and gender separately as if people experience these aspects of identity separately. For Black women who are seeking to belong in computing, these sorts of analyses are problematic. Black feminists have been critics of these analyses, suggesting analyses studying women are mainly concerned with the issues of white women [7]. Analyses studying race are "consumed with the educational barriers negatively affecting young Black men, ignoring the educational needs of young Black women" [8].

Ong et al. states that the intersectional identities of minority women play an important role in their development and persistence in STEM fields [3]. Charleston et al. describe how Black women are subject, "to the complex interplay of sexism and racism, conceptualized as the double bind" [9]. The double bind suggests that Black women face the distinct problem of pursuing interests that conflict with both their racial and gender identities [3].

Intersections of Black women's race and gender yield unique experiences for them. Because of racism and sexism oppression, Black women are in multiple jeopardy of race, class, and gender exclusion in educational institutions [8]. Black women "are not white women plus color, or Black men, plus gender" [1]. Thus, analyses that only focus on women's experiences or Blacks' experiences leaves out the many nuances that result from one being both a woman and Black. Educational concerns for young Black women need to reject essentialist arguments and generalizations and not view identity as an additive.

Black feminists call for more minority female scholars to "unabashedly directly confront the social and educational needs of minority girls of color" [8], [10] in an attempt to "reveal aspects of reality obscured by more orthodox approaches" [7]. In this paper, we address some of the educational needs of Black women to provide a voice for Black women in computing. Much of the computing education research on broadening participation can benefit from understanding the importance of analyses that take into account the intersections of race and gender.

This paper is an exploration of "what it means to belong“ in computing. By analyzing Black womens multiple identities through an intersectional lens, this paper will show that most research for Blacks or women is not inclusive of Black women's unique perspectives. We make visible a gap in computing education research that does not address intersectionality.

II. Intersectionality as a Lens

Research on intersectional identities suggests, "Black women's success in computing hinges on the development of an identity that is compatible with their gender and racial identities" [11]. Gender and race are socially constructed and when used as categories of analyses, neither can be understood decontextualized from the other; people do not experience them in isolation [10], [12]. An intersectional approach explores how these factors combine to alter the meaning and effects of each other [12]. For example, Collins writes, "White women are penalized by their gender, but privileged by their race" [7]. Whiteness creates many advantages for White women, even though gender produces many disadvantages [12].

The social construction of a "Black woman" is "inextricably linked to racial hierarchy," suggesting it is embedded institutionally and systematically [10]. Black women experience discrimination that is both similar to and different from discrimination experienced by White women and Black men [13]. However, they often experience double-discrimination, or the combined effects of discrimination on the basis of race and gender or just discrimination from being "Black women" [13].

An intersectional view has been shown to be helpful in illuminating patterns of social inequality [12]. For example, theories of femininity in education suggest that femininity is often seen as "fragile and vulnerable" arguing that "girls experience declining self-esteem in school and that boys tend to dominate teachers attentions"[14]. However, femininity through an intersectional lens challenges these notions, suggesting Black girls do not accept quiet and passive roles [12]. Historically, Black women worked outside the home and occupied prominent positions in Black communities [15]. Their experiences and understandings of being a woman differs markedly from White women. Bettie and Morris describe that "girls not privileged by Whiteness" construct alternative notions of femininity different from dominant definitions of femininity as quiet and passive [16], [12].

In computing education, an intersectional approach can help the research community think more deeply about research practices, create a more inclusive language, and not make generalizations based on categories like women, Black, Latinx, low-income, LGBTQIA, minority, etc [17]. Waller suggests we should rethink "statistical analyses which use independent, categorical variables to capture race, gender, first-generation status," and to be careful when collecting qualitative data, realizing that racism or sexism may be affecting the data [17].

III. The Invisibility of Black Women in Computing

Black women are not prototypical category members of women or Blacks. Non-prototypical members are less likely to be recognized as members of the category [18]. This means that when one thinks of a typical woman (prototyped as a White woman) or Blacks (prototyped as Black men) they are not likely to think of Black women [19], [18].

A side effect of Black women's status of being non-prototypical is that they are subject to different outcomes and frequently overlooked and rendered invisible in comparison with prototypical Blacks and women [19], [18]. Sekso et al. define invisibility as "a lack of individuation of or lack of differentiation between group members, which is evident in Black women's faces going 'unnoticed' (being poorly recognized), and their voices going 'unheard' (i.e., misattributed to others), relative to those of White women and Black men" [18]. However, Black women's invisibility has both advantages and disadvantages. In comparison to prototypical members, i.e. Black men, Black women are less likely to be targets of discrimination in classrooms (teachers usually punish Black men more than Black women), but are less likely to have their voices heard and, thus, be marginalized [18], [12].

Historically, Black women have struggled against race and gender oppression in different ways than White women and Black men [12]. Fordham writes the following [20]:

> African-American womens history stands in striking contrast to that generally associated with white womanhood and includes (1) more than 200 years in which their status as women was annulled . . . (2) systemic absence of protection by African-American and all other men; (3) construction of a new definition of what it means to be female out of the stigma associated with the black experience and the virtue and purity associated with white womanhood; and (4) hard work (including slave and domestic labor). Thus, the historical exclusion from White, ideal models of femininity and the requirement to be independent from men has forged outspokenness for many Black women and girls (pg. 8).

Many Black women have been made invisible in the Women's Liberation Movement, the Civil Rights Movement, and, most recently, Black Lives Matter, due to a lack of recognition of their lives and experiences [18]. This invisibility can also be seen in computing.

Both Women and Blacks in computing are disadvantaged groups that have been discriminated against. Both groups have made tremendous efforts in fighting for a voice, creating safe spaces to celebrate their contributions to computing, and redefining what a computer scientist "looks like."

Celebrations about the many achievements and advancements women have made for technology constantly refer to astounding women like Grace Hopper, Anita Borg, and Ada Lovelace, all White women. The Notable Women in Tech Cards is a project to showcase outstanding and innovative women in technology. There are 52 women featured on their own card. Of the 52 women featured, there are two Black women.

The most recognizable, and stereotyped, representation of a computer scientist for Black people often come from tv shows. Two of the more prominent exemplars of the "Black nerd" include Dwayne Wayne from the tv show *A Different World* and Steve Urkel from the tv show *Family Matters* [21].

Code.org features a 6-minute video on their homepage that is meant to inspire more people to learn to program. In the video there are interviews with nine people, including innovators in technology, famous musicians, and athletes. Of the nine people interviewed, two were Black and both males: basketball player Chris Bosh and musician Will I Am. The video also featured interviews with software engineers; there was one interview with a Black male software engineer. Throughout the nearly six minute video, there was only three Black girls shown in b-roll.

These are just some of the examples of Black women being rendered invisible in computing. These representations are meant to broaden notions of a computer scientist, but can be problematic when one does not see his or herself reflected. For Black women, this can create feelings as being the other.

Sesko et al. states that invisibility stems from issues in ways of thinking about Black women [18]. Black women are considered either too much like women or too much like Blacks [13]. Therefore, their experiences are either absorbed into the collective experiences of either group or is considered too different, in which case their needs and perspectives get placed at the margins of women and Black agendas [13], [18].

IV. Research on Belonging in Computing

Research on belonging in computing has described challenges and ways to help Blacks and women belong. However, some of this research has hidden biases that makes the research "not for" Black women. In this section we analyze some of the literature on belonging to make those biases visible.

A. Blacks Belonging in Computing

Black students' underperformance and lack of representation is typically attributed to access and socioeconomic status rather than more probable causes of racial identity [22]. Walton et al. found that Black students are discouraged from pursuing computing when they feel they do not belong [2]. When Black students feel discouraged, they may even convince their peers to not pursue computing [2]. DiSalvo et al. states the following [22]:

> People are more likely to identify with something if they perceive it to be the norm in their social group. However, the corollary is that people will disidentify with something they don't believe to be within their domain of self-identity. Disidentification with computing contributes to under-representation among Blacks (pg. 2967).

CS is known for having a "geek culture" that is a gatekeeper for joining the field [23], [24], [21]. Geeks are profiled as "predominantly white males, who do well in school especially in mathematics and sciences, have high IQs, collect technical products, and are science fiction fans, but are socially inept" [25]. This profile projects one "way as the only way to be and do CS" [24]. Disalvo et al. states that people who do not fit the mold of a geek are often considered the "other" [23].

For Black students wanting to join CS, they have to navigate this "geek culture" [23], [24] that often goes against their identity as "a Black person" [2]. Kohl describes students frequently choose to not engage if they feel a confliction with their cultural values [26].

1) Analysis: Theories of disidentification are suggested as one reason why Blacks feel like they do not belong in computing. However, historically, disidentification has been attributed to Black men, and not Black women [27]. DiSalvo's research on Glitch Game Testers does a great job describing how Black men disidentify with computing [28]. Her work describes how Black men "engage in defensive posturing, rejecting schools and other institutions that they perceive as actively rejecting them" [28]. When Black men disidentify, they are rejecting an institution before that institution can reject them [28].

Examples of disidentification can be traced to historic roots in American slavery [27]. Black men's masculinity was constantly being tested as not being masculine enough, which has led to this hypersensitive nature where they tend to retreat from situations that infringe upon their masculinity or identity [27]. Black women, however, have been seen as the "backbone" of the family, often having to work at jobs where they were discriminated against to provide [7]. Thus, historically, Black women have never had the privilege of being able to "disidentify" with something, because they had to take care of their family [20].

B. Women Belonging in Computing

Women as a whole are a disadvantaged group in computing [29]. Gender comparisons of achievement in programming courses have repeatedly found that female students perform as well or better than male students [11]. These findings have been a large catalyst for researchers to look into other reasons as to why women do not persist in computing. Of the many factors found, the most influential was a lack of "fitting in" or "feeling of belonging" [11], [30].

The current culture has made it so that creating technology is a "man's job" [29]. Women in this field are described as feeling like "outsiders," and constantly having their confidence undermined due to subtle, and not so subtle, indications that they do not belong [29]. Women deal with patronizing behavior like negative stereotypes about their ability ("you got in because you are a girl") [29], [11].

Female college students have reported feeling less confident in their programming abilities and usually ask fewer questions in class than male students [31]. This made them feel less engaged and isolated. These differences in confidence begin when students are still in K-12 [31]. Male students are perceived to be more interested in CS, therefore they receive more encouragement to pursue the field.

Walton et al. suggest that women feel like they belong when they focus on their ability and not their social worth (e.g., women being "nice") [2]. Fordham describes the only-commandment for women in the academy is "Thou must be taken seriously" which is a euphemism for "thou must not appear as woman" [20]. To be taken seriously in academia, women must know content well, "survive and prosper in a world organized by and for men (not women)," and transform their identities to appear less female (e.g. less submissive, or nice) [20].

V. Black Women Belonging in Computing

The previous section was an analysis to expose some of the hidden biases in current understandings of belonging for Blacks and women in computing. From our analysis, we saw these understandings of belonging were based upon notions of Black masculinity or White femininity. These understandings of belonging are indicative of the invisibility of Black women due to their non-prototypicality. In this section, we use some of the existing literature to show how an intersectional lens exposes the unique experiences of Black women that affects their sense of belonging in computing.

A. Choosing an Identity

W.E.B. Du Bois describes the presence of a “double consciousness” among Blacks - a “twoness” that he describes as “an American, a Negro; two souls, two thoughts, two unreconciled strivings” [32], [33]. Morris suggests Black womens unreconciled strivings and stirred consciousness are informed by their identities: “In fact, most people walk through life consciously unaware of their multiple identities (no one is just Black, just a woman, just a parent, just a student, etc)” [33].

Charleston et al. detail Black womens experiences in CS [9]. In CS, Black women often attempt to understand if they are treated a certain way because they are Black, a woman, or a Black woman. They respond to this treatment in one of two ways.

The first is they choose an identity by either being “just Black” or “just a woman,” depending on how they assume others perceive them. This strategy essentially requires them to reject their “Blackness” or “womanness” to take on a raceless or genderless persona for academic success [15]. If they assume one sees them as a woman, they try to downplay their “Blackness” by being more respectable and acting out accepted, universal forms of femininity. The inverse happens if they assume they are seen as a Black.

The second way they can respond is by accepting that they are “Black women” and that their identities cannot be separated [11]. Evans-Winters et al. and OConnor suggest that Black women who accept that they are Black women are “academically resilient” and “have a strong sense of racial identification and commitment to fighting against race, class, and gender injustices at school, in the community, and in society overall” [8], [34]

For Black women to feel like they belong in computing, they need to acknowledge their whole self, realizing there is no hierarchical structure for oppression [33]. The interaction of oppressed identities (woman and Black) generates a more complex worldview than just a singular identity: “This assertion (that no single form of oppression is more important or dominant than another) is key to understanding and combating the harmful and dehumanizing experiences faced by all manner of human beings, including all too many Black girls” [33].

B. Acting More Feminine

Because “Black men” are prototypical of Blacks, Blacks are implicitly associated with masculinity [19]. Black women are non-prototypical of their racial category and therefore, often assumed to be more masculine [19]. Their perceived “blackness” impacts perceptions of their femininity: “Their assertive behaviors, which schools and families often subtly encourage for White and middle-class children, tended to be interpreted as abrasive and aggressive” [12]. School officials, and even other students, stereotype Black girls as “loud, aggressive, and masculine” [8], [12], [20].

In a study by Charleston et al., Black women in computer science described being aware of the stereotypes about being a Black woman in computer science and how that dictated how they were supposed to act [11]. For instance, peers automatically assumed a Black woman would get upset or “defiant” if something unfavorable happened, or they were viewed as bossy if they were assertive [11], [35]. CS classrooms were thus unwelcoming to them due to their preconceived misperceptions and stereotypes.

In response to this, some students and professors in computer science attempt to change Black women to fit into more standard ideals of femininity [12]. Morris describes how Black femininity is seen as “inadequately feminine,” where school officials believe Black women need to be reformed to more “acceptable” forms of femininity [12]. This “acceptable” form of femininity includes becoming passive and silent. Many teachers encourage Black women to “exemplify an ideal, docile form of femininity,” to act like “ladies” or saying microaggressive statements like “Dont take classes from the chicks in this department” [35].

Born into a cultural legacy of slavery, Black women have interpreted defiance as something that is not inherently bad or masculine, but a rejection to oppression. Black women were often expected to “speak only when spoken to,” a clear sign of “subjugation and relative insignificance” [33]. There were always expectations of who the “good” Black women or girl was. Black girls learn to be assertive to survive; they are not afforded the same systemic protections as other girls or Black men [20]. Black girls embrace this strategy of a loud and “aggressive” persona to reject oppression in classrooms in order to be rendered visible and no longer marginalized [20], [8].

VI. Recommendations and Conclusions

We explored one area of computing education research, issues of belonging, that was not fully taking advantage of using intersectionality as a lens on analyses. Great research has been produced to understand how to make discriminated and underrepresented communities feel like they belong in computing. However, much of this research is guilty of making generalizations and essentialist claims about single categories (e.g. women and Blacks) that are meant to represent everyone (e.g. Black women). By analyzing Black women’s multiple identities through an intersectional lens, we show that most research for Blacks or women is not inclusive of Black women’s unique perspectives. In this paper we focused on belonging, but intersectionality could be useful for understanding retention, persistence, and, more broadly, broadening participation.

This work is not the representative of every Black woman; this paper is more reflective of cisgender Black women. Understandings of belonging changes, and may be more difficult to analyze, when using other identities in the analysis (e.g. sexuality, class, etc.). Thus a dark skin lesbian Black woman will have different needs to belong than a dark-skin transgender Black woman.

We love to say that every analysis should take advantage of an intersectional lens. However, realistically, that is not feasible. A robust intersectional analysis requires enough representation in the data and well collected demographic data; sometimes neither of those are available. In response to this, one practice that researchers can begin to immediately do is fully disclose who the participants are, when that information is available. For instance, in the previous paragraph we bluntly stated that this paper is not representative of every Black women. While an intersectional lens may not always be feasible, we as a community can make better attempts at fully disclosing who participants in studies are and who the research "is for."

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Evaluating Computer Science Professional Development Models and Educator Outcomes to Ensure Equity

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***Abstract*—Google's educator professional development (PD) grants (formerly Computer Science for High School [CS4HS]) provide annual funding to education nonprofits that design and deliver Computer Science (CS) PD to educators in their local communities. As CS education is an emerging field, many education stakeholders can be ill-equipped to identify CS PD needs, evaluate options, and assess educator and student outcomes. As a result educators may participate in CS PD that fails to address their needs, which worsens equity gaps in CS education. Therefore, models of evaluating CS PD programs and outcomes are critical to equitable CS education. This paper provides an update on earlier research findings from 2014 with data from the 2015 and 2016 evaluation cycles, as well as updates to our evaluation measures and methodology.**

Keywords—Computer Science, Computer Science Education, Professional Development, Evaluation, Equity, Teachers, Educators

I. Introduction

Google's educator professional development (PD) grants (formerly Computer Science for High School [CS4HS]) provide annual funding to education nonprofits that design and deliver Computer Science (CS) PD to educators in their local communities. Google aims to scale equitable and sustainable access to CS education through localized PD that meets on-the-ground needs of educators and their school systems, with a focus on underrepresented and low-CS-momentum communities. Since 2009, Google has reached over 50,000 educators in more than 50 countries.

CS education is an emerging field (relative to other K–12 education disciplines), as is CS PD, which further complicates CS PD design and the evaluation of outcomes. As discussed by Darling-Hammond, Hyler, & Gardner (2017), "Few schools, districts, or state education agencies have created good systems of tracking PD, let alone systems for analyzing the quality and impact of PD" (p. 22). Given that CS is a field historically challenged with issues of representation, it is critical that K–12 education stakeholders are mindful of evaluating how CS is implemented in the classroom to ensure equitable access, participation, and outcomes.

Equity divides in CS education are worsened when educators are not prepared for the challenges they will likely face in the classroom. These challenges include students' lack of foundational skills, a lack of support and direction from administrators, and a lack of resources [1][6], as well as lack of a Community of Practice (COP) with shared purpose. Darling-Hammond et al. (2017) note that these communities reduce the "traditionally strong relationship between socioeconomic status and achievement gains in mathematics and science" (p. 17). Since 2014, Google has required that applicants incorporate a COP into their PD to provide ongoing support as educators implement CS in the classroom.

Google is committed to understanding the impact of its funding on increasing the number of educators who are confident and competent in CS education, therefore broadening access to the discipline in K-12 schools. As a result, the grant program is run with an evaluation strategy that surveys PD providers and participating educators. The purpose of this annual evaluation is to examine the goals, objectives, and activities of the grant program and measure growth in attitudes and CS content knowledge over the course of the program. The data and findings are utilized to inform the growth and development of Google's CS education engagements. It is critical that educational leaders and institutions understand CS PD needs, evaluate PD options, and assess outcomes to ensure that education is equitably improving student participation, perceptions and proficiencies in CS. While Google currently funds a variety of PD programs representing different methodologies, we believe it is possible to design a common evaluation method that measures educator outcomes as they relate to participant demographics and CS PD design.

II. Method

Educators who attend Google-supported PD opportunities are requested to complete optional Pre- and Post-surveys at the first and last sessions of their PD/COP opportunity respectively. The research questions that guide these educator evaluations are:

- To what extent do Google-supported PD opportunities affect educator confidence and competence to teach CS in the classroom?
- To what extent do Google-supported PD opportunities equip educators with the skills, content and pedagogy needed to provide a quality learning experience for their students?

Since 2014, the evaluation methodology and measures have been refined to capture more precise data from educators while reducing the response burden. In 2014, we began measuring aggregate mean differences in pre-to-post responses for educators in the United States and Canada. In 2015, the evaluation process included a mechanism to link survey responses to a single individual with email address identifiers. The evaluation process has continued for the 2016 and 2017 grant years. In 2016, the evaluation process expanded to Google-supported PD programs in Africa, China, Europe, and the Middle East. In 2017, the evaluation process expanded to Google-supported PD programs in Australia and New Zealand.

In this paper, we present the evaluations' scale reliability, and pre-post outcomes (using paired t-tests through voluntary, user-submitted email address identifiers) of educators who participated in the 2014, 2015, and 2016 cohorts of Google-funded CS PD opportunities in the United States and Canada (US/CA). The 2016 data are analyzed by demographic subgroups of prior CS teaching experience, middle or high school teaching, COP expectations, and content implementation.

III. Results

Results of the 2014 evaluation process were published as an "early findings" article in TOCE [5] This article compared self-reported learning gains and experiences of educators in four Google-funded PD opportunities. The findings were based on unmatched pre-post data, however we were able to determine participants in both the pre-survey and post-survey were demographically and experientially very similar which suggested our analyses still had merit. Analyses from 314 pre-surveys and 129 post-surveys illustrated that the CS educator participants were quite heterogeneous, suggesting that some ability to customize PD based on educator background and needs would benefit educator outcomes. We reported a preliminary finding that the two face-to-face PD experiences appeared to engender a stronger sense of community than the online or blended experiences. Finally, among the outcomes we measured, educator concerns [5] were more sensitive to change than our measures of self-efficacy, outcome expectations, readiness, or beliefs. We highlighted the variety of CS educator PD experiences and the need to study the effective ways to scale CS teacher education to meet the needs of a wide range of educators and contexts, and we highlighted methodological and measurement challenges to assessing online PD outcomes.

Since the previous results were shared, we have had the opportunity to improve our data collection and replicate and improve on many of the findings. The updated findings we present for RESPECT 2018 include the 2015 and 2016 evaluation cycles:

TABLE I. Grant Program and Survey Participation

	2014[a]	2015	2016
Program sites evaluated	n = 4	n = 14	n = 36
Pre-survey response rate	n = 314	18% (n = 348)	68% (n = 672)
Post-survey response rate	n = 129	8% (n = 148)	38% (n = 373)
Linked response rate	n = 0	4% (n = 75)	7% (n = 68)

a. 2014 cycle did not identify original participant counts; response rate not calculated.

Not only did the validity of the data increase from 2014 to 2016 as a result of adding the voluntary email identifiers for paired t-test analysis, but also the response rates have consistently increased, indicating that the conclusions are increasingly representative. Further, we have revised the evaluation process to include more effective measures that produce actionable learnings across sites and outcomes, analysis by demographic subgroups, analysis of COP influence on educator outcomes in CS education, and analysis of educator outcomes as they relate to classroom implementation of content learned in the PD opportunity.

A. More effective measures

The 2014 study indicated the Concerns items were the measures for which we saw the most significant changes. Reliability for the measures continued to be strong ($\alpha \geqslant 0.82$) for all US/CA scale scores for both the 2015 and 2016 evaluation cycles (Tables II and III). While the Concerns measures still show statistically significant change, new "Readiness" items added in 2015 are also sensitive to change. We still are not seeing a statistically significant change in self-efficacy for the scale and most items. Given that the self-efficacy scale scores are already positive at the pre-survey, we suspect that participants' speculative analysis of the self-efficacy items (e.g. "I can effectively teach the concepts required by the curriculum") is more difficult for the respondents to answer because they have not completed a full cycle of classroom implementation with the PD-learned CS content. In contrast, educators have the opportunity to reflect on their concerns and readiness attitudes throughout the PD, potentially demonstrating to themselves that they have improved in those areas.

The measures used are refined each grant year for multiple reasons. First, we identify gaps in what we are measuring relative to the priorities of the grant program or CS education landscape (e.g. whether educators implement PD-learned content and if it is successful was added for the 2016 grant year). Further, the 2014 study included exploratory measures intended to generate data about how different PD delivery models relate to educator outcomes. Through the 2015 and 2016 evaluation cycles, items that had no relationship to the outcomes educators gained nor to the site-by-site contexts of the PD opportunities funded were removed. These items were not answering the most important questions about whether outcomes change as a result of participating in PD, or which elements of PD relate to those outcomes. We replaced those dropped measures with attitude items on "Readiness" that were more effective in showing variation across sites and relationships to outcomes. This resulted in a reduced response burden and more actionable learnings. The items we added include the following:

- I am confident in my ability to teach CS effectively;
- I have the knowledge and skills I need to teach CS effectively;
- I have the curriculum tools and resources I need to teach CS effectively;
- I have a social network that enables me to teach CS effectively.

TABLE II. US/CA PRE-POST CHANGES IN ATTITUDE SCALES (2015)[A]

	α[b]	N		Mean (SD)		Change	Effect Size[c]
		Pre	*Post*	*Pre*	*Post*		
Concerns							
Linked	0.83	75	75	2.48 (0.56)	2.08 (0.64)	-0.40	-0.71**
Unlinked	0.83	345	128	2.54 (0.56)	2.09 (0.67)	-0.45	-0.80**
Self-Efficacy							
Linked	0.84	75	75	3.87 (0.70)	4.02 (0.57)	0.15	0.21
Unlinked	0.84	345	126	3.89 (0.68)	4.08 (0.55)	0.19	0.28*
Readiness							
Linked	0.82	75	75	3.31 (0.86)	4.00 (0.65)	0.69	0.80**
Unlinked	0.82	343	128	3.44 (0.88)	3.97 (0.71)	0.53	0.60**

a. Using paired t-tests and ANOVA (unpaired). ** $p < 0.001$. * $p < 0.01$.

b. Reliability. Cronbach's alpha.

c. Effect sizes are based on pre-SD.

TABLE III. US/CA PRE-POST CHANGES IN ATTITUDE SCALES (2016)[A]

	α[b]	N		Mean (SD)		Change	Effect Size[c]
		Pre	*Post*	*Pre*	*Post*		
Concerns							
Linked	0.89	64	64	2.50 (0.56)	2.15 (0.60)	-0.35	-0.62**
Unlinked	0.89	662	369	2.51 (0.53)	2.08 (0.66)	-0.43	-0.81**
Self-Efficacy							
Linked	0.89	67	67	3.90 (0.71)	4.00 (0.70)	0.10	0.14
Unlinked	0.89	670	373	3.86 (0.73)	4.04 (0.65)	0.18	0.25**
Readiness							
Linked	0.87	67	67	3.41 (0.94)	3.84 (0.81)	0.43	0.46**
Unlinked	0.87	668	374	3.27 (0.96)	3.91 (0.81)	0.64	0.67**

a. Using paired t-tests and ANOVA (unpaired). ** $p < 0.001$. * $p < 0.01$.

b. Reliability. Cronbach's alpha.

c. Effect sizes are based on pre-SD.

B. *Sub-group outcomes*

As of 2015, we were able to analyze pre-post gains by subgroup. We see significant changes in attitudes (in intended directions) for both those who have taught CS before and those who have not, as well as for both middle school and high school educators. Although we only had 19 matched cases in 2016 for teachers who had never taught CS before, their gains were significantly higher than gains reported by teachers with prior experience teaching CS. This finding underscores the importance of a focus on CS fundamentals and pedagogical content knowledge, so that educators are resilient in the face of technology changes and prepared to support diverse student needs. From 2015 to 2016, we saw a 52% increase in educator respondents who indicated no prior CS teaching experience. It is critical that PD providers continue to address the varied needs of this educator population to ensure an equitable rollout of CS education to all students.

C. *Communities of Practice*

We introduced communities of practice (COP) as a focus in 2014 and have continued studying how a sense of community relates to educator outcomes. Here we focus on changes in readiness attitudes according to whether or not participants' expectations for the COP were met. Educators whose COP expectations were met improved their attitudes more than those whose were not met. For example, the pre-post change on the readiness scale for those whose expectations were met ($n = 31$) was a statistically significant 0.62 ($ES = 0.75$, $p < 0.001$), while for those whose expectations were not met ($n = 35$) the change of 0.30 did not reach statistical significance ($ES = 0.36$, NS, $p < 0.10$). Moreover, the pre-post change was significant on all four readiness items ($p < 0.05$) for those whose expectations were met, but for those with unmet expectations the change was significant only for the knowledge and skills-related item. The biggest difference related to COP expectations had to do with having a social network. For teachers whose expectations were met 81% (out of 16) of those with a negative or neutral pre-score shifted to a positive response, while only 29% (out of 21) with unmet expectations had a similarly positive shift (Chi-Sq, $p < 0.002$).

D. *Implementation of content*

Unlike in the previous study, we linked data on self-reported implementation of PD content to attitude shifts in the 2016 evaluation cycle. Overall, 64% of educator respondents estimated they implemented around 50% or more of the content they learned in their Google-supported PD. The pre-scores on readiness attitudes were similar for those who did and did not implement 50% or more of the content. However, those who implemented 50% or more of the content improved their readiness attitudes more than others. The pre-post change for those who implemented 50% or more ($n = 33$) was 0.59 ($ES = 0.69$, $p < 0.001$) while for those who did not implement 50% ($n = 30$) it was 0.29 ($ES = 0.34$, NS, $p < 0.10$). For those who implemented 50% of the content, the pre-post change was significant on all four readiness items, while for those who did not implement 50% of the content the change was significant only for the knowledge and skills-related item. The biggest difference related to implementation of content involved curriculum tools. Specifically, 67% (out of 18) of the high implementing teachers with a negative or neutral pre-score shifted to a positive response, while only 27% (out of 15) who implemented 50% or less had a similarly positive shift (Chi-Sq, $p < 0.02$).

IV. Discussion

Since 2014, the evaluation process has refined the measures used to evaluate educator outcomes, increased the number of educators who respond, and replicated trends we found in pre-post educator outcomes. Additionally, the measures have produced reliable results, despite the highly varied PD opportunities in which educators have participated (e.g. face-to-face versus online, AP Computer Science Principles versus Exploring Computer Science). Current survey measures and further analyses can be obtained by emailing the authors.

Considering the greater and more significant outcomes of certain educator subgroups (no prior CS teaching, COP expectations met, majority of PD-learned content implmeneted), the findings of the 2015 and 2016 evaluation cycles support the 2014 conclusion that PD customized to educator background and needs benefits outcomes. This further underscores the need for robust evaluation of PD needs, options, and outcomes to scale CS education equitably.

There are two primary limitations to this evaluation process. First, the Google team has no direct engagement with educators who participate in PD opportunities, nor their students. While we provide documentation about the evaluation process, PD providers ultimately decide if they will distribute surveys and how they are communicated to educators. This lack of direct access to educators and students prevents Google from conducting longitudinal/multi-year analysis of educator outcomes, or evaluation of student changes in belief, attitude, or proficiency in CS. A second limitation is the varying nature of PD opportunities supported by Google; a hallmark of the program is that applicants identify the CS PD needs of local educators and tailor their PD opportunities accordingly. While tailoring CS PD to educator needs produces greater outcomes for both educators and students [2], it prevents Google from designing and executing a controlled, comparative assessment of PD models to identify what formats, curricula, and so on are most effective in CS teacher training.

V. Conclusions

Google maintains that educator professional development can affect widespread participation in CS through institutional change. However, it is critical that educator and student outcomes of CS PD opportunities are appropriately measured to ensure that perception and proficiency gaps are not widening inequitably.

Despite limitations, the Google evaluation process has effectively measured pre-post changes for educators with significantly different backgrounds in demographics, education, CS, and CS education. In addition to identifying measures and methodologies for tracking the outcomes of educators who participate in a variety of CS PD oppotunities, we have also learned that the programs funded by Google can be linked to objective increases in CS educator confidence and competence. Finally, extant research has shown that a localized PD model produces greater outcomes for educators and students that can help overcome traditional equity barriers in education and CS [1][2][3][6] Our evaluation process indicates that the model of Google's CS educator PD grants program (i.e., localized PD coupled with an academic year COP that support educators during CS implementation) is consistent with these findings from the literature.

It is possible to evaluate attitudinal outcomes of a wide variety of CS PD opportunities through shared evaluation measures while also identifying what PD elements are most impactful. However, more controlled studies of CS PD programs are needed to better understand which PD models provide the best outcomes for students and educators in varying contexts. As the CS education field looks to broaden participation in CS to ensure sufficient representation, developing models to identify CS PD needs, evaluate PD options, and assess outcomes are paramount to maintaining consistent engagement of all students with CS.

Acknowledgment

The authors would like to acknowledge the PD providers and educators who participated in the evaluations process and contributed their experiences to better our understanding of the CS PD landscape. We would also like to thank Chris Stephenson, Karen Parker, Olga Garcia and many others at Google who have supported this evaluation process since 2014. S.D. would like to thank Kat and Steve Davis, Elliot Bartz, Joshua Garoon and all of the family, friends, and educators who supported the journey to this research.

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Promoting High School Teachers' Self-efficacy and the Understanding of Equity Issues in CS Classrooms

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***Abstract*—Effective and equitable CS teaching in classrooms is contingent on teachers' high-levels of self-efficacy in CS as well as a robust understanding of equity issues in CS classrooms. To this end, our study examined the influence of a professional development (PD) course, Teaching Exploring Computer Science (TECS), on promoting teacher self-efficacy and equity awareness in CS education. This nine-week PD was offered in a hybrid format, delivering on-line and face-to-face classes to high school teachers across various disciplines who served under-represented students. The participants completed a self-efficacy survey focusing on their ability to teach ECS, both before and after the course. Results showed that teachers' self-efficacy in the content knowledge and pedagogical knowledge of ECS significantly increased as a result of taking the course. We also evaluated teacher's understanding of the equity issues by conducting a content analysis of their reflection essays written at the end of the course. Four major themes emerged from the content analysis, highlighting the impact of equitable practices on CS participation. This research demonstrates the role of a professional development course in promoting teachers' self-efficacy beliefs in teaching CS and their understanding of the equity issues and presents tools for assessing teachers' development in these areas.**

***Index Terms*—Self-efficacy, Equity, Professional Development, Exploring Computer Science**

I. Introduction

CS education at the secondary school level contributes to the equality of the CS education pipeline and promotes fundamental skills such as computational thinking [1]. Among others, the Exploring Computer Science (ECS) curriculum has been designed and widely adopted around the nation to promote CS education in secondary schools through broadening participation, instilling interest, and enhancing equity in CS classrooms [2]. Because the ECS curriculum is intended to engage students' interest and inspire their passion for computing, the effective implementation of the ECS curriculum is not solely contingent upon teacher's content knowledge—teachers' self-efficacy in teaching CS and the in-depth understanding of the equity issues in CS classrooms are also critical prerequisites for effective CS instruction [3]. However, there has been a dearth of research on the development of teachers' self-efficacy in teaching ECS and on the teachers' understanding of the equity issues in CS education. To further this research, we engaged in-service high school teachers in a professional development course—Teaching Exploring Computer Science (TECS) and addressed research questions in: 1) What is the influence of the TECS class on the high school teachers' self-efficacy in the content and pedagogical knowledge of teaching TECS? 2) What are the high school teachers' understandings of the equity issues in CS education after completing the TECS course?

II. Background

Efforts devoted to broadening participation in formal CS education has focused on issues related to access in the past decade–offering high quality CS courses in more schools and attract a wider audience of students, especially females and underrepresented students [4]. Propelled by the national initiatives such as CS10K, substantive and high quality CS curriculum have been developed to facilitate the understanding of essential CS concepts, deviating from the overemphasis on technology literacy in traditional CS courses. However, the challenges to broadening participation still remain in the other aspects of access-the lack of professional development programs to nurture effective CS teachers, and the complexities involved in the equity issues in CS classrooms. Therefore, much of the existing research on CS education has recognized the importance of preparing teachers with the content and pedagogical knowledge of teaching CS and the strategies to promote equity practices [3]. However, research in other STEM disciplines has shown that teachers' self-efficacy beliefs in the content and pedagogical knowledge are of equal if not greater importance than the mastery of such knowledge [5]. On the one hand, self-efficacy beliefs are predictive of the teachers' persistence and effort levels when challenges arise [6]; on the other hand, teachers' self-efficacy in a discipline provide models for students and facilitates students' self-efficacy in the same discipline [7]. Therefore, examining the teachers' development of self-efficacy in the content and pedagogical knowledge of teaching ECS is necessary and can provide information on how to structure PD programs to facilitate such development.

A. *Self-efficacy in CS Teachers*

Teacher self-efficacy is an important construct in teacher education and has been found to not only influence student learning, but also predict teaching behaviors and teachers' persistence in the face of challenges [8], [9]. For example, several prior studies have identified that teacher efficacy has predictive roles in teacher burnout, student achievement and students' self-efficacy [10]. However, although the research on teacher self-efficacy has been established for decades in other disciplines, the research for CS teachers' self-efficacy has been limited. In this section, we draw on the research from other fields to inform the framework for the current study.

Self-efficacy describes the extent to which one believes that one can successfully perform a task in a specific situation or area [6]. In the context of teacher self-efficacy, one strand of research examines teachers' belief in whether educational practices can influence student learning [10]. In comparison, another strand of research is more focused on Bandura's definition of self-efficacy and measures teacher self-efficacy as teachers' belief in their ability to complete certain tasks in teaching [8], [11]. These two types of theoretical backgrounds have resulted in variances in the construction of teacher self-efficacy surveys. However, recent developments on teacher self-efficacy have suggested adhering to the original definition of self-efficacy as defined by Bandura—one's belief in the ability to successfully accomplish a task [8]. In addition, self-efficacy is domain specific in nature, where narrowly defined measures are more predictive of future behaviors than those covering a broad spectrum without defining specific tasks or behaviors [8], [9]. Therefore, in this study, we created content-specific measures and followed Bandura's model on constructing self-efficacy surveys to examine teachers' self-efficacy in teaching ECS [11].

To identify the content-specific items for the self-efficacy survey, we drew on the teacher education literature that identified the content knowledge, pedagogical knowledge and pedagogical content knowledge (PCK) as essential to the development of teacher knowledge [8], [12]. While PCK or the "adaptation of subject matter knowledge for pedagogical purposes" [13, p.7] is an important aspect of teacher knowledge, it is built upon teachers' content knowledge and the pedagogical knowledge [13], [14]. Therefore, in the current study, instead of examining teachers' self-efficacy in PCK, we focused on the teachers' self-efficacy in the content knowledge and pedagogical knowledge of teaching ECS.

To promote teachers' self-efficacy, the social cognitive theory has suggested that it is important to tap into the four major sources of self-efficacy, including mastery experiences, vicarious experiences, physiological state and social persuasion [8]. Among these four sources of self-efficacy, the mastery experiences have been identified as the most influential factor contributing to teachers' self-efficacy. For example, [5] found that mastery experiences were especially beneficial for developing novice teachers' self-efficacy judgments. Similarly, several studies in the filed of science teacher self-efficacy have found that professional development programs that support the major sources of self-efficacy and emphasize both the content knowledge and pedagogy practices tend to significantly promote teacher efficacy as measured in personal teaching efficacy and outcome expectancy [15]. Therefore, teacher training programs that aim at promoting teachers' self-efficacy beliefs should provide experiences that cater to one or several of the major sources of self-efficacy, especially providing mastery experiences [9].

B. *Equity in CS Education*

Promoting equity has been at the forefront of CS education and become the focus of many national initiatives such as CS10K [4]. However, research on the equity issues in CS education has been limited. Therefore, in this study, we first draw on the relevant research in science education, which shows that factors such as the growing diversity of student populations in schools, the achievement gaps among demographic groups, and the importance of scientific literacy in the modern world have imposed urgency and challenges to equity [16]. To address these issues, the science education community has called for discipline-specific and diversity-oriented approaches to bring about science for all students, premised on the fact that high level of performance and achievement are obtainable for all students regardless of the students' cultural, linguistic, and socioeconomic backgrounds. This premise requires educators to recognize that achievement gaps in science among different demographic groups are more likely to be the results of the varying amount of learning opportunities available in the students' environment, rather than students' innate abilities stereotyped by cultural biases. Therefore, educators need to consider the alignment of the students' cultural and linguistic resources and the classroom practices, value the experiences that students bring in the classroom, interpret science knowledge in accordance with students' cultural backgrounds, and provide resources to support science learning for all students [16]. In summary, the science education research has highlighted the urgency of addressing equity issues through providing equal access and promoting equitable practices in classrooms for all students.

Perhaps not coincidentally, a similar constellation of factors have challenged the equitable practices in CS education [4]. In alignment with the science education research that highlighted the importance of equal access to disciplinary resources, pioneering work in CS education has shown that the unequal access to resources such as technology tools and curriculum has caused disparities in CS education, disadvantaging students from low-SES backgrounds and underrepresented ethnic groups [17]. Informed by these disparities, national initiatives and research efforts have been devoted to creating inspiring and engaging curriculum to provide students from diverse backgrounds equal access to CS resources [4].

Under the broader context of the remarkably low percentage of females and underrepresented minorities in CS classrooms and beyond, it is easy to fall under the impression that promoting access and broadening participation–getting more students from diverse background in CS classrooms–has addressed much of the equity issues. However, equity issues are also deeply rooted in social and cultural practices [16]. For example, educators and students' faulty beliefs about what types of students can excel in CS have also prevented students from diverse background to participate equally in CS education [17]. Therefore, in addition to creating equal access, it is also important to promote equitable teaching practices such as changing the social interaction dynamics in classrooms and encourage educators and the community to form a more comprehensive view about human cognition–recognizing that all students can understand and work with CS problems. It's just that students need different types of support based on their prior experiences with CS.

Besides, creating equitable CS classrooms has been complicated by the ubiquitous and complex nature of CS. On the one hand, although CS is a relatively new discipline, its applications have permeated our society and are more deeply rooted in our daily life than traditional disciplines such as math and science [18]. As a result, students with more resources are more likely to be equipped with the essential prerequisites to CS education, whereas students who are from underprivileged backgrounds are likely to suffer due to the lack of CS experiences in their home environment and social life [19].

On the other hand, CS as a discipline is considered to be innately challenging and requiring unique mindsets and approaches to problem solving [3]. Such deviation from the traditional disciplines predicates that students who are without CS experiences in their home and community are not likely to acquire problem solving strategies unique to CS elsewhere. In addition, teachers' deficit views about students' abilities are prone to be even more prevalent in CS than in the other disciplines, where students' level of understanding is difficult to measure using traditional methods [20]. For example, because CS problems are often complex and involving multiple solutions, the students' seemingly mistaken early stage trials may lead to promising solutions. This phenomenon has created challenges for educators to maintain an equity stance in CS education because it may reinforce the belief that some students just will not "get it", when in fact the students are approaching the problem from a different angle [21]. Therefore, it is important to bridge the connection between creating access opportunities and the in-depth understanding of students' problem-solving processes in CS –forming a recognition that all students can become effective CS problem solvers and CT thinkers as long as they are given proportionate time and support.

In summary, research on equity in science education and computer science education has suggested the imperative of investigating teachers understanding of equity issues in CS classrooms, especially on issues related to equal access and equitable teaching practices that value the background students bring in the classroom. Along this line of research, prior research in CS education has shown that high school teachers' reflections on the equity issues tend to focus on the material aspect (the access to the course content and the access to the quality instruction) and the non-material aspects (the access to the identities as computer scientists and the access to the peer relationships) [22]. In this study, we analyzed high school teachers' reflections on the equity issues in CS education and intended to enrich the frameworks proposed in previous work.

III. Methods

A. Participants

The participants are high school teachers from various disciplines in schools that mainly serve underrepresented minority students in Southern California. A total of 27 teachers attended the TECS PD course. The participants' prior teaching experiences and demographic information are presented in Table I and Table II. Due to factors beyond our control (i.e. sick leave, personal scheduling issues), 24 teachers completed the course and filled out both the pre and post self-efficacy surveys.

TABLE I
Participants' Teaching Experiences

Categories		Count
Credentialed Subjects *		
	Math	14
	English	3
	Science	4
	World languages	1
	Business	2
	Technology related credentials [a]	4
	Special Education	1
	Social Sciences	1
Years of Teaching		
	1-5 year	3
	5-10 year	6
	10-15 year	7
	15-20 year	5
	21 years and above	3

* Some teachers are credentialed in more than one subject area.
[a] Including Music Technology, Industrial and Technology Education, ICT, Computer Science and Technology.

TABLE II
Participants' Demographic Information

Categories		Count
Gender		
	Male	16
	Female	8
Ethnicity		
	Asian	5
	White	14
	Hispanic	4
	Other- W Middle Eastern	1

B. Measures

1) Self-efficacy Survey: To assess the teachers' self-efficacy beliefs, we designed a self-efficacy survey that included items on the content knowledge and pedagogical knowledge of teaching ECS.

The content knowledge section has 20 items in total and was developed based on the CS domain content identified in the Praxis Computer Science Content Validity Survey (PCSCV). The PCSCV survey was distributed by ETS and obtained insights from a national committee of CS teachers, educators, and national CS organizations on the major domain knowledge appropriate for entry-level CS teachers. Therefore, the content items identified in this survey were considered as appropriate for the content knowledge self-efficacy items for the current study. To align the content knowledge items with the scope of the ECS curriculum, we selected the representative items from the PCSCV survey that reflect the learning objectives in the ECS curriculum. To construct the survey, we followed the model proposed in [11]'s work on constructing self-efficacy items while incorporating the content knowledge items selected from the PCSCV survey. The internal consistency of the content knowledge self-efficacy items are Cronbach's alpha=0.96. Sample items include: Based on your current understanding and skills, please rate your confidence in your ability to perform the following tasks: I can explain how to use sorting algorithm to solve problems. I can identify the major criteria for evaluating the quality of a website.The participants rated the items on a 5-point scale that ranges from Strongly Disagree(point value of 1) to Strongly Agree (point value of 5).

The pedagogical knowledge section has 10 items in total and was developed based on the model proposed in previous research on teaching self-efficacy in STEM [23]. Previous work has examined teachers' teaching self-efficacy from the personal teaching efficacy and outcome expectancy aspects [23]. However, considering that recent developments on teacher efficacy have highlighted the importance of adhering to the original definition of self-efficacy and separating outcome expectancy from teacher self-efficacy measures [8], we mainly focused on the personal teaching efficacy in this study. We adapted the personal teaching efficacy items established in math and science to reflect teachers' belief in their ability to successfully apply teaching strategies related to the CS classroom, such as inquiry based learning and equity practices. The internal consistency of the items are Cronbach's alpha=0.71. Sample items include: Based on your current understanding and skills, please rate your confidence in your ability to perform the following tasks: I can effectively monitor students' engagement in computer science learning activities. I can use inquiry-based teaching methods to promote student learning in computer science classes.The participants rated the items on a 5-point scale that ranges from Strongly Disagree(point value of 1) to Strongly Agree (point value of 5).

2) CS Education Equity Essay: Each participant completed a 2-page (500-600 words) reflection essay on the equity issues in CS education at the end of the TECS course. The instructions given for the reflection essay allowed the teachers to draw from their observations of the equity issues in CS education either at their schools or in the society. While writing the essays, the teachers can refer to any online resources, and/or the reading materials assigned during the course, including Stuck in the Shallow End [17], and Racing to Class [24] . There were no requirements on the types of equity issues that should be discussed in the paper.

C. Procedures

The participants engaged in the 9-week Teaching Exploring Computer Science (TECS) professional development course in a hybrid format involving online asynchronous learning modules in learning management systems, online synchronous classes on a video conferencing platform, and three monthly face-to-face classes. The learning experiences in the TECS PD course were designed to highlight the main thrusts of the ECS curriculum: Inquiry, Equity, and CS concepts. In online asynchronous modules, the participants completed weekly assignments including reading reflection essays on book chapters related to equity in CS education (i.e. chapters from Stuck in the Shallow End), computing artifacts (i.e. webpages created in HTML/CSS, animation/games created in the Scratch environment), and lessons adapted from the ECS curriculum that can be used in the teachers' classrooms. In the online synchronous classes and the face-to-face classes, the teachers reflected on the teaching demonstration of major ECS lessons that integrate the best practices in promoting inquiry and equity (i.e. using inquiry-based learning to introduce "What is a computer?"; using hands-on activities such as making a PBJ sandwich to introduce the concepts of algorithms) and the experiences of creating computing artifacts as learners. Using PD frameworks suggested in previous research for the ECS curriculum [3], the current study engaged the participants in the Teacher-Learner-Observer model during the online and face-to-face classes.

Immediately before and after the course, the participants took a pre and post survey to assess their self-efficacy in the content knowledge and pedagogical knowledge of teaching Exploring Computer Science. Because previous research has suggested that in a pre-post research design, participants may experience response-shift bias, where their self-evaluation criterion may change after experiencing the interventions, resulting in discrepancies between the actual pre-post change and the survey responses [25]. To ameliorate the impact of such response-shift bias, the current study implemented a retrospective pre and post format in the post survey design. Thus, in addition to having the participants rate their self-efficacy after completing the course, we also asked the participants to rate their self-efficacy prior to taking the course based on their current understanding of the ECS content knowledge in the post survey.

In addition, as described above, at the end of the TECS course, the participants completed a 500-600 words reflection essay on the equity issues in CS education.

D. Data Analysis

1) Self-efficacy Survey: The total score of the self-efficacy survey was used in the analysis. We conducted a series of paired sample t-test for the content knowledge self-efficacy survey and pedagogical knowledge self-efficacy survey. Because the teachers gave retrospective before and after ratings in the post surveys, we conducted two sets of paired sample t-test to compare the pre survey vs. the retrospective-after rating, and the retrospective-before vs. the retrospective-after ratings for each survey.

2) Equity Reflection Essay: 24 participants completed the reflection essays, which were examined using the content analysis method [26]. Because the goal of the content analysis is exploratory where we identified emerging themes in the participants' reflections of the equity issues, open coding was used during the content analysis and was conducted in iterative cycles [27]. In the first cycle of coding, two researchers worked independently and assigned preliminary codes to the text relevant to the equity issues in CS education. After doing such open coding for five essays, the two researchers discussed and consolidated the preliminary codes. Then one researcher assigned the consolidated codes to the remaining essays. The researcher also generated new codes in the process when the existing codes did not fit with a particular group of text. In the second cycle of coding, the researcher read all the text under each code and either combined or split the codes into categories or subcategories [28].

To establish the reliability of the codes, after the codes were organized as a hierarchical coding structure, a second researcher randomly selected 25% of the essays and applied the existing codes to the text. The inter-rater reliability showed that the two researchers reached 97% agreement on the application of the codes.

IV. Results

A. Self-efficacy

To answer the first research question on the influence of the TECS class on the high school teachers' self-efficacy in the content and pedagogical knowledge of teaching TECS, we compared the participants' ratings on the pre and post self-efficacy surveys.

1) Content Knowledge Self-efficacy: There are 20 items in the content knowledge self-efficacy survey. Each item was rated on a 5-point scale that ranges from 1 to 5. Therefore, the total score of the content knowledge self-efficacy survey ranges between 20 to 100. Results from the paired sample t-test show that the participants increased significantly from the pre survey to the retrospective-after survey, $t(23)=14.17$, $p<0.001$, $d=2.70$. The participants' self-efficacy ratings also increased significantly from the retrospective before to retrospective after survey, $t(23)=8.66$, $p<0.001$, $d=1.5$ (The descriptive statistics are shown in Table III).

2) Pedagogical Knowledge Self-efficacy: There are 10 items in the pedagogical knowledge self-efficacy survey. Each item was rated on a 5-point scale that ranges from 1 to 5. The total score of this survey ranges from 10 to 50. The paired sample t-test of the teaching self-efficacy survey shows that the participants increased significantly from before to after taking the TECS course, $t(23)=3.82$, $p=0.001$, $d=0.96$. The retrospective before and after ratings also increased significantly, $t(23)=7.20, p<0.001$, $d=1.53$. (Descriptive statistics are shown in Table III).

B. CS Education Equity Essay

To answer the second research question on the high school teachers' understandings of the equity issues in CS education, we examined the results from the content analysis. As shown in Table IV, the coding categories generated from the content analysis of the participants' reflection essays include 1) *Students' Role in Equity*: Students' beliefs and characteristics influence the equity in CS education 2) *Teachers' Role in Equity*: Teachers' beliefs and practices influence the equity in CS education 3) *The Uniqueness of CS as a Discipline*: the unique characteristics of CS contribute to the inequality in CS education 4) *The Societal Influences on Equity*: the belief system and resources of the society impact the teachers' equitable practices and the students' equitable participation in CS.

TABLE III
Descriptive Statistics of the Pre and Retrospective Before and After Content Knowledge and Pedagogical Knowledge Self-efficacy Surveys

Survey		N	M	SD
Content				
	Pre Survey	24	33.54	21.22
	Retrospective-Before	24	53.08	22.36
	Retrospective-After	24	84.75	9.40
Pedagogical				
	Pre Survey	24	33.83	4.26
	Retrospective Before	24	26.17	8.95
	Retrospective After	24	37.88	4.20

Under the *Students' Role in Equity* category, the subcategories focused on the students *Personal Beliefs/stereotypes about CS* (i.e. female students perceive themselves as not suited for CS classes), the influence of the students' *Cultural and Demographic Background* on their development (i.e. low SES students have inadequate prior knowledge), and the *Inequality in Students' Participation in CS* (i.e. White male students are the majority of the CS classes). Among these categories, the teachers discussed the *Inequality in Students' Participation in CS* the most (65.38%), suggesting that the teachers in our study consider students' equal access and participation in CS education programs as the most prevalent issue in students' role in equity.

The *Teachers' Role in Equity* category, which essentially describes teachers' agency in promoting the equity in CS classrooms, involves the *Personal Beliefs/Stereotypes about CS*, such as what types of students should attend CS classes. The teachers attributed the development of such stereotypes to the lack of exposures to the CS discipline and CS-related professional development. In addition, the teachers mentioned that the TECS professional development changed their stereotypes and helped them to see that CS is for all students. The teachers also discussed *Equitable Teaching Practices* (i.e. recruiting diverse students for CS classes, or keeping students' diverse background in mind while teaching). There were also discussions related to *Teacher Community*, where references were made to the importance of learning from and contributing to the teacher community regarding equitable practices (i.e. the need to learn from other teachers on promoting equity in CS classes, influence peers and change other teachers' stereotypes about CS). As shown in Table IV, under the *Teachers' Role in Equity* category, most of the discussions (66.23%) mentioned the intention of implementing a variety of *Equitable Teaching*

TABLE IV
CODING CATEGORIES

Categories/Subcategories	Excerpts of Coded Examples	Percent (%) *
Students' Role in Equity		
Personal Beliefs/Stereotypes about CS	"Many of my female and Hispanic students shied away from the topic. Most were indifferent, and many thought that CS was not even on their radar."	23.08
Cultural and Demographic Background	"Not all students come to us with a level playing field. Many students are poor, hungry, mistreated, bullied, etc."	11.54
Inequality in Students' Participation in CS	"For these reasons and others, very few women and minorities are found in computer science classes."	65.38
Teachers' Role in Equity		
Personal Beliefs/Stereotypes about CS	"We as Computer Science teachers need to overcome negative attitudes about Computer Science...that only white collar experts use computers, which is not true."	22.07
Equitable Teaching Practices	"I am becoming more and more mindful of inclusion and have been working on recruiting more female students into my classes."	66.23
Teacher Community	"I will steal as many ideas from other teachers to challenge the high achieving students and to support the low achieving students."	11.69
The Uniqueness of CS as a Discipline		
The Importance of CS	"Computer science is a unique subject that has an opportunity, that not all other subject matters have, to teach students a variety of skills that transfer across all disciplines and prepare students for a complex world."	77.78
CS is Constantly Changing	"These developments make it difficult to stay consistent and demonstrate mastery with the information that is being taught."	13.89
CS Content is Challenging	"...but a problem lies in the...massive amounts of information that are created"	8.33
The Societal Influences on Equity		
Societal Stereotypes and Misconceptions about CS	"Several common misconceptions surrounding the subject that keep many students at a distance"	34.07
Lack of Resources/Curriculum in the System	" It's still amazing to me that in the 2017 we dont have any computer science courses in many high schools"	12.09
Lack of Teacher Training in the System	"To make Computer Science a better thing for teacher and students, we need to better educate and train teachers"	15.38
The System Needs to Provide CS Education for All	"Schools and districts need a systematic approach to dispensing computer science curricula to K-12"	27.47
Inequality in CS Education influences CS as a Discipline	"Computer science will be suffering from the lack of diversity. By limiting the people involved in computer science, the output of these computer scientists will also be limited."	10.99

* The percentage for each subcategory is a ratio between the subcategory's code frequency count and the corresponding category's total code frequency count.

Practices as a result of participating in the TECS PD, which changed their personal beliefs about CS education.

The category of the *Unique Characteristics of CS as a Discipline* focuses on the main characteristics of CS that make it an important yet challenging discipline. For example, while acknowledging the *The Importance of CS*, which teaches a variety of important and fundamental skills, such as critical thinking and computational thinking, the participants also described that *CS is Constantly Changing* and that *CS Content is Challenging*. Such uniqueness of the discipline, the participants observed, may have led to inequality in the students' and teachers' access to CS education (i.e. the field is constantly changing, making it difficult for the teachers and students to keep up; the curriculum has to change constantly to keep up with the field of CS). Among the subcategories, most of the discussions were focused on *The Importance of CS* (77.78%), indicating that the teachers were able to recognize the necessity to prepare students with the fundamental skills taught in CS. However, the low percentage of *CS Content is Challenging* statements may suggest that teachers did not necessarily gave high priority to the influences of the challenging nature of CS on equity issues.

The category of the *Societal Influences on Equity* focused on systemic factors, such as the society, the district, and the school's beliefs and practices that contribute to the inequality in CS education. The participants described that there are *Societal Stereotypes and Misconceptions about CS* (i.e. the society tends to perceive women as less suitable for CS than men), the *Lack of Resources/Curriculum in the System* (i.e. many schools don't offer CS classes), the *Lack of Teacher Training in the System* (i.e. there are very few CS PD programs available), and *The System Needs to Provide CS Education for All*. Notably, in the subcategory of the *Inequality in CS Education Influences CS as a Discipline*, the participants described the interplay between the students' participation in CS and the inequality in the CS discipline/industry and society. For example, the participants suggested that the inequality in the CS workforce can reinforce the stereotypes of a "CS person" and prevent students, especially female and underrepresented students from attending CS courses. In addition, the participants observed that the CS discipline and the society would in turn suffer from the inequality and lack of diversity in CS education. Among the subcategories, most of the discussions were focused on the *Societal Stereotypes and Misconceptions about CS* (34.07%), showing that when examining the relationship between the society and equity, teachers in our study were most concerned with the belief systems in the students' environment on their equitable participation in CS education.

V. Discussion

A. Teachers' Self-efficacy

This study builds on previous research on teacher self-efficacy and CS education by demonstrating self-efficacy surveys that can be used to assess the changes in teachers' self-efficacy in teaching CS. The findings from this research showed that teachers who participated in the TECS course increased significantly on the self-efficacy in the content and pedagogical knowledge of TECS from before to after taking the course. The significant increase in self-efficacy is consistent with prior research that identified significant improvement in teachers' self-efficacy through professional development in STEM areas [5]. This current study also differs from the previous research by including tasks that are directly related to the CS content in the self-efficacy survey and may better reflect the changes in self-efficacy as a domain specific construct.

Based on the previous research, a potential rationale for the teachers' change in self-efficacy is that the professional development program in the current study provided mastery experiences, one of the most prominent sources of developing teachers' self-efficacy [6], [8]. For example, the hybrid courses in this program may have contributed to the significant gains in teachers' content and pedagogical knowledge self-efficacy by engaging teachers in creating computing artifacts using the content knowledge and practiced teaching strategies in micro-teaching sessions.

Another potential source for the improvement of self-efficacy is vicarious experiences, where the teachers observed teaching strategies appropriate for the TECS content through experiencing the ECS content as learners (i.e. applying the Teacher-Learner-Observer model [3]) and watching the instructor who is an experienced ECS expert teacher from non-CS background during the online synchronous classes and the face-to-face classes. The similarity between the model and the self has been identified as a key factor in gaining self-efficacy through vicarious experiences [8], which is the case in this professional development program–the instructor is similar to the participants in terms of the profession and teaching experiences.

It is also necessary to explore if providing experiences that align with the other sources of self-efficacy can enhance teachers' self-efficacy in teaching ECS, such as through professional learning communities where mentors and peers can provide social persuasion for the teachers.

B. Teachers' Understanding of the Equity Issues in CS Education

The findings from this research corroborate previous literature by showing that the equity issues in CS education are multidimensional, encompassing the material and non-material dimensions [22]. This study also builds on previous research by showing that the participants interpreted the equity issues from the dimensions of the teachers, the students, the CS discipline, and the society. In addition, the participants were able to identify the bi-directional relationship between the system and the agents within the systems (i.e. the teachers and the students): the inequality in the system reinforces the students' unequal participation in CS education; the inequality in CS education in turn exerts negative impact on the system. Such a finding implies the necessity to help teachers identify the disciplinary and societal impact on their equitable practices and the types of strategies that can be implemented to ameliorate the negative impacts from the system.

Besides, under each of the four major categories, the teachers most frequently discussed the *Inequality in Students' Participation in CS*, *Equitable Teaching Practices*, *The Importance of CS*, and *Societal Stereotypes and Misconceptions about CS* subcategories respectively. In alignment with findings from the science and computer science education research, teachers' discussion of these subcategories demonstrated understanding of the mechanisms behind the equity issues –recognizing the urgency of addressing equity issues through broadening participation, providing equal access, and promoting equitable practices in classrooms for all students [29].

Most notably, the teachers described both the equal access and equitable teaching practice issues in CS education. They mainly centered on the phenomenon that students from demographic groups that are traditionally identified with CS are more likely to enroll and be confident in doing well in CS classes, whereas students from demographic groups that are traditionally considered under-performing in these areas may not consider signing up for CS courses. The teachers' discussion of such disparity in equal participation is consistent with previous research that showed even after students from traditionally underrepresented groups are enrolled in CS classes, they tend to be reinforced by the implicit cultural stereotypes and shy away from being actively engaged in CS activities, extending the vicious cycle of inequality in equal access [17].

While the teachers acknowledged the importance of equal access, their understanding of the influence of CS as a challenging discipline on the equitable practices in CS classrooms can be further developed and strengthened. For example, most of the discussions on equitable practices were centered on reaching out to more diverse students during recruitment and the necessity to consider the students' diverse background. Few statements connected the challenging nature of CS and the equitable practices in classrooms. However, there are deep connections between the social/cultural influences and the equity teaching practices [16]. Additionally, due to the complex nature of CS and social/cultural influences, teachers are particularly prone to form a deficit view about students' abilities in CS, a great obstacle to equitable teaching practices [29]. Besides, while a deficit view is relatively easier to be contradicted in science and math as the solutions are likely to be exhaustive and within teachers repertoire, such views are particularly difficult to counter in CS due to the multitude of possible solutions/algorithms to a given problem. Quite often, a seemingly faulty early prototypic solution may have great value and lead to something innovative later on. As a result, holding deficit assumptions about students' understanding and performance in CS classrooms can create devastating impact on equitable teaching practices. Thus, teachers' recognition of the value of the students' cultural background and knowledge, as well as the need to counter the deficit view of students' abilities are the key to equitable practices in CS classrooms [16], [17]. This is especially true considering that the theoretical advances on the multi-dimensionality of human cognition have highlighted the need to understand how each student may approach problems differently based on their prior knowledge and background. Therefore, to promote teachers' understanding of equity issues in CS classrooms, it is important to help them see the value of students' background knowledge, develop an in-depth understanding of students' problem-solving processes in CS, and counter deficit views to recognize that all students can engage in effective problem-solving in CS given appropriate support.

VI. Conclusions

The participants increased significantly in their self-efficacy in teaching ECS from participating in the professional development course. These results suggest that the professional development programs that provide mastery experiences and vicarious experiences for teachers can promote teachers' self-efficacy in the content knowledge and pedagogical knowledge of teaching CS. The findings also suggest the necessity to develop content-specific measures to gauge teachers' self-efficacy.

The findings on teachers' understanding of the equity issues in CS education suggest that teachers were able to see their roles as the agents of change and the students' participatory roles in the context of the societal system. In addition, the teachers' reflection on the mutual influences between the society and the agents within the societal system suggests the need to help them develop effective strategies that mediate the societal influences on the students' participation in CS education and on their equitable teaching practices.

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Embedding K12 Professional Development Through Co-Teaching Experiences- Sustaining Computational Thinking in Interdisciplinary Courses

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***Abstract*— Focusing on interdisciplinary lesson development in K12 core courses has potential to broaden participation in computing by communicating computer science relevance to youth with limited computer science background within the courses they are already taking (e.g., high school chemistry). The DISSECT professional development program has demonstrated evidence of sustained effort beyond the years of the program—this case study was designed to understand factors that may have supported sustained use.**

Keywords—teacher professional development, sustained change, computational thinking

I. INTRODUCTION

Laws related to K12 computer science policy in the minority/majority state of New Mexico are in political turmoil [1], and so efforts to infuse computational thinking into regularly occurring courses that all students take has been the strategy utilized to broaden participation in computing. A novel focus on interdisciplinary lesson development in the core courses has the potential to broaden participation in computing in two ways. First, by highlighting intersections between computer science and fields with high student interest, such as forensic science, sports medicine, and creative writing, computing relevance is contextualized and communicated to students. Second, infusing *Computational Thinking (CT)* work into courses that all students take ensures equitable practices in educating minority youth about the benefits of CT [2].

The NSF-funded *DIScover SciEnce through Computational Thinking (DISSECT)* project (2010-2016) paired K-12 math, science and literacy teachers with computing graduate students in southern New Mexico to develop, implement, and revise computational thinking lessons into the core curriculum. Past studies of the project have described lesson implementation and have explored student growth in computational thinking through pre/post testing and surveys of computing interest [3, 4, 5]. In contrast, this paper is reflective, and theorizes the mechanisms by which DISSECT has created sustained change in teaching practices.

A follow-up study of past DISSECT teacher participants over the 6-year program showed that of those who are still working in similar capacities (e.g., same district, teaching similar subjects) have continued their work—an average of 63% of participating teachers' students receive some instruction that involves computational thinking in the Fall of 2017, with the proportion of students engaging in computational thinking currently ranging from 15-100%. This retrospective case study investigates the sustained nature of the DISSECT program for its teacher participants and seeks to understand what elements of DISSECT led to sustained computational thinking instructional practice.

II. PROFESSIONAL DEVELOPMENT TO SUPPORT K12 IN COMPUTATIONAL THINKING

Implementing teacher professional development that realizes longer-term impacts has been shown to be particularly challenging. Although professional development opportunities may have initial appeal that leads to implementation in the short-term, realizing long-term implementation of tools and methods from professional development is complex [6]. Sustained implementation requires persistence of teachers even after the program has ended. One important feature that can lead to effective long-term implementation of teacher professional development is the presence of well-defined roles within the learning opportunity [7]. Another element is multiple opportunities to learn and practice using new methods [8]. Providing a focus on or link to content knowledge is an additional characteristic that can aid implementation in the classroom as well [9]. Creating teacher professional development that truly succeeds in creating long-term implementation of the professional development program's methods is a worthy, if complex, endeavor.

III. RESEARCH AIMS

This study is a mixed methods case study investigation of a long-standing professional development program in Las Cruces, New Mexico, a region that serves greater than 75% Hispanic youth. We focus this article on teacher professional development through co-teaching practices in computational thinking.

The research questions that drive this study are:

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1) How does co-teaching computational thinking content in the K12 classroom influence teachers' instructional practice over time?

2) How do graduate students benefit from participating in the project?

3) How does co-construction of computational thinking curricular materials influence use and reuse in the K12 setting?

4) How does an embedded professional development model influence teacher motivation to sustain computational thinking approaches in classroom teaching?

IV. METHODS

We use a case study methodology as it is ideal for understanding unique practices, and is particularly useful in understanding context-rich phenomena [10] Case studies are particularly advantageous for making sense of process-related research questions, such as those listed above. Studying professional development over time in the DISSECT program has involved the following data collection strategies:

a) Document analysis of program agendas, student and teacher logs, and lesson plans

b) Annual individual or group interviews with fellows and teachers (2010-2016)

c) Midyear and end of year surveys for teachers and fellows to assess effective collaboration, utility of lessons, and needs

d) Observations of CT lessons, rubric assessment using a modified version of the RTOP protocol [11]

e) Annual student assessment via questionaires and content assessment (2013-2016)

f) Follow up survey for participating teachers (fall 2017) to assess sustainability, use of lessons following participating in the professional development

g) Teacher lesson reflective analysis, with a focus on cognitive apprenticeship [12]

Much of the analysis is qualitative for this research paper, though claims of sustained practice involve mixed methods. Qualitative data analysis has been ongoing over the six years of the project and involved an iteration of inductive and deductive coding [13 14] on recurring themes. The first two authors are learning scientists by training, and draw on sociocultural theories of learning in their research work [15 16 17]

V. SUSTAINING COMPUTATIONAL THINKING IN K12 CLASSROOMS

Surveys were distributed in the Fall of 2017 to understand the extent to which DISSECT teachers had continued their computational thinking efforts in the classroom beyond the professional development project. Teachers who had participated in the last 3 years of the grant were targeted for the survey (n=15), as staff changes at that time led to differing professional development practices for DISSECT. Eleven teachers responded to the survey, and ten were in applicable teaching positions to sustain computational thinking lessons. All teachers who responded remained in the Las Cruces or Gadsden school districts, which serve majority Hispanic populations (Las Cruces=75% Hispanic, Gadsden=96% Hispanic). Teachers were asked which resources they continued to use from the DISSECT project, the number of lessons utilized since the end of the project, and the proportion of students who received computational thinking lessons or content during the school year.

Given the sustained efforts of all responding teachers who participated in the DISSECT program, it is important to understand factors that may have led to continued efforts in computational thinking. The next sections develop claims that connect case study evidence with professional development literature and learning theory to build a case for sustained, embedded professional development efforts such as DISSECT.

VI. CLAIM 1: CT LESSONS FILLED UNMET CURRICULAR NEEDS

Interdisciplinary work is difficult to incorporate in secondary curriculum, particularly in traditional U.S. public schools where learning is typically structured in classrooms focused on a narrowly defined discipline. An element of the DISSECT program that may have increased its applicability and longevity in secondary classrooms is the ways in which teachers co-created the lessons and modules such that they complemented their curriculum, and filled an unmet need in a course.

DISSECT was developed to instill deep partnership and create strong relationships with teachers and graduate students. Rather than creating an educational pathway for injecting pre-made curricula into the secondary schools, the purpose of collaborative development was to connect curricular goals teachers had with computational thinking content. Given the standards-driven K-12 norms in US schools, this approach allowed for flexibility in implementation and development that appealed to teachers pressed for time and accountable for a myriad of learning outcomes.

Kelly* discussed her efforts with a middle school class and her partnership with DISSECT to create a lesson that introduced algorithmic thinking, related to grade level standards in science, and addressed an identified shortcoming in her students' problem-solving abilities.

> "Problem solving is a focus area because my students are just so random! I don't know if it's because they're so inundated with information all the time. Things aren't sequenced. … We did the module with weather tools and writing an algorithm. One group wrote the algorithm for making a weather vane and the other group writes one for a barometer, then they switch and have to use the other group's algorithm to build the weather instrument. Some of the kids were so frustrated when the other kids couldn't follow their algorithm due to (issues with) clarity and correctness."

The teacher went on to describe the value of the DISSECT lessons to her teaching:

> "For the most part I think the interdisciplinary lessons make whatever we're doing so much richer. It's always higher-order thinking. It always makes it so much more creative."

Kelly reports that three quarters of the students with whom she works are receiving computational thinking content now, three years since she participated in DISSECT.

VII. Claim 2: Graduate Student Co-Facilitators Scaffolded Teacher Understanding of CT Concepts

> "The graduate students are helping me understand what computational thinking is. It's how you write a program. If you miss something it's not going to come out the way it's expected. … There's a system you must follow. If you don't, things aren't going to work out for you. They've taught me to implement that in my everyday life. They even gave me examples like when you get dressed in the morning, you have certain steps you take. It's working in steps to reach a desired outcome."

Laura* (above) describes how the DISSECT professional development program is influencing her content knowledge regarding computational thinking, and credits the graduate students with improving her understanding of the content she then weaves into her classroom teaching.

In a professional development reflection activity, the researchers prompted DISSECT teachers to comment on the elements of cognitive apprenticeship [12] occurring in their co-teaching experiences. A theme emerged regarding the role the graduate students had in scaffolding teachers' understanding of computational thinking. An excerpt from lesson descriptions appear below.

> "Without classification schemes, understanding relationships between two objects is very difficult. My fellow was also demonstrating scaffolding and offering a deeper level of understanding of the content that she had experienced through her educational work experiences that I had never been exposed to. In this situation, she was the Master to both myself and the students. By modeling a technique, the students were shown how to roll inked fingerprints. After practicing, the students rolled another classmates' fingerprints onto a ten-print card. Next, the students examined their own prints and the prints of their classmates to look for similarities and differences between them. They were asked to create a list of descriptions or drawings to describe the different characteristics that they had seen.
>
> Next, in a whole group setting, the student was shown pictures of fingerprint patterns and minutiae that had been previously determined by scientists. After attempting to match the terms with the pictures, with the help of the other students, the students were asked to try to develop a classification system for identifying fingerprints that matched each other. The students came up a variety of classification structures. Some had the idea of creating dichotomous keys while others relied on "yes" or "no" questions to reach the answer.
>
> The students were coached and my fellow and I were modeling different aspects of the module. I modeled the process of inking fingerprints. My fellow and I were the Masters in this part of the module. We were both also filling the Master role as the students were being taught the importance of classifying. Without classification schemes, understanding relationships between two objects is very difficult.
>
> I was acting as a Cognitive Apprentice. My fellow was demonstrating scaffolding and offering a deeper level of understanding of the content that she had experienced through her educational work experiences that I had never been exposed to. In this situation, she was the Master to both myself and the students."

In the excerpt above, Blair* indicates the roles she and her graduate fellow took in the implementation of a lesson in a forensic science course related to classification and abstraction. She reflects on her dual roles as "master" and "apprentice" based upon her relative knowledge and understanding of the content in the interdisciplinary lesson, and indicated the work of her graduate student fellow as necessary in scaffolding her understanding of the processes of classification as they apply to computational sciences. Blair responded to the follow up survey to indicate that she continues to provide computational thinking content to 90% of the students she teaches.

In another lesson, a DISSECT teacher describes complementary roles he and the graduate students took on in the implementation of a lesson on neural networks.

> "The primary instructional method used in this interaction utilized modeling and coaching pedagogical styles. The students were shown an example of the task at hand (in this case modeling a neural network) and how a computer would interpret the commands. It was tied into the lesson by showcasing the similarities between computational neural networks and the nerve net used by jellyfish in response to their surroundings. Students were then given data 'stimulus' to determine their reaction to the input. Several students needed assistance, so the pedagogical style of 'coaching' was also utilized to assist with keeping students on task and motivated to carry out the task to fruition.
>
> …
>
> The fellows were the true masters during this activity as all instruction was carried implemented on their instruction. My role was primarily support and motivation to stay on task, as I too was a learner in this lesson. The students were the true apprentices in this activity, although it was still foreign to me, so in a way I was a novice as well.
>
> The students could see a concrete link between computational thinking and Zoology which was difficult for them to visualize in other lessons. The two concepts were seamlessly integrated and the students were able to interpret a foreign concept (basic neurological function) from a different perspective."

Bill's lesson was implemented primarily by the graduate students who teamed up to implement a neural network lesson for a zoology course in the high school. Bill indicated his intermediary role as the teacher of the course and co-learner, as the graduate student fellows had more complete knowledge of the role of computation in modeling a neural network.

In follow up work with Bill, he indicated that the same proportion of students who received computational thinking during his time with a graduate student (33%) were still receiving the content. This instructional practice was sustained following graduate student involvement. We contend that the modeling of co-developed lessons and content-knowledge coaching teachers received from the graduate students in DISSECT may have promoted sustained practice with computational thinking lessons in DISSECT classrooms even as graduate students faded from the classroom environment.

VIII. Claim 3: Graduate Student Co-Facilitators Had Scheduled Time Devoted to Lesson Development Which Improved Quality, Rigor

Teachers in the United States spend an average 80% of their work time in direct contact with youth, in contrast to other nations in which an average 60% of work time is spent directly engaged with youth [18]. Given the lack of dedicated time to plan, the development of original curriculum is a challenge for the average secondary teacher. DISSECT teachers who were paired with fellows could direct the development of curriculum for their needs, yet relied on the labor of the fellows to ensure adequate preparation, research, and planning.

A teacher who continues her computational thinking lessons in her high school science courses, Jenni* describes how her work with a fellow was collaborative, yet relied on outside efforts of the graduate student to create a prototype lesson.

"We talked at lunch and would get ideas. He was the one who did a lot of work and planning. (Graduate student partner) really liked doing lesson development with forensic science. It wasn't a struggle. It was mostly about him looking at my topic, we'd talk, he'd get ideas, and then he'd develop that. He would bring it in. We would talk about it – how to change it and how we'd use it the next week."

Jenni described how teacher and fellow collaborated prior to implementation to ensure the lesson was addressing computational thinking and course-related goals. Jenni continues to implement computational thinking lessons to over a third of her students two academic years following her work with graduate fellows in DISSECT.

Another teacher who participated in DISSECT, Pamela*, spoke of the quality of the lessons, and detailed her professional development experience in which a shift in graduate student hour policies during the early years in the program enhanced the quality of lessons implemented.

"This year was a lot better. Last year they had to spend 8.5-9 hours just with us (shadowing the teacher) in the classroom. So that was a day they would teach and a day they would help. This year they had to be in the classroom 5-6 hours but then **the additional time was prep outside the classroom.** So, I saw quality in the product we came up with. It was a high-quality product. I saw the research that (graduate student) did for what he was going to teach with me. I saw a difference in that this year. **Allowing them outside research time increased the quality**."

In follow up surveys, Pamela reported continuing her computational thinking content in the classroom, primarily by reusing elements of the developed lessons, resources, and the vocabulary related to computational thinking.

Another teacher, Bill*, described a well-implemented lesson that related to the subject they were covering in his high school course, cancer diagnosis. He details the ways in which the graduate student took the lead in development.

"Generally, we'll meet on either Mondays or Wednesdays during my planning period so that gives us plenty of time to hash out what I need to cover and she can streamline the curriculum into whatever topic we're covering. Then she'll email me back what she's come up with, whatever mini-module that she's creating out of it. … We did loops with cancer diagnosis because we were covering cancer terminology. She took them through the flow of cancer diagnosis to emphasize iteration. She had things on magnets and each student went up and placed an event on the board. They had to explain how that event was applicable. It was really, really, good. I really liked how that one came out. She'll email me the lesson that she's planning on doing to make sure it will work. I'll email back and say that sure we can do that. Then we execute that on Fridays."

By providing teachers with graduate students well-versed in computational thinking who had structured time in their weekly schedules to devote to lesson development, the DISSECT program created opportunities for tailored interdisciplinary lessons to emerge. The curricular development labor was offloaded from the teacher's role to the graduate student, who at the same time benefited from shadowing the teacher and having weekly access to the youth who would engage in the computational thinking content. Qualitative data from the case study of DISSECT indicate this investment in graduate student development time may have had an impact in the sustained influence of the program.

IX. Claim 4: Teacher Transformation Led to Greater Motivation to Implement CT

Teacher transformation is often the goal of professional development—to influence teachers' values, ways of thinking, and approaches to learning and teaching is (perhaps) to sustain change in public education [19]. The DISSECT teacher professional development participants, to some degree, describe changes in perceptions of computing and computational thinking, and the ways in which they approach teaching.

A. *Advocacy for computational thinking*

"Now after seeing the integration into and across Chem and Earth Sci, my interest in integrating CS in all of my classrooms… I think some of my colleagues wish I would shut up about this. I keep saying we should introduce this, or have a module about this. I think my interest has grown because of the exposure. I think the monthly meetings that we had before and me brainstorming with Taylor… it has grown [her interest]. I think there is no class that couldn't integrate CS. And certainly, they could all integrate CT. and I argue that for the humanities as well. I've argued that they could create a graphic novel using technology. There are so many more opportunities to integrate the technology in a more fundamental way."

Cierra* indicates ways in which she advocates for computational thinking integration across the curriculum—her quote that she thinks her colleagues might wish she "shut up about this" could hint at the insistence of her advocacy.

B. *Evolving understanding of computational thinking*

In a survey, Laura defined computational thinking like this:

"Developing an algorithm for acquiring a desired outcome."

Through her efforts in the professional development program, Laura's understanding of the concepts addressed evolved. Two years later in an interview, Laura describes her evolving understanding of computational thinking in this way:

"To me, computational thinking is trying to be able to look at a problem from every single angle and be able to figure out the different paths to what you're trying to solve. There's not really a right or a wrong way, like when we look at the difference between sorting and branching. How do we take this data apart? How do we create an understanding of what we've experienced and how do we help someone else understand it? Computational thinking is a way to understand all the data that is coming in to you. The sensory, the numerical. How do I figure this out? Like if I'm trying to figure out the polar ice caps. How can I figure out the length of time until the polar ice caps are totally gone? I could create a program that would show a simulation that I could put in different variables and see what may happen. That is the end goal."

Laura indicates a nuanced understanding of computational thinking that shifted from her original definition extracted early in the professional development.

C. *Shifting world views*

Kelly also recounted her work in relation to her experiences learning about computational thinking in DISSECT:

"I incorporate computational thinking into the learning tasks that I design for students. I emphasize the importance of programming and using computational thinking in a variety of activities that I do with students. Having the background knowledge and an understanding of the importance of integrating computational thinking into all STEM lessons helps me to design relevant 21st-century curriculum. I believe it is vital for a student's ability to function in any STEM field or in STEM courses that they take (even if they don't go into a STEM field). In our rapidly evolving digital world, students need to understand what goes into the creation of the technological tools that they use rather than just being blind consumers and users."

Kelly's comments indicate a worldview that highlights the need for youth to understand and be critical consumers of technology, and an inclusive view of computational thinking within her curriculum development—it appears her instruction with youth continuously includes computational thinking elements.

X. Claim 5: Graduate Students experience development of communicative skill

While this paper focuses on the development of sustained educational activity in computational thinking, the practice itself emerged from a project directed at graduate student development—specifically the NSF GK12 (Graduate STEM Fellows in K-12 Education) program was developed to "*provide an opportunity for graduate students to acquire value-added skills, such as communicating STEM subjects to technical and nontechnical audiences, leadership, team building, and teaching while enriching STEM learning and instruction in K-12 settings."* [20] Group and individual interviews with fellows themselves indicate their skill in communicating science to a variety of audiences improved during their time working in K-12 classrooms with their partner teachers. Fellows described ways in which the professional development program improved their communication with others, specifically how they began to focus on simplifying concepts and gained confidence in the ways they described their research. Fellows mentioned how this improved communicative skill has professional benefits.

A. Focus on Simplifying Concepts

Melissa* indicated how her experience in the classroom influenced her ability to simplify her research work for individuals with multiple levels of understanding of science.

"I think the program has helped me tremendously (in terms of communicating science). I avoid that kind of high-level explanation of my research …I think this has really helped me sort of simplify things for myself, first, and then being able to provide that information to students and teachers, because they're all at different levels of knowledge from the people that I work with in my research."

B. Improved Confidence in Explaining Research

Kelly* stated her confidence in communicating science to others has improved since joining the DISSECT team, as has her communication about her research efforts specifically.

"(DISSECT) definitely **improved my confidence in and approach to communicating science. I**t has made me take the way I typically talk about my work with my peers in the Psych department and simplify it for the students and teacher. I think the biggest way that played out was in trying to prepare for our introduction with students. When I first started my research and people asked me what I did- it took me a long time and I don't think I conveyed it very well. So just in general I am able to say it more succinctly than I did."

C. Improved Academic Products

Gabriel* indicated learning that complicated descriptions of his research could turn off an audience to the subject. He also indicated that in learning to communicate research to other audiences, his academic writing became more clear.

"Usually when I would talk to my family (about my research) I could totally see that it was over their heads. And now that I am working with middle and high school kids I realize you need to tell them as basic as possible. Not because they are not capable, but because if they think they don't understand, then they just shut off. I think now that I am writing my thesis it helps me writing in the past 2 semesters giving as much detail as possible on the process and program that I'm writing so that a reader would understand."

XI. Discussion

In this exploratory research study, we found in follow-up surveys, that past participants were continuing to infuse their curriculum with computational thinking elements. We used a case study method for posing research-backed claims for the efficacy of the professional development provided in the DISSECT program—in sum, we build a case for how the embedded nature of the DISSECT program with its tailored curriculum development, coaching elements, and time designated to graduate students for lesson development may have led to sustained, transformative teaching practice.

XII. Acknowledgment

We thank the K-12 teachers of Las Cruces and Gadsden, New Mexico, for their expertise, time, and dedication to student learning. This paper was supported in part by funds from NSF grants CNS-1440911, HRD-1345232, and DGE-0947465.

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"Where Are You Really From?": Mitigating Unconscious Bias on Campus

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***Abstract*—This experience paper describes an ongoing effort at Carnegie Mellon University (CMU) that works to mitigate the negative effects of unconscious bias among the campus community. Our paper describes the BiasBusters@CMU program, session details, logistics, and preliminary findings from the analysis of pre and post session surveys. Our goals are to illustrate how research findings can be used in practice in higher education a) to help mitigate bias, b) to promote bias awareness, and c) to share our experiences with others who might be interested in bringing bias and inclusivity programming to their campus.**

***Keywords*—Unconscious bias, culture, stereotypes, higher education, intervention, diversity, inclusion**

I. Introduction

This experience paper describes an ongoing effort at Carnegie Mellon University (CMU) that works to mitigate the negative effects of unconscious bias among the campus community. Our paper describes the Google-inspired origins of the BiasBusters@CMU program, session details, logistics, and preliminary findings from the analysis of pre and post session surveys. Our goals in this paper are to illustrate how research findings can be used in practice in higher education a) to help mitigate bias, b) to promote bias awareness, and c) to share our experiences with others who might be interested in bringing bias and inclusivity programming to their campus.

Unconscious bias is a persistent and pressing social issue with significant negative consequences especially for populations which bear the brunt of stereotyping. Indeed, evidence of bias impacting fields such as medicine [10] [13] [25], the legal system [2] [17], and education [9] [12] [23] [28], are well documented. Some aspects of academic research have revealed far more bias than scientific models would have us believe [5] [11] [26]. Evidence suggests that the field of higher education is not immune: unconscious gender and racial biases pervade academia [19] [20] [21] [22].

Unconscious bias, also known as implicit bias, is a natural and necessary part of our thinking processes. Indeed, the fast-thinking aspects of unconscious bias may be beneficial when presented with life or death situations. But the automatic and unintentional nature of unconscious bias often leads to quick and potentially harmful judgments about people, judgements endorsed by misleading cultural stereotypes. Even those of us who believe we are fair and unbiased in our interactions can all too easily perpetrate "the hidden biases of good people" [1].

Efforts to combat the harmful impacts of unconscious bias are now widespread [14] across industry (e.g., Google, Facebook, Pinterest) and academia (e.g., Emory, University of Wisconsin, University of Washington, Northwestern). The Google-CMU collaboration is largely fueled by the lack of diversity in computer science and engineering [6] and the recognition that bias is hampering the advocacy of diversity in our communities and workplaces. At CMU, diversity and inclusion are part of the institution's value system and embedded in the strategic plan, in part because research has shown that diversity is a means to: better problem solving, higher productivity, and greater innovation. At Google, CEO Sundar Pichai says "A diverse mix of voices leads to better discussions, decisions, and outcomes for everyone."

II. BiasBusters@CMU

BiasBusters@CMU is modeled on Google's Bias Busting@ Work program, created as an extension of the Unconscious Bias @ Work Workshop (UB@Work), a course aimed at raising awareness of how unconscious biases work, and how they can negatively influence workplace interactions. In the spring and summer of 2015, Google and CMU collaborated to create the Bias Busting @ University program; the program is inspired and informed by the Ada Initiative and their Ally Skills workshop.

BiasBusters@CMU is the version specifically tailored for CMU and designed by CMU faculty. The program was piloted in the School of Computer Science (SCS) and the College of Engineering (Carnegie Institute of Technology or CIT) to

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engage over issues of bias, diversity, and inclusion. One of the major goals of the program is to create an expanding community of allies across campus, allies who recognize bias and support each other in their efforts to mitigate the impact of bias. BiasBusters sessions are led by members of the CMU community who have volunteered to be trained as program facilitators. Program facilitators have a huge influence on the BiasBusters experience so we take great care in selecting and preparing facilitators who are passionate about mitigating bias within the community, curious to learn the science, and willing to engage in potentially sensitive conversations.

Enthusiasm for, and engagement with, BiasBusters@CMU surpassed the expectations of the program's leaders. BiasBusters@CMU now reaches communities across the CMU campus and well over 1,500 faculty, staff and students have participated. Requests for these optional sessions occur frequently. Keeping the program optional is a deliberate approach in response to studies that suggest making such programs mandatory can lead to backfire and less, rather than more, openness towards diversity issues [18].

III. Several things distinguish BiasBusters@CMU from similar programs

First is the framing: the program has an academic tone, focusing on summaries of research evidence into which discussions of experience are woven. Most importantly, discussions include the personal experiences and acknowledgement of bias from the session facilitators.

Second is the recognition of situations and bias triggers: the program includes discussion, videos, and some specific situations that are most likely to be common bias triggers. These situations are set up as scenarios for the role play. They also provide an opportunity for the facilitators to collect new examples of biased situations and assess those experiences that participants find difficult and sensitive to deal with.

Third is the role-playing: role-playing is based on relevant and real life scenarios (provided by the CMU community), which has proved to be a powerful and effective approach for engaging participants, both at Google and at CMU, creating commitments to greater inclusion.

This framework is based on research findings which suggest that mitigating the effects of unconscious bias requires a) recognizing what it is and how it works (homework, research evidence and discussion), b) recognizing that certain situations and interactions (scenarios) are more likely to trigger bias, and c) providing practice (role-play) and tips for breaking what Devine calls "the mental habit" of prejudice [7]. One well-known example of situational approaches is Jane Elliott's "blue eyes/brown eyes" activity in which participants are discriminated against based on their eye color. The use of situational approaches has been empirically validated and found to be far more effective at reducing bias than simply educating people about bias [24].

Certain research findings presented in the sessions are selected so they support the specific focus of the group of attendees. As discussed later, in CIT we have created versions of BiasBusters@CMU with faculty recruiting, promotion and tenure, or graduate admissions in mind, thereby providing in each case evidence on how unconscious biases relate to gender, race, nationality, or even academic lineage, and how they may affect decision making in these situations [3] [8] [21]. These BiasBusters@CMU sessions were paired with specific guidelines and checklists that committees had to follow during the selection process [4].

BiasBusters@CMU also makes use of videos and short exercises which are particularly effective at promoting discussion. For example, towards the beginning of the session we hand out playing cards which are designed with left handed players in mind. Without telling the participants about the "lefty cards" we simply ask them to sort the cards as if they were going to play a game. We then discuss the experience. We use this as a simple, non-threatening way to introduce the idea that the world is often made for the majority and ignores, even makes life difficult for, those who do not fit what we think of as "societal norms."

IV. Homework

We ask participants to do a little homework ahead of time. Facilitators have found this valuable for keeping the discussion on track without unnecessary diversions. The homework includes asking participants to take at least one Implicit Association Test (IAT). Taking the Harvard IAT helps participants understand how this type of bias creeps in when making quick decisions without time for thoughtful reflection. We also ask that they watch (most of) the video "Unconscious Bias @ Work" by Dr. Brian Welle, a Director, People Analytics at Google, in order to gain a sense of the research evidence and to see Google's efforts at reducing the impact of unconscious bias in the workplace.

V. The fear and fun of role-play

The role play and scenarios are an essential part of each session. Facilitators recognize that this can seem intimidating to some people, indeed some participants have confessed they were going to avoid the sessions because of the fear of role-play. To put people at ease facilitators now include a quick and entertaining "roleplay demo" early in the session, using common bias scenarios such as "Where are you really from?" or "You don't look like an engineer". The scenario is revisited and discussed later in the session. Role play places participants in situations in small groups, usually 3 or 4, and most agree afterwards, even those with trepidation, that the experience is extremely valuable and even when dealing with serious situations they have fun with it. BiasBusters@CMU also provides and discusses tips for interrupting bias. Participants can refer to these tips, developed by Google, as they take on roles in the role play.

VI. Participants

The majority of our BiasBusters sessions involve a mix of faculty, staff and graduate students with a few for undergraduates, especially those in leadership positions such as Teaching Assistants and Resident Assistants. Some sessions have been designed specifically for faculty. These sessions are particularly relevant and valuable in decision making situations such as faculty reviews, faculty hiring, reviewing graduate school applications and committee selection. In faculty sessions, facilitators focus on things like Confirmation Bias (the tendency to seek evidence that confirms our decisions and ignore evidence that refutes them), Affinity Bias (the bias toward people we view as being "like us"), and Elitist Bias (bias which changes your perception of a person based on where they are from, what school they went to, or who they worked for, etc. This can make you overvalue or undervalue an application. Neither is good).

VII. EVALUATION

BiasBusters@CMU also includes an evaluation component to assess participant experiences and the effectiveness of the sessions. The evaluation is comprised of a pre and post assessment survey. At the beginning of the session, a pre-assessment survey is used to gather information about the participants': 1) awareness of unconscious bias; 2) understanding of strategies that can be used to interrupt bias (conscious or unconscious); and 3) ability to use strategies to interrupt bias (conscious or unconscious). At the conclusion of the session, a post-assessment survey is used to gather information on the participants' learning outcomes, their qualitative feedback on the session and their demographics. Responses are confidential (no identifying information is collected) and participation is voluntary.

Surveys were administered to a total of participants including a range of members from the university community: undergraduate students, graduate students, staff, faculty, and post docs. The gender distribution was balanced and the ethnic identity of the participants include a range of backgrounds.

We found the participants experienced three significant outcomes. First, participants reported an increased awareness of unconscious bias after completing the session. Qualitative comments support this finding as well – as one participant explained – the best part of the session was "awareness - the more we learn about it, the more we can combat biases." Second, participants also reported an increased understanding of strategies that can be used to interrupt bias. Qualitative comments support this finding as well – participants explained – the best part of the session was "learning how to intervene" and "starting the conversation." Finally, participants reported an increased likelihood to intervene and interrupt bias. Qualitative comments suggest the role playing was critical in this change – participants explained – the best part of the session was "the role play really brings everyone into the situation" and "practicing allyship in the context of our real experiences."

Initial results suggest that BiasBusters@CMU plays a positive role in the understanding of unconscious bias and interventions that can be used to mitigate bias. Going forward, additional evaluation will be needed to understand the long term impact. Follow-up surveys and/or interviews will be used to ask BiasBusters participants to describe any experiences of observing bias and interrupting bias on campus as well as asking if they have felt greater awareness of unconscious bias and changed anything about the way they think or behave in regard to unconscious bias.

VIII. BIASBUSTERS@UNIVERSITY

With the successful experience of BiasBusters@CMU the Google-CMU collaboration moved forward with BiasBusters@University. The goal is to make the generic program available to any college or university interested in bringing bias and inclusivity programming to their campus. Schools adopting this program would ideally "pay it forward," helping the next school learn from their experiences, and conduct train-the-facilitator sessions with interested teams at the next school. Google hosted a one-day train-the-facilitator session with CMU for other interested schools. Basic guides, case studies and relevant tools are also available at rework.withgoogle.com.

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Awareness and Readiness for Graduate School of African American Male Computer Science Students

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***Abstract*—This paper investigates the preparedness, knowledge, and confidence of African American male undergraduate Computer Science students in applying to graduate school. Recent data has shown a gross underrepresentation of African Americans and other minority groups in computing and technology at the Masters and Doctoral levels. With a greater demand for diversity within the field of computing, it becomes more prevalent to find the causes for a lack of participation of such populations at the post-secondary level and find solutions to help increase the numbers. The study conducted looked at students' knowledge and experience in conducting and presenting research as well as their academic capabilities and programming experience. The study also probed the students about their knowledge and confidence in applying to graduate school and if they feel their inner circle was sufficient in preparing to apply. Our findings from the survey revealed that although the participants appeared to meet the academic requirements and had some level of research experience, they indicated that they did not possess much knowledge about nor feel confident in their ability to get into a graduate program. Findings also showed that the students know of people they can seek out to learn about graduate school, but most of them do not hold a Ph.D. At the end of the paper, current practices that help to provide students with the knowledge, confidence, and ability to pursue graduate studies in computing are reviewed.**

***Keywords*—Mentoring, Computer Science, Graduate School, Research Experience for Undergraduates, STEM**

I. Introduction

Within the field of computing, there is a significant lack of representation of minorities, both in the industry and academic spaces. According to the U.S. Bureau of Labor Statistics, jobs in Computer and Information Technology are projected to increase by 12% between 2014 and 2024 [1]. However, there may not be enough qualified people in the U.S. to fill those jobs. According to a 2017 report, there were only 43,000 Computer Science graduates in the workforce, not nearly enough for the more than 500,000 available jobs in computing nationwide [2]. Within academia, the same problem persists with select minority groups, including African Americans. According to the 2016 CRA Taulbee Survey, the percentage of African Americans in Computer Science and related fields were among the lowest of all applicable ethnicity groups [3]. Looking at enrollment numbers, at the Masters and Ph.D. level, minorities make up only 2.1% and 1.5% of the total enrollment across all computing departments, respectively. In terms of degrees awarded, these groups represent 1.5% and 1.4% of Masters and Ph.D. degrees, respectively. Comparing to students at the Bachelors level, the numbers are higher for both enrollment (5.4%) and degrees awarded (4%) [3]. This shows that there exists a drop-off of blacks between their undergraduate and graduate pursuits. Researchers have looked to implement solutions to address this gap.

Seeing how the percentage of African Americans with Computer Science Bachelor degrees shrinks significantly when compared to a M.S. and Ph.D., a study was conducted at an all-male historically Black college (HBC) to understand how African American male Computer Science students feel about applying to graduate school to pursue a graduate degree in computing. The study consisted of a survey which asks African American male Computer Science undergraduate students about their academic proficiencies, experience in research, and knowledge and confidence in applying to graduate programs in computing. The results from the study will help to answer the following research questions: 1) How knowledgeable are African American male undergraduate Computer Science students about conducting research and applying to graduate school?; 2) How confident do African American undergraduate Computer Science students feel in their abilities to apply to graduate school?; 3) Where do African American undergraduate Computer Science students go to learn about conducting research and applying to graduate school? The rest of the paper will go as follows: section 2 will provide the rationale and justification for the study; section 3 will provide a detailed description of the study that was done; section 4 will detail the analysis and results; section 5 provides the conclusion.

II. Project Rationale/Justification

A. *Need for More Computing Graduates*

A 2010 report by the National Academy of Science [4] states that minorities are critically underrepresented in science and engineering, yet they are the most rapidly growing segment of the American population. More recently, the National Research Councils Expanding Underrepresented Minority Participation [4] report notes that underrepresented minorities comprise "29 percent of the U. S. population but only nine percent of the college-educated professionals" in STEM fields.

Computing is one of many STEM areas in need for increased participation nationally, with specific efforts towards a building a workforce that reflects the diversity of the US population. Additionally, a report [5] on Science, Technology, Engineering and Math from the Georgetown University Center on Education and the Workforce forecasts 51 percent of STEM occupations will be computer occupations by 2018 indicating ongoing opportunities for qualified computer science graduates to become employed in a computer science profession.

B. Underrepresentation of African Americans in the Computing Workforce

In a 2008 report by the National Science Foundation [6], it was shown that Black Computer Science bachelor degree graduates (not just those from HBCUs) are disproportionately likely to NOT go into a science or engineering job or enroll in graduate school. Approximately 29 percent of Black graduates were employed in non-science and engineering jobs compared to 13 percent and seven percent for White and Asian graduates, respectively. The U. S. Census [7] reports that Computer Science occupations already make up half of all STEM occupations and in those occupations, only 7.3 percent of workers are African American compared to those in Math occupations which are over 9 percent African American.

In another report by the Georgetown University Center on Education and the Workforce [5], it is explained how not only is there a problem feeding STEM bachelors degree graduates into STEM careers, but it is also a problem retaining students to finish with a STEM degree. Data shows that only 19 percent of students who enter college as STEM majors graduate with a Bachelors degree in a STEM field. Of those, only half end up working in a STEM field after college and only eight percent of those same graduates are working in a STEM field 10 years later. According to the National Science Foundations Science and Engineering Indicators 2014, African Americans and Latino/as each comprised less than 10 percent of earned Masters degrees in 2011 at 9.8 and 7.5 percent respectively, after increasing two percentage points each over the previous decade, from 7.8 and 5.3 percent in 2000. Recently, seven Silicon Valley Companies (e.g., LinkedIn, Yahoo, Google and Facebook) released diversity of staffing data and on average only two percent were Black, revealing the how these disparities extend beyond college and into the workforce [8].

III. Study Design

In order to understand how much undergraduate students know about pursuing graduate school in computing, a quantitative study involving the use of a survey was employed. The purpose of the survey was to ask participants about their prior research experience, academic standing, including classification and GPA, knowledge of research experiences, knowledge of how to apply graduate school and their confidence in applying to graduate school. The data collected would be used to compare how certain variables such as GPA, sources to learn about research and graduate school and prior research experience would affect their confidence in applying to graduate programs in computing. From the results of the survey, the research team would attempt to derive a relationship between certain answers to the survey questions and the participants confidence in pursuing graduate study.

A survey instrument was created and administered to students enrolled in two senior level Computer Science courses at an all-male historically Black college in the southeastern United States. The selected college is one of the top producers of African-American male doctoral students in Computer Science. The procedure for this research was done by using a single-targeted population. The sample population was chosen using convenience sampling. A convenience sampling technique was chosen due to the small number of students availible to participate in the study as the sample were students in an undergraduate senior-level Computer Science course.

The survey used was designed specifically for it to be used in a way that can best capture the information needed to better understand the mindset of the participants with regards to their capabilities, their understanding of research and the process for applying to a graduate program. Table I shows the questions from the survey and will be referenced by their question name moving forward. Questions developed for the survey include basic but non-identifying information such as classification (Q1) and race (Q2). The survey was designed to be anonymous to maintain confidentiality and prevent the risk of identifying students. The survey asked about the students coding experience (Q3) and GPA (Q4) to learn of their academic performance. Regarding research, the survey asked students about giving an oral research presentation (Q6), presenting a research poster (Q5), participating in a Research Experience for Undergraduates (REU) (Q9), and how they came to learn about research in computing (Q7). There were also questions regarding students knowledge (Q14) and confidence (Q15) in applying for graduate school, how many people they know they can talk to about applying to graduate school (Q16), and of those people the percentage that holds a Ph.D. (Q17).

The survey provided was in paper form; administering a paper study during classroom time would encourage a higher response rate. The students completed the survey immediately after their classroom lecture, which gave the participants 30 minutes to complete the survey before the end of class. As compensation for their participation, participants would receive a movie-style box candy of their choosing. Students turned in their completed survey to the instructor and in return received the box candy.

IV. Analysis

In the analysis, responses were collected from 37 total participants. All responses were carried into the analysis.

TABLE I
TABLE OF SURVEY QUESTIONS

Question Name	Question
Q1	Classification
Q2	Race/Ethnicity
Q3	Years of coding experience
Q4	Major GPA (GPA based on courses in your major)
Q5	Have you ever created and presented a research poster?
Q6	Have you ever given an oral research presentation?
Q7	How did you come to know about research in computing?
Q8	Who can you talk to about research in computing?
Q9	Have you ever participated in a Research Experience for Undergraduates (REU)?
Q10	If yes to 9, how likely are you to continue conducting research?
Q11	How knowledgeable are you about Research Experience for Undergraduates (REU)?
Q12	If you answered 2 or higher in question 11, how did you come to know about Research Experience for Undergraduates (REU)?
Q13	What area(s) of computing are you interested in?
Q14	How knowledgeable are you in applying to graduate school?
Q15	How confident are you in applying for graduate school?
Q16	How many people do you know you can talk to about applying to graduate school?
Q17	Of those people, what percentage (%) have a Ph.D. (Doctorate of Philosophy)?
Q18	How likely are you to pursue a Master's degree in computing?
Q19	How likely are you to pursue a Doctoral degree in computing?
Q20	How likely are you to pursue a graduate degree in a field other than computing?

Because the study was conducted at an all-male institution, all of the participants are male. From the sample, 35 of the participants identified themselves as African-American/Black; one identified as Native-American/Alaska Native and one identified specifically as Bahamian. In regards to classification, 14% (5) of the sample are Freshmen, 24% (8) are Sophomores, 35% (13) are Juniors, and 27% (10) are Seniors. Information about participants coding experience in years was collected and can be seen, broken down by classification, in Fig 1. As expected, most upperclassmen have at least 1 year of coding experience and all freshman participants have less than 1 year of experience. For the sophomores and juniors that reported having less than 1 year of coding experience, it was concluded that these students may have transferred into the Computer Science major. Examining the GPA distribution, 78% reported having a GPA at or above a 3.0 with the remaining 22% having a GPA below a 3.0.

We now look at the distribution of results stemming from the survey questions concerning research. Participants were asked about 1) creating and presenting a research poster (Q5) and 2) giving an oral research presentation (Q6). For Q5, 70% reported No as a response with 30% reporting Yes; for Q6, 51% reported Yes while 49% reported No. Students were asked about the source of knowledge about research within the field of computing (Q7). Fig. 2 shows a pie chart showing the distribution of the various sources reported for Q7. According to the chart, 46% of the responses were for Faculty followed by Peers (27%). The results are fairly identical to the results for Q8, shown in Fig. 3, with Faculty being first at 46% and Peers at 32%. As expected, within the academic space, students are likely to look towards members of the department faculty and peers with experience in research to gain the required knowledge. Participants were also asked if they participated in a Research Experience for Undergraduates (REU) (Q9). From the sample, it was found that only 24% (9) participated in an REU. Students who reported Yes to Q9 were asked if they were likely to continue to conduct research. They answered from a Likert scale from 1 (Not Likely) to 5 (Very Likely) and 6 for Not Applicable if they reported No from the previous question. Out of that population, 67% reported either a 4 or 5, meaning they are likely to continue to do research in light of their experience in an REU.

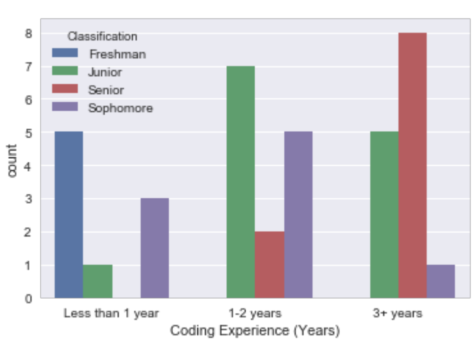

Fig. 1. Coding Experience by Classification.

The last two research questions, Q11 and Q12, asked students about 1) how knowledgeable they are about REUs and 2) how they learned about REUs, respectively. Q11 was set up with Likert Scale answers from 1 (Not Knowledgeable) to 5 (Very knowledgeable). From the data, only 27% (10) reported being knowledgeable or very knowledgeable about REUs and 70% being somewhat knowledgeable or not knowledgeable; 1 (3%) student reported as indifferent. For Q12, only responses from those who reported at least a 2 or higher from Q11 were counted. Fig. 4 shows a pie chart of the sources reported by the participants. The chart shows that most responded with Faculty as the main source with 57% followed by a tie between Peers and Website at 13% each.

The second portion of the survey asked students about their knowledge and confidence in applying to graduate school. Looking at the data for Q14, 62% of participants reported that they were somewhat knowledgeable or not knowledgeable about applying to graduate school; 35% reported to be knowledgeable or very knowledgeable and the rest reported as indifferent. For Q15, 43% reported as somewhat confident or not confident; 30% reported as confident or very confident, and 27% reported as indifferent. Students were asked how many people they know they can talk to about applying to graduate school (Q16) and of that number what percentage holds a Ph.D. (Q17). 87% of participants said they know at least 3 people to whom they talk about the subject. When observing the percentages of those people they know, they were less than 40% for most of the responses, with a mean of 35.6, a median of 25 and a standard deviation of 39. From what the data points out is that most of the participants do not know about the process of applying to a graduate program and therefore are not very confident in their ability to do so. Furthermore, while they know people they can go to to learn about the process of applying to graduate programs, most of them do not carry a Ph.D. Students were not asked about the qualifications of the people they know other than whether or not they have a Doctoral degree, so no assumptions were made that their sources are either faculty or staff members or merely their peers. The last set of questions (Q18-Q20) asked students the likelihood of pursuing a graduate degree in computing or in a field other than computing. Fig. 5 shows the distribution of the responses for each of the 3 questions. Q18 had most respondents saying they are likely to pursue a Masters degree in computing followed by responses of indifferent. For Q19, the majority of the responses were Indifferent, Somewhat Likely or Not Likely. For Q20, most of the responses were Not Likely and Somewhat Likely. Most participants are willing to go for their Masters degree in computing but not as likely to pursue a Doctoral degree in computing.

In addition to the distribution of the responses from the students, the relationship between certain questions and the students grouped into their classification was also examined. The objective was to see if there was any significance in how students responded depending on their classification at their institution. In particular, we looked at questions Q11, Q14, Q15, Q18, Q19, and Q20. These questions contained Likert Scale responses ranging from 1 (Not) to 5 (Very). To determine if there is a significant difference between classifications in their responses, the Kruskal-Wallis test was employed. The Kruskal-Wallis test was chosen as the appropriate statistical tool for the One-way Analysis of Variance (ANOVA) because the data does not represent a normal distribution, in which the Kruskal-Wallis test does not make such an assumption [9], therefore making it a nonparametric statistical method. Another potential option was to use the Mann-Whitney U test; however, the Kruskal-Wallis test is more appropriate when dealing with more than two groups. For this method, the null hypothesis will be that there exists no significant difference amongst the classifications, which will be the independent variables, for the responses to each question, which are the dependent variables. The Chi-square (Chi^2), and P-value for each question can be seen in Table II, all with a degree of freedom (df) of 3. For all questions, using 0.05 as the significance value, the p-values were higher, thus we accept the null hypothesis that there is no significant difference amongst the classifications. From the results, it was concluded that the classification of the students have no impact on their knowledge of research and applying to graduate school as well as their confidence in applying or their likelihood to pursue a graduate degree in computing.

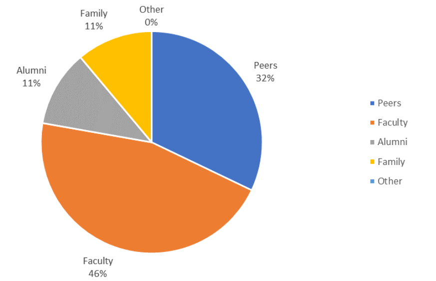

Fig. 3. Sources Students Can Go to Learn About Research.

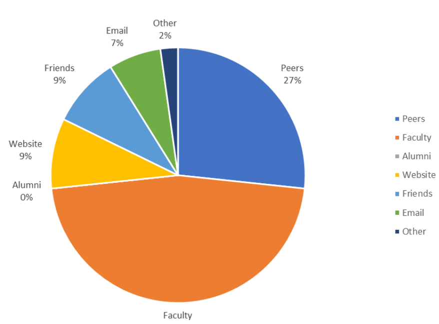

Fig. 2. Sources Students Used to Learn about Research.

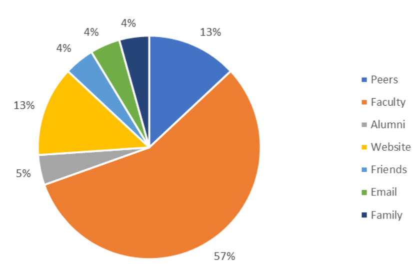

Fig. 4. Sources Students Used to Learn of REUs.

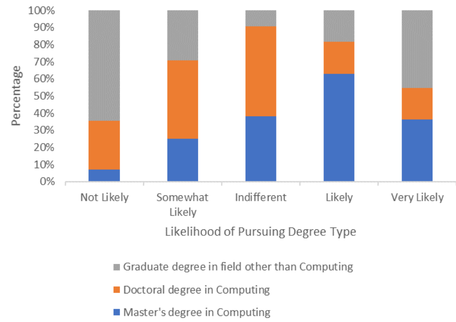

Fig. 5. Distribution of Likelihoods to Pursue a Graduate Degree

V. Conclusion

The study examined the awareness and experience of conducting research of African American male undergraduate Computer Science students as well as their knowledge and readiness for applying to graduate school. From the survey results and the analysis, most students are not knowledgeable about the process of applying to a graduate program in computing and they don't feel confident in their ability as such. Even as most of these students are academically capable to apply to a graduate program and many have some experience in research, the overall outlook is that they do not feel they are prepared to pursue a graduate degree in computing.

When examining their sources for information, most pointed towards the faculty and their peers as contacts they can seek advice to learn about how to apply for graduate school. From the number of sources indicated, most of them do not carry a doctoral degree. From the data, it shows that traditional mentoring from a peer or professional may not be sufficient to encourage students to undertake graduate study. The study was faced with a number of limitations that prevented further investigation into the problem. One was the size of the sample. With only 37 participants, the results do not reflect the population as a whole within this context. Additionally, as the sample consisted of participants at an all-male HBCU, the results of the study may not translate in other settings. Future work will involve conducting a similar study in different university contexts and include female participants. Secondly, data collected for GPA was in the form of various options of a given range (e.g. 2.0-2.9, 3.0-3.9). If concrete numbers were acquired, there would be a better assessment of the academic performance of the participants rather than relying on a general range.

TABLE II
Results of Likert Scale Survey Questions

Question	Chi^2	P-value
Q11	1.9393	0.5851
Q14	0.72332	0.8677
Q15	4.3913	0.2222
Q18	6.1085	0.1064
Q19	1.1784	0.7582
Q20	3.0129	0.3896

The question now is "What additional steps should be taken to further guide and push undergraduate computing students to want to pursue a graduate degree?" One plausible solution is to encourage more students to partake in REUs as this has been a proven intervention to encourage underrepresented students to pursue graduate school [10] [11]. From the survey, students who have participated in an REU were asked about the likelihood that they would continue conducting research and just over half responded Likely or Very Likely. There are, however, a number of obstacles which make REUs not scalable. The first obstacle is cost. REUs present a high cost to operate as it involves housing for students, use of facilities at the site, stipends for participants, to name a few. There may also be specific limits to the number of students that can be permitted to participate at the site such as the number of available research advisors for the students to work with over the summer. Limited slots at an REU can prove to be costly for students who meet the requirements for admission into the REU but are left out because of the competitiveness of those exclusive slots.

Mentoring has been a tool used to help guide students in the academic space and produce positive outcomes in academic performance as well as retention [12] [13]. This holds especially true when students are being mentored by someone of the same race [13]. Students who receive mentoring are more likely to continue into a graduate program after their baccalaureate career than students that do not [14]. However, mentoring is not without its obstacles. Some factors that can limit the full potential of mentoring include whether the mentoring is done formally or informally, the duration of the mentoring relationship, any geographical barriers that may exist depending on how close the mentor and protege are to one another and the ability to meet physically, and time limitations, such as finding a mutual date and time to meet. Telementoring helps to address the geographical obstacles by using electronic means such as email, video chat, or interactive websites [12] but time limitations are still a problem due to the availability of mentors and the number of students in need of mentorship. While mentoring provides a more scalable alternative to an REU, it currently is not conclusive in helping students become more confident in applying to a graduate program, nor does it provide the research experience of a REU or the exposure to cutting-edge research projects and laboratories.

Another potential avenue to augment the mentoring effort is virtual mentoring. It is similar to telementoring in which users interact through electronic means, however mentees interact with a computer program where mentoring content from knowledgeable mentors are stored and disseminated. One virtual mentor was developed using an embodied conversational agent (ECA), a virtual human design to engage in dialogue with a user [12]. This virtual human provided a full-time mentor for students that need help at any time with no regards to location, except on a computer. Previous work on ECAs has shown that their performance in terms of dialogue and providing information can be on par with that of an actual human being [12] [15]. This is not to say that a virtual mentor will replace physical, face-to-face mentoring and telementoring. Instead, it will be viewed as a possible supplement to existing forms of mentorship.

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Maryland Computing Education Growth From 2011-2016

Megean Garvin, Michael Neary, Kayla Carrigan, and Marie desJardins[1]

Abstract— **Nationally, computing education is growing at a rapid pace. Barriers to equitable implementation of computer science (CS) high school classes include the lack of CS teachers, funds, and political support [3]. A grassroots effort in Maryland has focused on increasing computing education access from kindergarten through high school, and recently established the Maryland Center for Computing Education (MCCE). To understand the growth in computing education, we analyzed the demographics of Maryland public high school graduates, economic differences between the local education agencies (LEA) and the workforce within each county, and the perceptions of Maryland high school CS teachers. Although each subgroup of public high school graduates taking at least one CS class has increased, the rates of increase vary across gender, race, and ethnic subgroups. The LEA economic differences reflect the current dominant industries and overall wealth within each LEA. Finally, Maryland high school CS teachers' perceptions of students taking CS in high school are consistent with the increases reported by the state.**

I. INTRODUCTION

Computing is no longer an isolated field of study: every discipline utilizes the power of computing to complete tasks, analyze and visualize data, and automate various functions. With the increased emphasis in our society on computing skills and knowledge, there is an increased demand for computing education. The "Generation CS" student population has doubled college CS enrollments since 2009, and there has been a significant increase in non-majors taking CS courses at all levels (introductory, mid-level, and advanced college courses) [1]. However, the availability of high school computing classes has not kept pace with the demand to better prepare students for college. The newly developed K-12 CS Framework [2] provides guidance in how to integrate CS in every classroom, but there are still numerous issues to be addressed. While the demand for more computing knowledge and skills is surging at every level of education, the resources (qualified teachers, funding, and political support) are difficult to secure at a state level [3]. Furthermore, the broadening of participation at the national level, particularly among women and underrepresented minorities, is increasing, but the increases are still minor percentage increases when compared to the overall growth [4]. The "digital divide" and the lack of diversity in the computing education pipeline from education to workforce continue to present challenges at the national and state levels [6].

Similar to the national trends, Maryland has also shown growth in computing education. Since the emergence of a grassroots effort in 2011, Maryland has worked collectively to increase computing education at all levels (pre-kindergarten through college). This effort, led by Marie desJardins (University of Maryland, Baltimore County), Jan Plane (University of Maryland, College Park), and several high school CS teachers, has expanded to include a steering committee with industry and government representation. The growth from a small circle of about 12 computing educators (university and high school) increased to a contact database including over 1,000 individuals. Statewide computing education summits (in 2012, 2013, 2016, and 2017) and other events have enabled input from educators, industry, and government (federal and state) representatives to directly influence the Maryland computing education initiatives. Recently, the University System of Maryland (USM) established the Maryland Center for Computing Education (MCCE), with the mission of continuing to expand access to high-quality computing education for all Maryland public school students.

Maryland is strategically streamlining efforts at all levels of education in order to strengthen the future workforce. According to the United States Department of Commerce 2015 Enterprising States report, Maryland ranks first in academic research and diversity intensity, high-tech share of all businesses, high school Advanced Placement scores, and STEM job concentration; second for talent pipeline; third for innovation and entrepreneurship; and fifth for high technology performance [9]. The industry and government growth and the increase in students majoring in CS, in the face of a continued lack of gender diversity and racial diversity, and a need for stronger foundational skills, has motivated grassroots effort to reform K-12 computing education. In this paper, we investigate current computing education trends in Maryland, focusing on three research questions:

1) How well do the demographics of Maryland public high school graduates taking CS high school classes reflect the population of Maryland public high school graduates, and how many of these graduates declare a computing major in college?
2) What economic differences exist between the Maryland Local Education Agencies (LEAs), and how, if at all, does this data relate to the industry and workforce within each county?
3) What are CS high school teacher perceptions of students taking CS in Maryland high schools, and how, if at all, does this data align with the data reported by the state?

*This work was supported by NSF 1339265. We would like to thank Caroline Kery and Josh Massey for their work on this project.

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II. DATA SOURCES

To analyze computing education in Maryland, we identified several data sources, including data from the Maryland State Department of Education (MSDE) [7], three landscape surveys of Maryland CS high school teachers, the Maryland Longitudinal Data System (MLDS) [10], and the Maryland Department of Labor, Licensing and Regulation (DLLR) [8]. MSDE annually reports aggregated (LEA and state) student data, including economic data (wealth and expenditures per student) and the number of students who receive free and reduced price meals (FARM).

In 2012, we developed a baseline survey of Maryland CS teachers modified from the Computer Science Teachers Association (CSTA) national survey and administered it to CS high school teachers in Maryland. The goal was to provide baseline data for Maryland CS high school teachers' background, professional development needs, classroom demographics, and the types and number of CS high school classes. This survey was sent to CS teachers from 247 high schools in Maryland; 85 CS teachers responded [5]. The survey was modified to include additional questions regarding Maryland teacher certification and prior industry work experience and administered twice more (2014 and 2016), with response numbers of 84 and 67, respectively. We scaled all of the responses such that the weight of the responses from each LEA would be proportional to the student population distribution in Maryland. We then imputed response values for the unrepresented LEAs from each survey, based on their similarity to other LEAs. By analyzing the various attributes for each LEA using our data sources, we grouped LEAs based on the following categories: LEA size, region, SAT Math scores, HSA Algebra I scores, SAT participation rates, race and ethnicity percentages, and Advanced Teacher Certification rates. For the analysis in this paper, we report on only two of the relevant questions from the survey.

In 2017, we partnered with the Maryland Longitudinal Data System (MLDS), which provided data about student performance data at all levels of education and workforce data. We submitted a special data request for how many graduating high school students took at least one CS class in high school and how many students then declared CS as their major entering college. Data was aggregated at the state and LEA level. Finally, the DLLR maintains data about Maryland's industries and workforce. We retrieved data for the average weekly income by county and the top three employed sector by county.

III. DATA ANALYSIS

A. BROADENING PARTICIPATION

The Maryland CS workforce pipeline is challenged to have the workforce mirror the diversity of the overall population. One effective method to promote diversity in the workforce is to expose high school students to CS, increasing student interest. Participation in CS at the Maryland public high school level has increased in the past few years, as shown in Fig. 1 and 2. In 2013, most public high school graduates throughout the state had not taken a CS class upon completion of their degree. Only five LEAs in Maryland had between 11% and 20% of their graduates take at least one CS class before graduating; fewer than 10% of graduates in each of the other 18 LEAs had taken a CS class. In 2016, only five LEAs had fewer than 10% of their graduates take a CS class before graduating. All of the other LEAs saw a significant amount of growth in this metric, with some increases as high as 30%.

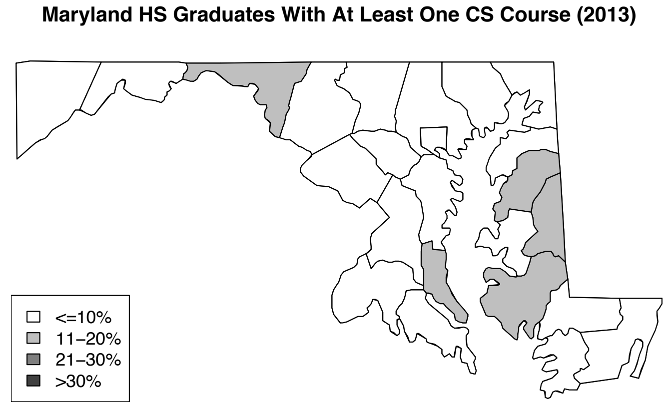

Fig. 1: The percentage of Maryland public high school graduates in each LEA who had taken at least one CS class in high school prior to graduating in 2013.

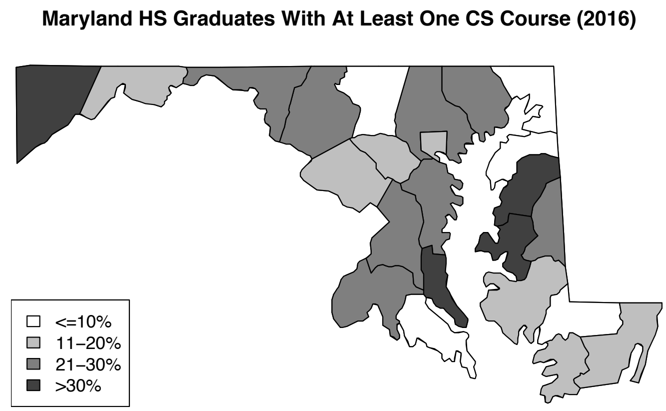

Fig. 2: The percentage of Maryland public high school graduates in each LEA who had taken at least one CS class in high school prior to graduating in 2016.

More students are being exposed to CS in high school, but a substantial change in gender equity has yet to be realized. Fig. 3 shows an upward trend in the number of graduates who take at least one CS class before graduation, but there are still far fewer females taking at least one CS class. The gap between male and female high school graduates who have taken CS is widening, albeit slowly, rather than shrinking. Fig. 4 shows another upward trend in the subset of these graduates who move on to attend college. Students who take CS in high school are more likely to declare CS as their major in their first year of college more often, but the rate of growth of women declaring CS is lower than that for men. Perhaps more alarming is the fact that there is a strong positive linear trend in the male population, while the female population seems to be plateauing. The growth of CS among

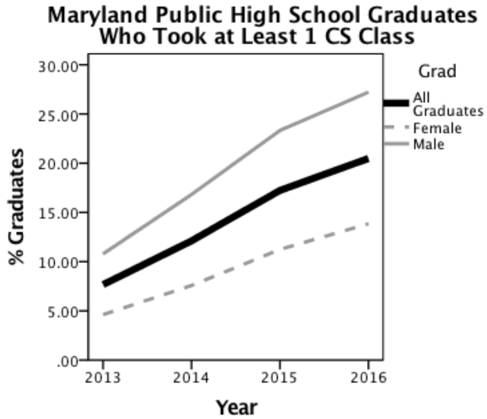

Fig. 3: Maryland public high school graduates per year who took at least one CS class, broken down by gender.

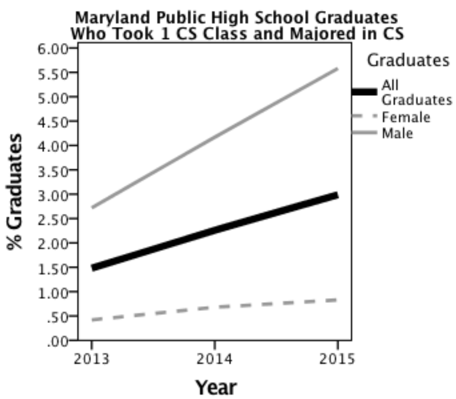

Fig. 4: Maryland public high school graduates per year who took at least one CS class and then majored in CS, broken down by gender.

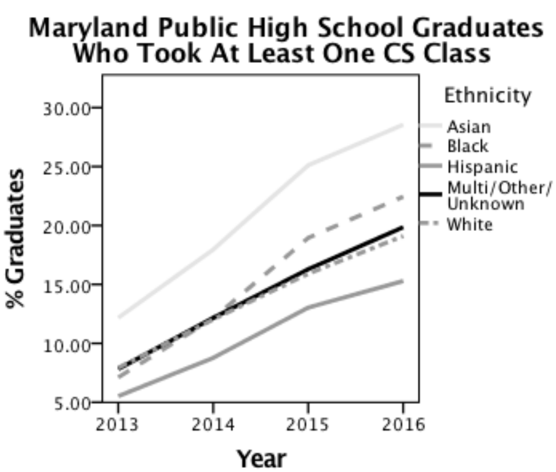

Fig. 5: Maryland public high school graduates per year who took at least one CS class, broken down by ethnicity.

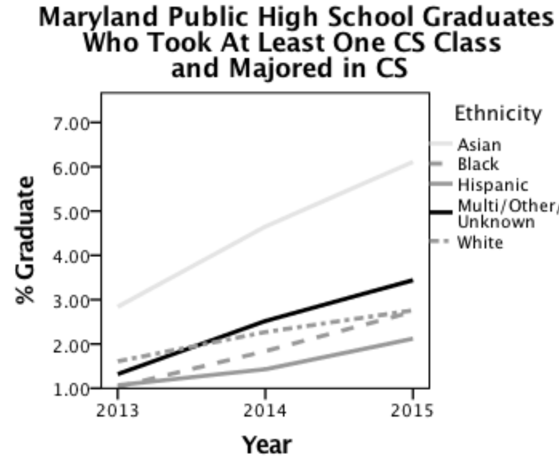

Fig. 6: Maryland public high school graduates per year who took at least one CS class, and then majored in CS, broken down by ethnicity.

high school graduates is also seen across race and ethnicity subgroups: Fig. 5 shows an increase students who took at least one CS class upon graduation in every ethnic subgroup, with the largest growth among Asian graduates. The same trend is also seen in these subgroups for students who declare a CS major, as shown in Fig. 6. The high school graduates reflect the population of Maryland, but the growth in CS high school classes and graduates who declare a CS major is still small compared to other majors.

B. *ECONOMIC DIFFERENCES*

Funding for computing education is often a barrier to offering CS high school classes. To understand economic differences of each LEA as well as the local county, we examined the socioeconomic status (SES) through various data sources. For each county in Maryland, we identified the top three employment industries and their corresponding average weekly wage as well as the entire county's average weekly wage from the DLLR data. We also use the wealth per pupil, expenditures per pupil, and FARM percentage average for each LEA's high school student population to examine the SES of both the LEA and the high school student population in each LEA.

The top three industries and therefore types of employers in each county enable us to estimate the level of education that is required to be employed within each industry sector. By computing the average weekly wage in the top three industries, we account for outliers on either side of the income spectrum. In Fig. 7, the Top Industry Income column refers to the average weekly income for the top three sectors. In each county, the top three industries employ 50% or more of all the employees in the county. In the economic differences table, the wealth per pupil column is defined by MSDE as the sum of a countys net taxable income, while the expenditures per pupil column is a measure of how much a county spends on each student [7]. The top three industries in both Western Maryland (Allegany, Garrett,

	DLLR				MSDE		
2016	Industry No. 1	Industry No. 2	Industry No. 3	Top Industry Income	Wealth per Pupil	Expenditures per Pupil	Percentage on FARM
Allegany	EHS	TTU	LH	$ 613	$ 294,349	$ 13,553	48%
Anne Arundel	TTU	PBS	LH	$ 976	$ 586,971	$ 12,987	27%
Baltimore	EHS	TTU	PBS	$ 937	$ 474,310	$ 13,203	43%
Baltimore City	EHS	PBS	TTU	$ 1,190	$ 272,638	$ 14,991	76%
Calvert	TTU	C	LGOV	$ 1,221	$ 453,195	$ 13,725	18%
Caroline	TTU	LGOV	M	$ 766	$ 284,996	$ 12,400	52%
Carroll	TTU	EHS	PBS	$ 803	$ 443,654	$ 13,253	15%
Cecil	TTU	LH	M	$ 843	$ 372,593	$ 12,741	36%
Charles	TTU	LGOV	LH	$ 664	$ 379,644	$ 13,427	28%
Dorchester	M	TTU	EHS	$ 734	$ 357,707	$ 13,962	56%
Frederick	TTU	PBS	EHS	$ 925	$ 402,478	$ 12,661	20%
Garrett	TTU	EHS	LH	$ 520	$ 623,611	$ 14,834	39%
Harford	TTU	EHS	FGOV	$ 1,030	$ 441,781	$ 12,481	25%
Howard	PBS	TTU	EHS	$ 1,248	$ 536,841	$ 15,397	18%
Kent	EHS	TTU	LH	$ 605	$ 780,720	$ 14,027	43%
Montgomery	PBS	EHS	TTU	$ 1,295	$ 657,040	$ 15,002	29%
Prince George's	TTU	LGOV	PBS	$ 1,027	$ 375,004	$ 14,102	54%
Queen Anne's	TTU	LH	LGOV	$ 630	$ 559,848	$ 12,457	22%
Somerset	SGOV	EHS	TTU	$ 873	$ 290,524	$ 15,370	62%
St. Mary's	PBS	FGOV	TTU	$ 1,547	$ 426,445	$ 12,171	24%
Talbot	EHS	TTU	LH	$ 755	$ 1,029,199	$ 11,869	33%
Washington	TTU	EHS	LH	$ 649	$ 334,161	$ 12,720	42%
Wicomico	TTU	EHS	LGOV	$ 818	$ 277,692	$ 13,094	49%
Worcester	LH	TTU	LGOV	$ 546	$ 1,094,782	$ 16,960	38%

TTU = Trade, Transportation, and Utilities M = Manufacturing FGOV = Federal Government
EHS = Education and Health Services LH = Leisure and Hospitality SGOV = State Government
PBS = Professional and Buisiness Services C = Construction LGOV = Local Government

Fig. 7: Maryland economic differences between LEAs as shown by two data sets: DLLR (top industries and average income) [8] and MSDE (wealth per pupil, expenditures per pupil, and percentage of FARM pupils.) [7]

and Washington) and Eastern Maryland (all counties east of the Chesapeake Bay) are the same. However, in 2016, 21% of their graduates in Western Maryland took at least one CS high school class, while Eastern Maryland only had 15%. Although these two regions may be nearly identical in terms of economics, Western Maryland is one of the leading regions for high school computing education growth, while Eastern Maryland is the most lacking. In the center of Maryland, including the Baltimore/Washington, D.C., metropolitan counties, industry and school system wealth vary. For example, Montgomery County and Prince George's County are both within the Washington, D.C., metropolitan area, but Montgomery County LEA wealth per pupil is $657,040 and the FARM student population is 29%, whereas Prince George's County wealth per pupil is only $375,040 and the FARM student population is 54%. Prince George's County is therefore at an economic disadvantage to implement new high school CS classes. However, our recent efforts (USM Minority Student Pipeline Math Science Partnership to train CS teachers and RiseUp4CS outreach and tutoring students for the AP CS A exam) have focused on increasing CS high school classes in Prince George's County, which partially accounts for the increase from 7% (2013) to 25% (2016) in graduates in this region who took CS in high school.

C. *TEACHER PERCEPTION*

The three landscape surveys (2012, 2014, and 2016) polled CS high school teachers to gauge their impressions of computing education in their schools. One question asked whether teachers believed that there are students who should be taking CS, but are not. From 2012 to 2016, the percentage of teachers with this belief increased from 67% to 86%. Teachers were also asked whether the availability of CS classes offered at their school had increased. The number of teachers who reported an increase of CS classes in their school has grown over time (21%, 39%, and 62%, respectively). These findings are consistent with the statewide increases in the number of graduates taking CS classes.

IV. CONCLUSIONS

Maryland high school computing education has grown significantly in recent years. The cooperation of educators, industry, and government representatives has enabled Maryland to strengthen the computing education workforce pipeline. The perceptions that teachers hold concerning an increase in CS offerings and enrollment are accurate and representative of the state as a whole. The increased belief that students should take CS demonstrates that teachers are becoming more aware of the impact that computing education can have on a student's future.

A primary goal for the MCCE is to broaden participation in computing education. Since the grassroots efforts began in 2011, Maryland has made significant gains in broadening participation; however, there is more work to be done to increase the number of graduates who take CS classes in high school. Ideally, every Maryland high school graduate should take at least one CS class before graduating. Efforts will continue to study the trends in computing education with a continued commitment to encourage women and underrepresented minorities to participate in computing education.

Economic differences highlight the need to address funding issues within each LEA. Across the state, LEAs expend similar amounts per pupil, but the wealth per pupil and the percentage of FARM students provide a clear picture of LEAs that require additional funding sources. By monitoring the economic differences that exist and persist between the Maryland LEAs, we intend to strategically partner with the specific LEAs, industry, and government to provide access to high-quality CS high school classes in every Maryland LEA.

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Bridging the Diversity Gap in Computer Science with a Course on Open Source Software

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***Abstract*—Stereotype threat, impostor syndrome, lacking a sense of belonging, and misconceptions about the field are just some of the reasons that contribute to the increasing diversity gap in Computer Science. To address this, our institution has developed an undergraduate course in which students contribute to Free and Open Source Software (FOSS) projects under the guidance of a dedicated mentor. By contributing to FOSS projects, students can: find a mentor or role model; collaborate with, participate in, and contribute to a welcoming and supporting community; and see that they can have real-world positive impact. This paper describes the course and our experiences in teaching it, and provides evidence that it can have a positive impact on diversity by increasing retention and improving students' confidence.**

Keywords—Diversity, Computer Science Education, Free and Open Source Software

I. Introduction

Diversity and inclusion (D&I) has long been a problem within Computer Science (CS). Over the past few decades, as underrepresented minority (URM) groups within CS dwindle, the problem has become more prominent. Even URM groups who have relatively more advocates and initiatives, such as women, are still underrepresented and their representation has decreased [1]. Other URM groups, e.g. based on socioeconomic background or sexual preference, have little to no community, supporting initiatives, or even statistics to get an idea on their representation within CS. D&I is commonly seen as a pipeline problem that starts well before one enters the workforce, and therefore, it is more beneficial to start more academic initiatives designed to recruit and retain URM students.

To that end, we have developed an undergraduate course aimed at addressing D&I issues by having students contribute to Free and Open Source Software (FOSS) projects. The course exposes students to the cultural, technical, and legal aspects of FOSS development by covering topics such as: the need for and benefits of open source software; open source licensing and business models; intellectual property; and humanitarian free and open source software (HFOSS).

Most importantly, there is a semester-long project in which students become involved in and make meaningful contributions to a FOSS project under the guidance of a mentor who is part of the project's community. This allows us to attract and retain more URM students and improve D&I by giving students the opportunity to find a mentor or role model; collaborate with, participate in, and contribute to a community; and see the opportunity for real-world positive impact.

This paper describes the course and our experiences in teaching it, and provides evidence that it can have a positive impact on diversity by increasing participation and improving URM students' confidence.

II. Motivation and Background

Here we present an overview of some of the challenges with recruiting and retaining URMs in the field of computing.

A. Literature Review

With the increased attention to the CS diversity gap, many researchers have tried to understand its underpinning causes. There are a few common reasons most researchers and educators believe could be a factor.

1) Stereotype Threat. Stereotype threat is a social phenomenon in which people believe they are at risk of conforming to stereotypes based upon their social groups, and is often considered a reason people are discouraged from CS [2]. If people are exposed to negative stereotypes about their social group, they will end up performing more negatively, as has been shown in fields such as athletics, math, and even standardized tests [3]. In general, marginalized and disadvantaged groups face more negative academic stereotypes, especially in the STEM fields, and are at a higher risk of stereotype threat [4]. In addition, URMs are usually portrayed as not as capable in STEM and other quantitative fields, which has a correlation in both situations where it has shown a decrease in confidence [5] [6]. The effects of stereotype threat from such negative stereotypes can cause individuals to be less confident and doubt if they made the right decision in their choice of study.

2) Imposter Syndrome. Imposter syndrome is a common social phenomenon within CS, meaning people do not experience an internal sense of success because they attribute their achievements to external factors, like luck [7] [8]. URMs often believe they are less competent despite similar comfort levels, grades, and abilities in CS to their white male peers [7]. Many leaving CS to another major or career path believe they are not smart enough and URMs have a higher chance of having imposter syndrome [9].

3) Sense of Belonging. The sense of belonging is intrinsic to human nature and the need for it is stronger in adverse and stressful environments, such higher education [8] [9]. URM students may be discouraged from CS because they do not see others like them. The lack of community makes them feel unwelcomed and alienated from their peers [2] [7], and are a better fit for those who are part of the majority [2] [10]. Those who manage to find a supportive community claim that this support kept them from leaving during moments of doubt [7] [11].

4) Lack of Diversity in Representation. The lack of diversity in the representative figures within CS is a severe problem. Studies trying to find causes of the diversity gap suggest that increasing the diversity of representation within the field can help alleviate the effects of stereotype threat and lack of sense of belonging [2] [7]. When students choose a major, it is also crucial that they can envision themselves in that occupation [2] [9]. Having a relatable role model can inspire URMs to continue studying CS, while an overwhelming representation of successful people different from them can induce a stronger effect of stereotype threat [5] [8] [10]. Seeing their role models succeed can show students possibilities they never envisioned for themselves before.

5) Misconception of Computer Science. Students feel that the academic work within a CS curriculum is usually different from the real-world experience in industry. Moreover, some say they started CS with the misconception of what working in a CS related role was. They envisioned themselves sitting in front of a computer and rarely interacting with others [2] [12]. Students who left CS said their new major was a better fit because there was more interpersonal communication and social interaction [7] [12]. This is a common misconception of CS [13], but CS actually requires working in teams and also interpersonal soft skills [14]. This is a sign that students do not get enough exposure to the industry they are studying for [12].

B. Student Survey at Our Institution

In addition to reviewing the existing literature, we sought to get a better understanding of the situation at our own institution, particularly whether students who identify as URMs perceive aspects of CS differently from those who identify as non-URMs when it comes to making a major feel inclusive. This includes mentorship, relatable role models, collaboration opportunities, sense of community, ability to have an impact on society, opportunities to express ideas and creativity, and networking opportunities.

We surveyed students in our CS1 course as well as an upper-level undergraduate course, and asked them to respond using a 5-point Likert scale (with 1 labeled "Strongly Disagree" and 5 labeled "Strongly Agree") to eight questions stated in the positive form: "*To what extent do you agree with each of the following: Computer Science is a field that offers me the opportunity to… (1) Find a mentor, (2) Find a role model, (3) Collaborate with others, (4) Participate in a community, (5) Contribute to a community, (6) Have a positive impact on society, (7) Express my creativity, (8) Connect with professionals.*"

Additionally, we asked whether the student identifies as member of an underrepresented minority in computing, with possible answers being "Yes," "No," and "I don't know." This prompt came at the end of the survey. Note that we did not explicitly ask for gender, race, ethnicity, etc., only whether the student identified as a URM.

In total, 33 students from the CS1 course and 15 students from the upper-level course completed the survey. Of the 48 respondents, 21 stated that they considered themselves part of an underrepresented group, 19 stated that they did not, and 8 answered "I don't know."

Because of the small sample size, we are unable to state the statistical significance of the results, but they do generally confirm many of our expectations:

- Across both courses, students who identified with a URM group felt that they were less likely to be able to find a mentor, have a positive impact on society, express their creativity, or connect with professionals.
- These differences were more pronounced in the students in the upper-level course than they were in the CS1 course, indicating that these misconceptions worsen over time.

Somewhat surprisingly, we also found that students who identify as URMs were *more* likely to agree that CS is a field in which they can collaborate with others, participate in a community, and make a contribution to a community, perhaps because those students have already formed peer communities through organizations such as WiCS, NSBE, SHPE, etc. Even though this did not match our expectations, surely it is important to continue to create interventions for our students that reinforce the notion that CS is a collaborative field.

Overall, these results demonstrate that there is need for our institution to attempt to address URMs' perspectives of computer science and improve diversity and inclusion.

III. A Course on Open Source Software

This section describes an undergraduate course that combines best practices of successful academic initiatives and contributions to open source software in hopes of maximizing their benefits and effects to retain URM students within CS and increase their confidence.

A. Why Teach Open Source Software?

Free and Open Source Software (FOSS) is software that is licensed to be free to use, modify, and distribute. The contributors are a mix of paid and voluntary programmers. Since FOSS is developed by a variety of developers, the product requires contributors to learn to communicate in a professional and realistic environment despite most of the communicate being virtual. Since the source code is public, there is complete transparency in all code, commit history, and documentation. The open source licensing allows the software to be modified by end-users. These factors make FOSS perfect for student contributors. Contributing to FOSS benefits students by teaching them technical and professional skills and allows them to learn within a professional community and distributed development environment [22].

B. Course Overview

The course is offered at our institution as an undergraduate special topics course entitled "Open Source Software Development," and is targeted toward students who have completed our traditional software engineering course.[1]

Students indicate their preferences from a curated list of FOSS projects for which a mentor in the community has been identified, and then are assigned to a project based on their preferences and availability of resources. Students must necessarily work in pairs and may suggest projects not on the curated list, as long as they are able to find a mentor in the community. Once the project is under way, the mentor specifies the approved development process, coding standards, etc., then gets the students ramped up on the project and assigns the tasks that need to be completed. Over the course of the semester, the mentor continues to support the students by conducting weekly check-in meetings, reviewing code contributions, and helping to coordinate work through issue tracking systems.

In addition to contributing to a FOSS project, students learn about the cultural, technical, and business aspects of open source software, with a particular focus on social issues, such as: what are the moral/ethical foundations of FOSS? what motivates people to contribute to FOSS projects? how can a FOSS community be more inclusive, and what happens when it is not inclusive? does FOSS live up to its promises, or can only those who are already at a socioeconomic advantage actually participate in and benefit from it?

Introspection and reflection are important parts of the course. Students are expected to make multiple posts to their public blog each week and respond to the things they are learning and experiencing as they contribute to their project and get a better understanding of FOSS.

C. Meeting Educational Objectives

To conclude this section, we describe how the course meets its objectives of addressing the challenges identified in Section II: stereotype threat, impostor syndrome, lacking a sense of belonging, and misconceptions about the field.

1) Engagement and Inclusion. A key pedagogical element of the course is that there are no lectures, as they may be biased against students from underrepresented groups [15]. Rather, class meetings are focused on discussion and interactive, participatory, active learning exercises in which students participate and engage with instructors and peers to work out problems and explore concepts. Most variations of active learning reduce procrastination and promote better study habits by requiring students to come to class prepared to participate in mandatory group activities [16], and the performance gap between non-URM and URM students, such as those from low socioeconomic backgrounds, is typically closed in such courses [17]. Likewise, there is a correlation in industry that shows that the majority of URMs have a lower level of soft skills when compared to their non-URM peers [18]. Active learning increases students' soft skills due to its mandatory group work [19]. In addition, students rotate leadership roles during the activities [21], which helps avoid negative effects of stereotype threat and imposter syndrome [20].

2) Sense of Belonging. The class is designed to be smaller than the large-scale CS courses that typically have 150+ students at our institution. Limiting enrollment to around 20 helps students feel closer to the peers in this course and get a chance to know them better. The small group discussions and activities ensure the students interact with one another. Moreover, every student gets a chance to integrate themselves into their FOSS project's community. These activities give students an academic, social, and professional community.

3) Finding a Role Model or Mentor. A key difference between this course and traditional CS courses is the opportunity to find a role model or mentor. Instead of just choosing and implementing one large new feature for the project and submitting a pull request at the end of the semester, students are expected to be fully integrated with the community to explore what possible contributions they can make. For a FOSS project, the project's community is an important factor that influences its growth and development. Thus, every student is expected to regularly communicate with a mentor and the overall FOSS community. They will be exposed to more people and the mentor can help them find successful professional role models.

4) Increased Confidence. Increasing confidence can negate the negative effects of stereotype threat and imposter syndrome. Previous graduate courses surveyed their students after they contributed to FOSS projects for a semester and there was significant increase in the students' confidence in their technical skills [22]. In addition, students' confidence can increase when they have the chance to provide their own input and ideas, help their peers, and receive validation for their work. The discussions and activities allow all students to share their views and feel valued while the projects will, ideally, accept and merge the students' contributions. These small steps show them that they are closer to being recognized as a "real world" programmer.

5) Real World Experience and Impact. Real world experience can counter the misconception people have about CS. The course project provides an opportunity for students to experience contributing to a project with a team of professionals. In addition, there are guest speakers who speak about their expertise and how it helped their successful FOSS projects. Moreover, topics in the syllabus cover not only technical knowledge, but also essential soft skills and legal knowledge that developers need. Last, students who contribute to Humanitarian FOSS projects understand the potential for social good that can come from the field of CS.

[1] The course website is available at http://www.seas.upenn.edu/~cdmurphy/foss and a more complete syllabus can be found at http://foss2serve.org/index.php/FOSS_Course,_UPenn,_Murphy

IV. Results

To date, 54 undergraduate students have completed the course across five offerings (the first author was a student in the course during its most recent offering; the second author is the course instructor) and have made contributions to 33 different FOSS projects, including MongoDB, Mozilla Firefox and Servo, and OpenMRS.

Although the number of students is small, the diversity numbers are encouraging: 43% of the students who took the course are women, 4% are African-American, and 7% self-identify as members of the LGBT community. All of these numbers are higher than the percentages in our department overall. Among members of those URM groups, the end-of-semester feedback was very positive, demonstrating that the course was meeting its goals:

- "I gained confidence in talking to people who I have never met in person."
- "I feel more confident about contributing to more open source projects in the future."
- "This course satisfied my confidence that I am indeed a programmer and computer scientist."
- "The process of working with a large code base, navigating it and adding to it, and having an active dialog with people who spend much more time working with it have immeasurably boosted my confidence and informed my ability as to how exactly I as a computer scientist am contributing not just to existing projects, but the tech world at large."
- "Open source gave us the group of friends we never had."

V. Conclusion

Although stereotype threat, impostor syndrome, and misconceptions about the field of computing can have a negative effect on diversity, our experience in teaching a course on open source software development has shown that it can increase representation and improve URM students' confidence.

As part of future work, we intend to do a longitudinal study to determine the long-term effects of the course on the students who take it, and to measure its overall effects on representation within our department. Additionally, since the course is currently targeted at upper-level undergraduates, future work could evaluate whether such a course targeted at introductory-level students would also be effective, thus increasing the number of URM students who enter the field of computing.

Acknowledgment

We would like to thank Heidi Ellis, Gregory Hislop, Stoney Jackson, Darci Burdge, Lori Postner, and other members of the foss2serve team for their encouragement and for allowing us to participate in the POSSE series. We would also like to thank Jay Borenstein and the Facebook Open Academy program for starting us in this direction, and all the FOSS project mentors who supported our students.

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Including Disability in Diversity

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***Abstract*— For over a decade, AccessComputing has worked to increase the participation of people with disabilities in computing fields. A key component of this work is to influence institutional change in educational institutions, computing organizations, government labs, and industry companies. This paper considers lessons learned in working with these partners in ensuring that disability is included in larger conversations around diversity.**

Keywords—disability, broadening participation, institutional change

I. Introduction

For over a decade, *AccessComputing* has worked to increase the participation of people with disabilities in computing fields. Through National Science Foundation (NSF) funding, *AccessComputing* has helped students with disabilities successfully pursue degrees and employment in computing fields and worked to increase the capacity of postsecondary institutions, employers, and other organizations to fully include individuals with disabilities in computing education and careers. We've previously documented lessons learned in engaging computing students with disabilities [1]. This article considers lessons AccessComputing has learned in work with organizations including educational institutions, computing organizations, government labs, and industry.

Demand for computing professionals is outpacing supply. The underrepresentation of women, racial/ethnic minorities, and people with disabilities [2]–[6] contributes to the current shortage. Individuals with disabilities are less likely than their nondisabled peers to succeed in careers [5]–[8]; complete degrees [5]–[10]; and pursue science, technology, engineering, and mathematics fields [11], [12].

To be successful in a computing career, individuals with disabilities must overcome barriers imposed by inaccessible facilities, curricula, and information technology; inadequate academic supports; and lack of encouragement and role models. Students with disabilities in computing fields report issues including difficulty navigating technical interviews, inaccessible programming environments and hardware, disability disclosure in the classroom and the work environment, and additional complications related to relocation for internships or employment [1].

AccessComputing began in 2006 as a joint effort between the Allen School of Computer Science and Engineering and the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center at the University of Washington (UW) as a multi-objective national project with the goal of increasing the number and success of people with disabilities in computing fields. The objectives included direct interventions for students, institutional change for organizations, and creation and curation of resources for individuals and organizations. In the process we have engaged over fifty academic and organizational partners who share our goals and commitments. In 2015, the UW Information School joined the effort and our objectives were expanded to include promoting the teaching of accessibility and working with computing industry to help them become more equipped to recruit and retain more people with disabilities as interns and permanent employees. Evaluation results of *AccessComputing* activities suggest that computing departments, professional organizations, and employment opportunities have become more welcoming and accessible as a result of engagement with *AccessComputing* [13].

II. Impact on Educational Institutions

AccessComputing has impacted computing education both at the K-12 level and the postsecondary level. At the K-12 level, this includes development of a Web Design and Development course (WebD2) by our information technology accessibility specialist Terrill Thompson in collaboration with K-12 teachers [14]. WebD2 integrates accessibility and universal design (UD) principles and methods throughout the curriculum, thereby increasing accessibility awareness, knowledge, and skills among future computing professionals. The curriculum has been used extensively—over six thousand users worldwide have created instructor accounts and over one thousand individuals have subscribed to a discussion list created to support teachers with the curriculum.

In 2014, we received a complementary grant from NSF, *AccessCS10k* to increase the participation of students with disabilities in computing education at the K-12 level. It is

This material is based in part upon work supported by the National Science Foundation under Grant Number 1539179. 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.

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important to ensure that students with disabilities are included in the current movement to bring computing education into K-12 schools [15]. In collaboration with Andreas Stefik at the University of Nevada, Las Vegas, this project has taken a two-pronged approach. Because many popular tools used in K-12 computing are inaccessible to students who are blind or have mobility impairments, this project develops and promotes the Quorum programming language, an accessible alternative [16]. The project also provides professional development for individuals who develop trainings for K-12 teachers. This professional development includes information about accessible tools as well as information about how universal design of learning (UDL) can make a classroom more welcoming and accessible to students with a variety of disabilities [17]. Starting in 2018, through an additional grant, *AccessCSforAll*, we will hold professional development workshops for teachers of students who are blind, deaf, or have learning disabilities so that they can offer an accessible Advanced Placement Computer Science Principles (CSP) course. *AccessCSforAll* will develop an accessible CSP curriculum that employs the Quorum language and emphasizes the impact of accessible technology on society.

At the postsecondary level, *AccessComputing* works with a nationwide network of computing departments at thirty-five colleges and universities each represented by a committed individual partner. These partners engage with each other via phone meetings, online communities of practice (CoPs), and in-person capacity building institutes (CBIs) and commit to taking steps that will make computing courses, resources, programs, and/or project activities more welcoming and accessible to individuals with disabilities. Several of these partners have disabilities, others have research interests related to accessibility, and some are interested more generally in broadening participation in computing.

Through project activities, *AccessComputing* helps partners identify steps they can take to increase the participation of people with disabilities in computing. As a result, partners have recruited student team members, hosted interns with disabilities, included students with disabilities in outreach activities, and made their websites more accessible and welcoming. Several of our partner institutions, including Carnegie Mellon University, Georgia Tech, New Mexico State, and Landmark College have worked with *AccessComputing* to host CBIs at their institutions. These collaborative meetings include a variety of stakeholders and focus on actionable steps their institution can take to more fully include people with disabilities in computing fields, make resources accessible, and incorporate disability-related content in courses. In addition, *AccessComputing* has developed and disseminated a large collection of online resources that educators can use to make their courses, departments, and schools more welcoming and accessible to students with disabilities [18]. This includes publications related to UDL, accessibility of computing labs, and information technology as well as videos on related topics.

Since 2015, *AccessComputing* has been working to increase the inclusion of information related to accessibility and disability in postsecondary computing courses. Tech companies report that they need more employees with an understanding of accessibility [19], [20]. Additionally, acknowledging disability in the curriculum may serve to make computing more welcoming and accessibility to individuals with disability and other diverse backgrounds. When people with disabilities are involved with the development of technology, it can help to ensure that technology is accessible from its inception [21]. Many, though certainly not all, individuals with disabilities are interested in accessibility and may be more interested in careers in technology when exposed to this content [22], [23]. In CBIs and other presentations, we have promoted the inclusion of accessibility in computing courses and offered strategies for doing so. We have also partnered with Teach Access in a variety of activities with similar goals. Teach Access is an initiative of tech companies and educational institutions interested in expanding what undergraduates are taught about accessibility in computing fields [20]. At the UW, *AccessComputing* co-PI Andrew Ko has worked with instructors in the Information School to integrate information about accessibility into existing courses. As a result, large groups of UW undergraduates are learning about the topic. As of Fall 2017, accessibility is officially part of the curriculum in the Information School. All sections of INFO 200 (Intellectual Foundations of Informatics) now include at least one day of accessibility content in the 10-week quarter, reaching 900 students per year.

III. Impact on Organizations

In addition to postsecondary partners, *AccessComputing* also works with a network of organizational partners that include computing associations, broadening participation groups, and groups focused on disability. Through this work, we have seen several groups make changes that have had a positive effect on individuals with disabilities in computing fields. At the inception of the Center for Minorities and People with Disabilities in Information Technology (CMD-IT), *AccessComputing* PI Richard Ladner advocated for the inclusion of people with disabilities along with other underrepresented groups to be part of its mission. Ladner is a founding member of the Board of Directors of CMD-IT. For the past several years, the Tapia Celebration of Diversity in Computing has been presented by CMD-IT. Because of this and *AccessComputing*'s involvement, there has been an increased focus on disability at the event. Recent years have seen multiple keynotes from individuals with disabilities including Annie Anton of Georgia Tech, Chieko Asakawa of IBM, Shaun Kane of the University of Colorado, and Daniel Sonnenfeld of Salesforce. Disability has had an increased presence at the conference in terms of attendees and program content.

AccessComputing has impacted other conferences as well. We have worked with the Grace Hopper Celebration's Women from Underrepresented Groups committee to ensure that women with disabilities are represented in their tracks, and we send students to the conference annually. In conjunction with Jonathan Lazar from Towson University, we have worked extensively with the Association for Computing Machinery (ACM) Special Interest Group on Computer-Human Interaction (SIGCHI) to make their conference more accessible. We worked with the ACM Special Interest Group on Computer Science Education (SIGCSE) to implement an accessibility chair at their conference and presented multiple sessions in recent years related to disability.

AccessComputing plays an important role with the ACM Special Interest Group on Accessible Computing (SIGACCESS). We have supported people with disabilities attending ASSETS, their conference. Over the past ten years, the number of people with disabilities attending ASSETS has increased remarkably, with many of them being *AccessComputing* partners or student participants.

Each summer *AccessComputing* funds research experiences for undergraduates (REUs) for about five students wtih disabilities per year. Most often, these students work with faculty members at their home institutions and are not part of a larger REU site. We partner with the Computing Research Association Distributed REU (DREU) program to track and provide structure for these students. Through these REUs students with disabilities gain research experience and faculty members gain experience working with students with disabilities.

Since 2010 *AccessComputing* has worked with CMD-IT, the Computing Alliance for Hispanic-Serving Institutions (CAHSI), and the Coalition to Diversify Computing to coordinate the Academic Careers Workshop, which brings together senior graduate students and young faculty members in computing from underrepresented groups with senior mentors. Every year, students and faculty members with disabilities attend to learn about networking, grant writing, and the tenure and promotion process.

AccessComputing has worked with a variety of other computing organizations to help them include accurate information about disabilities in their own resources or to make their resources more accessible. Examples include csteachingtips.org, NCWIT (the National Center for Women in Information Technology, ncwit.org), and the ACM (acm.org).

IV. Impact on Industry

Since 2015, *AccessComputing* has begun working more directly with industry via our partnership with Teach Access mentioned above, as well as by creating strategies to increase the participation of people with disabilities in the computing workforce. We work with a network of industry partners interested in recruiting, onboarding, and retaining employees with disabilities. Partners include Lawrence Livermore National Labs, Microsoft, Salesforce, and Oath. In June of 2016, we held a CBI for our partners. Proceedings are available online [23]. Industry partners engage with *AccessComputing* staff and partners via regular telephone conferences; work towards creating a welcoming and accessible environment for interns and employees with disabilities; have access to a resume database of computing students who have disabilities for potential internships and permanent employment; and explore opportunities for *AccessComputing* students to test products for accessibility.

Interactions with industry partners have varied. Salesforce has organized recruiting events for students with disabilities and partnered with *AccessComputing* to recruit interns and employees with disabilities. We have worked closely with Microsoft and Oath on initatives related to increasing the amount of accessibility content in the computing curriculum, such as designing and holding a workshop for faculty at the UW. Teach Access has replicated this workshop in other settings.

V. Lessons Learned

Based on our experiences with *AccessComputing*, we offer the following lessons learned:

Disability is a part of diversity. People with disabilities encounter many of the same barriers as other underrepresented groups, including women and racial and ethnic minorities. Including disability in diversity conversations enriches our understanding of broadening participation.

Meet partners and collaborators where they are. Different partners and collaborators have different needs, which means that we engage with each of our partners differently. Determining what a partner might be interested in doing and working with them on that can lead to effective change rather than approaching all partners in a cookie cutter approach.

Develop a strong infrastructure to expand your impact. The administrative and staffing infrastructure that the DO-IT Center has developed has allowed us to apply for related grants, namely *AccessCSforAll* and *AccessEngineering*, to expand our impact on the representation of people with disabilities in K-12 computing and engineering, respectively.

Be persistent. Some organizations can be slow to change and require continued effort. Once change has been made, persistence is necessary to ensure that organizations don’t revert, particularly as leadership changes.

Adapt to stakeholder shifts over time. Over time, we have added new partners to our network, allowing us to reach new schools and organizations and expand our work into industry. In addition, we’ve seen individual partners increase or decrease their involvement based on myriad factors. Regardless, the overall work and efforts to change move forward.

Leverage existing networks. Many of our partners were existing contacts within our PIs’ networks, including collaborators, students, and others who work in similar research areas. Many of them joined our efforts because of these existing relationships.

Engage diverse communities to promote change. Within our project, we work with computer scientists, social scientists, industry engineers, disability service professionals, and others. This diversity allows participants to learn from one another and leads to rich conversations and change.

Build community through different interactions. We engage with partners at our CBIs, at national conferences, in phone meetings, and via our CoPs. Each interaction is a chance to build community, have conversation, and find ways to collaborate and make change. Different partners are more active in different arenas depending on their own preferences.

AccessComputing has also learned from challenges that we have encountered.

Be mindful of small numbers. When we formed targeted CoPs that included individuals interested in specific disabilities, we found that the communities never took off. The groups were small and segmented our community too much. Our CoPs have been more effective with a larger yet more diverse group.

Engaging in a common activity with diverse partners may be difficult. We hoped to engage with our university partners to collect data on students with disabilities on their campus. Not all partners wanted to participate. Others were unable to obtain the data. Data that we did obtain varied across institutions.

Take time to learn about new groups. We have tried to engage with veterans with disabilities over time with mixed results. Many veterans have disabilities related to their service and yet many veterans are reticent to identify as an individual with a disability. Learning more about military culture has been critical to engaging with veterans.

Over the last decade, *AccessComputing* has been changing the conversation about diversity in computing by working to ensure that disability is included through our work with a variety of stakeholders including individuals with disabilities, educators, computing organizations, and industry. We look forward to continuing to do this work and seeing disability become a more prominent part of the conversation about broadening participation in computing.

We encourage others who are interested in increasing the participation of individuals with disabilities in computing to get involved. Faculty members can refer computing students with disabilities, join our online mentoring community as a mentor, or host an intern in their lab. Educators can find ways to make change within their departments by becoming a partner, joining one of our online CoPs to engage in online conversations, including information about accessibility in their courses, and utilizing our online resources to find ways to make their departments and schools more welcoming and accessible to individuals with disabilities. Industry professionals can also become partners and utilize our resume database of students with disabilities in computing to recruit interns and employees to their organizations.

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The Challenges of Tracking and Understanding Student Retention in the CS Major

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***Abstract*—This panel focuses on the challenges of collecting sufficient and reliable data relating to retention challenges in undergraduate computer science education programs. The panelists will explore different perspectives on the retention of women in undergraduate computing, their challenges in collecting and analyzing student data, and what they have learned from their efforts to date.**

***Keywords*—retention, computer science education, undergraduate programs**

I. Introduction

Retention of women (and students from other underrepresented groups) in higher education computer science programs remains a challenge. Despite high profile success stories at colleges like Harvey Mudd College and Carnegie Mellon University [1,2] the percentage of women at most colleges and universities remains around 18% [3]. While it appears that the pipeline is leakiest after CS1, in reality most schools have little information about the intentions of their students coming into these classes and whether or not they intend to continue.

Much retention work assumes that there is a universal set of retention issues in computing. On the contrary, students in different contexts with different backgrounds likely have vastly different reasons for staying or leaving the discipline. Truly understanding students, their intentions, and their trajectories is the first step in closing the leaky pipeline. Different institutions also experience different barriers, different students, and different sticking points.

In 2017, the ACM Education Board convened a committee of educators from different institutions of higher education to examine pipeline barriers leading to low participation of women in computer science. This committee has worked for nearly a year to gather persistence data for women and men in computer science programs in colleges and universities across the United States. In this panel, committee members will articulate the challenges to understanding students' motivations and trajectories in a variety of contexts. These panelists will provide different viewpoints on:

- Different notions of "retention" in different contexts.
- Different types of data available for tracking and understanding students' goals and motivations.
- Challenges of data collection specific to each institution, and for creating a unified data set to help us understand student retention across institutions.
- Insight that has been gained from initial data analysis at different institutions and across institutions.

II. Panelists

A. *Chris Stephenson: Head of Computer Science Education Strategy, Google*

Chris Stephenson works with internal Google teams and external computer science organizations globally to improve computer science teaching and learning. Stephenson has served on a number of computer science education bodies and currently co-chairs the ACM Retention Committee and is a member of the ACM Education Committee. Stephenson believes that successful interventions to current retention challenges must be data-driven and that the community will benefit signficantly from increased sharing regarding successes and failures as institutions grapple with the complexities of retention data collection and analysis.

B. *Lecia Barker: Associate Professor, Department of Information Science, University of Colorado and Senior Research Scientist, NCWIT*

Lecia Barker will talk about the challenges in studying retention with a heterogeneous data set, the NCWIT Tracking Tool. The NCWIT Tracking Tool allows departments to enter data related to students' entry into the major, retention in the major, and graduation, all broken down by race/ethnicity, gender, student level, and transfers. As of late 2017, about 175 departments of computer science, computer engineering, and

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cognates have submitted several years of data. It can be used to study retention, but its extreme heterogeneity poses a challenge. The data collected on different campuses also varies a great deal. Lecia will discuss this and other sources of variation during the panel.

C. *Mehran Sahami: Professor (Teaching) Computer Science Department, Stanford University*

Mehran Sahami works at the crossroads of computer science education, data analytics, and machine learning. He has been involved in numerous educational projects including co-chairing the ACM Education Board and serving as co-chair of the ACM/IEEE-CS joint task force on Computer Science Curricula 2013 (CS2013). Mehran has also worked on building statistical models to aid in the analysis and understanding of educational data. For example, he has built models analyzing gender dynamics in CS programs as well as created models of student performance in introductory courses to understand population dynamics in the face of significant enrollment increases.

D. *Elsa Villa, Research Assistant Professor, College of Education, The University of Texas at El Paso*

Elsa Villa directs the Center for Education Research and Policy Studies at UTEP, having taught at numerous levels: grades 7 through12, community college, and university in the disciplines of mathematics, science, education, engineering, and computer science. Villa led a NSF-funded qualitative study investigating identity and agency in undergraduate Latina students. Since 1994, Villa has led and co-led numerous STEM grants from corporate foundations and state and federal agencies. Villa brings critical minority institution and minority student perspectives to the panel, providing valuable insight into the hurdles Latinas face in computer science and engineering undergraduate studies.

E. *Stuart Zweben, Professor Emeritus, The Ohio State University*

Stu Zweben coauthors the annual reports of the CRA Taulbee Survey of doctoral-granting departments in the CS, CE and Information areas, and the ACM NDC Study of non-doctoral-granting departments in computing. His many years of experience doing these surveys, his recent work with the CRA Generation-CS Report on the current enrollment surge in computer science, and his more than a decade in academic administrative positions at a large public university, give him an understanding of the type of data that realistically can be obtained from most academic departments. Stu also has familiarity with data about retention that have been collected by NCWIT and ASEE, and coauthored a study of IPEDS and other data concerning the representation of women in academic computing programs over the past two decades.

III. Panel Structure

Panelists from the ACM Retention Committee will report on their efforts to collect and analyze retention data. The panel content will be structured as follows:

- 15 minutes: Panel overview, panelist introductions, flow of majors at each panelist's institution
- 20-25 minutes: Panel moderator seeds discussion with some or all of the following questions:
  - What are the major barriers to data collection at your institution?
  - What kinds of data are easy to collect and what are harder?
  - How do you address these challenges?
  - What retention strategies or projects have you started based on the results of data collection and analysis.
  - What novel approaches have you used to collect data?
- 10-15 minutes: Questions and audience discussion.

IV. Conclusion

Sucessful interventions to improve the retention of women and underrepresented minority students in undergraduate computer science programs require a better understanding of the extent and the nature of the problem at many different kinds of institutions. This panel will provide the audience with a better understanding of the complexities of data collection and analysis across a smapling of universities and provide practical suggestions on the kinds of data that can and cannot be successfully colected, how factors such as intention to major complicate efforts to understand retention, and how data-supported interventions can help to successfully address retention challenges.

Acknowledgements

The panelists wish to thank ACM and the remaining members of the ACM Retention Committee: Alison Derbenwich Miller (co-chair), Christine Alvarado, Valerie Barr, Tracy Camp, Erin Mindell Cannon, Carol Frieze, Colleen Lewis, Lee Limbird, Debra Richardson, and Henry Walker.

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Culturally Relevant CS Pedagogy - Theory & Practice

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***Abstract*— In order to increase the number of students attracted to the field of computer science and to retain the students currently in the pipeline, emphasis must be placed on what students are taught, how they are taught and the environment in which they are taught. Traditional computer science pedagogy has been unsuccessful in attracting, engaging, instructing, and retaining underrepresented students. Culturally relevant pedagogy can be leveraged to instruct a diverse range of computer science students. Culturally relevant pedagogical practices were introduced at Howard University and have had a positive impact. Since starting this initiative five years ago, we have seen an increase in internal and external transfer students (currently 17% of the department), the retention for the department has increased to 94% for underclassmen and we have seen an increase in the number of underclassmen passing the first three classes in the department's sequence. We discuss the theory behind the changes that have been made, what has been done, and the results.**

***Index Terms*- Culturally relevant pedagogy, Departmental change, Retention**

I. Introduction

Retention and attrition rates have fluctuated in computer science [1]. These fluctuations can be attributed to, shortcomings of the students, pedagogical and engagement issues, administrative issues [2], a lack of a sense of belonging and community [3], a lack of prior computer science exposure, and a lack of understanding of course content [3]. These problems have led to entry, engagement, retention, and graduation issues in university computer science departments across the country [1][3][4]. Culturally relevant pedagogy can address these problems. This paper discusses the theory of culturally relevant pedagogy and how it has been implemented at a Historically Black College and University (HBCU).

II. PEDAGOGY

Culturally relevant pedagogy is the use of good teaching practices [5] to create a supportive learning environment that builds on prior experiences, knowledge, and perceptions that students possess [12][14]. Culturally relevant pedagogy should address students' achievement by responding to structural inequities [5] that have negative impacts on underrepresented students' academic performance. It should be noted that underrepresentation does not refer solely to race or gender. It could also refer to, but is not limited to, age, socioeconomic status, lack of prior exposure to content or lack of exposure to the field.

Culturally relevant pedagogy is grounded in research on meaningful learning. Meaningful learning suggests that building on prior experiences, knowledge, and perceptions that students possess leads to long-term learning [6]. It enables the student to make deeper, more thorough, connections between information that they possess and new information. This makes it easier for the student to retrieve and transfer knowledge about that information into new situations [6]. Meaningful learning is more engaging because students have a reference point upon which to construct new information.

Culturally relevant pedagogy requires faculty to diagnose the classroom learning environment and not the students [7]. Information about the culture of the students may help inform the delivery of content and participant structures but the response of the students to the pedagogical approach should ultimately determine the approach used. Howard [8] suggests the following principles for culturally relevant teaching: 1. Students are affirmed in their cultural connections; 2. Teachers are personally inviting; 3. The classroom is physically and culturally inviting; 4. Students are reinforced for academic development; 5. Instructional changes are made to accommodate differences; 6. The classroom is managed with a firm, consistent, loving control; 7. Interactions stress collectivity as well as individuality.

A. Theoretical Framework

Culturally relevant pedagogy is grounded in Social Cognitive Theory which identifies the influence of behavioral and environmental factors on an individual's personal factors. Personal factors include the personality, self-efficacy, and motivation of the learner. Environmental factors refer to social and physical cues in the environment. Social Cognitive Theory states that social interactions act as response-consequence contingencies that help to model

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appropriate behavior, beliefs, and attitudes [6]. When members of a community observe others performing a behavior and the consequences of that behavior; they use this information to inform their mental model and subsequent behaviors. As individual members of the community change and exhibit new behaviors, other members of the community are influenced by their change.

B. *Misconceptions and misuse*

Some of the misconceptions about culturally relevant pedagogy include 1. Only teachers of color can be culturally relevant; 2. It is only appropriate for underrepresented students; 3. Caring compromises a teacher's ability to manage classrooms effectively; 4. It is meant solely to build students self-efficacy; 5. It should cater to the kinesthetic need of students; 6. It requires teachers to understand all details of a student's culture [9]. Generalizations have been shown to weaken pedagogical approaches by causing stereotypes that impede learning [7] and can even lead to discrimination [10]. Misused attempts at culturally relevant pedagogy can lead to awkward classroom moments, ineffective instructional practices and counterproductive professor-student relationships [7].

C. *Culturally relevant curricula*

Gay [11] notes that there are three kinds of curricula present in the learning environment, formal plans for instruction, symbolic curriculum, and societal curriculum. Formal plans in computer science (CS) are those curricula that guide accreditation. Symbolic curriculum are the "… images, symbols, icons, mottoes, awards, celebrations and other artifacts that are used to teach students knowledge, skills, morals and values" [11]. Societal curriculum are the portrayal of groups in mass media. Each of these curricula has psychological effects on students which can enhance or affect their academic performance. Structural inequities that impact underrepresented students' performance in computer science can exist in the symbolic and societal curriculum and be categorized into social, psychological and physical threats to belonging.

Social threats to belonging are group social identities that do not coincide with a student's individual self-concept or their perception of their social identity. Social, psychological, and environmental cues that an individual does not identify with or those that threaten their current perception of their social identity, self-worth and self-concept negatively affect their ability to belong. Social identities that impact CS belonging can be tied, but are not limited to, gender, race, programming aptitude, and commonly perceived CS subcultures (technophiles, science fiction/fantasy fandom and geeks/nerds). Computer scientists are stereotypically portrayed as socially awkward, unattractive, geeky, boring, sedentary, isolated, Caucasian, male, programmers who write code that have no relevant application to everyday people with regular lives [12][13][14]. Many of these misconceptions are fueled by stereotypical portrayals in media [15].

Psychological threats to belonging are influenced by an individual's mental models and their psychological processes. Whether genuine or perceived, these psychological threats can negatively affect an individual's performance [16]. These threats can manifest as lowered self-efficacy, stereotype threats [17] and impostor syndrome [18], which have all been shown to impact academic performance [16]. Culturally relevant pedagogy is culturally validating and affirming and signals to a student that they belong [11].

A department's learning environment consists of the "… physical surroundings, psychosocial or emotional conditions, and social or cultural influences" present [19]. Each of these environmental factors plays a role in influencing a student's sense of belonging. Research in CS [20] has shown that artifacts in the environment that reinforce the male, science fiction stereotype can lead female students to feel a sense of "belonging uncertainty" and stereotype threat. Research also shows that, CS classrooms are defensive [19][21], the field can be isolating [4][22] and the field lacks diversity [23]. It is important that departments ensure that their classroom climates are conducive to learning and encourage students to bring their social capital to the table when discussing concepts.

Departments must address cultural relevance by making a conscientious effort to diversify artifacts that are displayed in the learning environment and sending the message that they value diversity and community. Diversity efforts should represent, a wide range of ages, communication styles, races, both genders, diversity of achievements, diversity of values, the diversity of areas of study in the field and solutions to problems that impact a diverse range of socioeconomic and underrepresented groups [11][14]. Artifacts representing the field should come from traditionally accepted core specializations as well as emerging specialization that encourages human interaction (Human-Centered Computing, Human-Computer Interaction and CS Education). Faculty/Lecturers need to diversify their repertoire of examples by allowing students to inform their content. Building community among diverse learners helps students to expand their mental models of people and the world and allows them to be more informed when making decisions [11].

III. METHODOLOGY

This section describes Howard University's approach to culturally relevant pedagogy from the perspective of formal and symbolic curriculum change. The methods described in this section were implemented over a span of five years.

A. *Formal Curriculum: Introduction to Computer Science*

In order to address attrition at the introductory level, discussions were held with students, alumni, and industry partners. One of the major findings of this initiative was that the department's curriculum focused too much on technical content without tying it to real-world applications. Our introductory class was originally taught in C++ and covered the fundamentals of programming (primitive data types, two-dimensional arrays, logical operators, program flow control, testing and debugging). Assignments were not scaffolded and the emphasis was on implementing code and solving “mind-numbing problems”. Students expressed a lack of satisfaction “writing code whose results appeared in black screens.” There was not enough emphasis on computational thinking and the relationship between what the students were doing and possible impact on the real world. Industry and alumni feedback informed us that we needed to incorporate more computational and algorithmic thinking as well as cover more breadth in the class. In order to achieve this, we partnered with Google to develop curriculum that would engage and better prepare the students.

In 2012, a revised introductory class was introduced. The new class was co-taught in Python by university faculty and a Google Software Engineer (Googler In Residence (GIR)). The GIR was provided to the university for one academic year to help introduce real-world problems to the introductory class as well as to upper-level classes. The decision was made to change from C++ to Python because of reduced setup and installation on students’ personal computers, the syntax of the language is more intuitive and it has more functionality and high-level data types natively. Python also has a relatively easy to use image manipulation library. The new class curriculum was made more culturally relevant and emphasized computational and algorithmic thinking. It covered primitive data types, logical operators, program flow control, testing and debugging primitives, lists, queues, stacks, tuples, dictionaries, graphs, and Software Version control (GitHub). The content of the class was put into the context of students’ everyday experiences and student interaction and input was emphasized. Assignments were scaffolded to include visual elements. The class went from a lecture format to one of facilitation. The first few weeks of the class now focuses on computational thinking.

To introduce programming concepts we use Blockly Games’ Maze and Turtle. For advanced students who finish these activities quickly, we introduce them to Light-Bot which incorporates the concept of recursion. Those who have prior programming experience have little advantage because these activities focus on computational thinking without the stress of having to worry about syntax. We have also incorporated content such as CS Unplugged’s “The Muddy City” activity which allows students to engage in productive struggle to figure out an algorithm for optimization of a minimal spanning tree. Activities such as this show how CS theory is applied to real-life situations. It also builds student self-efficacy because they later see their solution formally in Prim-Dijkstra’s and Kruskal’s algorithm. Once they have seen the Muddy City example we connect this theoretical application of graph theory to real-life examples where graph theory can be applied. One such example is the Washington Metropolitan Area Transit Authority’s (WMATA) rail map seen in Figure 1 below. The students can intuitively see each metro station as a node and the tracks between stations as the edges. If the same theory were being taught in a rural area it would be more culturally relevant to use the road network or some other system that the students can relate to.

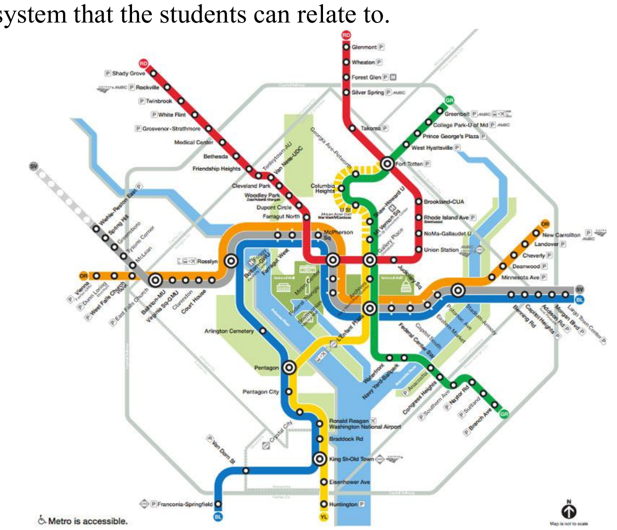

Figure 1: Showing the map of the Washington DC Metro System[1].

As students get accustomed to thinking algorithmically and computationally, we move into programming with Python. The lecture slides cater to global learners as well as sequential learners. The first few slides on any topic give a holistic overview of the content and are then followed by scaffolded implementations of concepts with questions and answers. In the lab, the first few slides are sufficient for the students who have had programming experience or are global learners, to skip ahead to the questions. For those who are new, the subsequent scaffolded content allows them to jump around to build their understanding. For visual learners, we incorporate the use of a python visualizer [24]. At the beginning of class, we leave five to ten minutes for students to ask questions and discuss the resources that they found useful in understanding a concept. We also create a shared document where students post resources for each of the topics of the class.

An example of successfully using culturally relevant pedagogy while teaching is using the concept of a searching a guest list in order to teach the students about binary search. Initially, the students are given an unordered list of names and asked to find specific names. Then they are asked what can be done to make finding the names easier. All students agree that sorting the names would make it easier. Students are then presented sorted lists of differing lengths and again asked to find names. Each time they choose a starting point for their search we ask them what page and line they chose and the reason for it and how it can be more effecient. Going through this process they eventually come up with an algorithm that is similar to

[1] 2017 Washington Metropolitan Area Transit Authority Rail Map: https://www.wmata.com/schedules/maps/upload/2017-System-Map.pdf

binary search. Binary search is then formally presented. This approach makes the explanation of algorithm and its complexity less intimidating because students have seen the algorithm in action and have an intuitive understanding of how time changes as the list size increases. This approach allows students to build upon real-life experiences that they have had and see how it applies to computer science.

It should, however, be noted that attempts at cultural relevance can sometimes not go as expected. During the second year of the class all of the questions on the final exam were created around characters in the movie Avengers. The assumption was that this would make the exam 'fun' and engaging. The questions asked during and after the exam made the instructor realize three things: 1) Not everyone was familiar with the characters; 2) The questions elicited stereotype threat; 3) Questions affected students' sense of belonging. Below is a sample of an Avenger centered question and how it was revised.

Avenger sample question

Heimdall is the guardian of the Bifrost, and part of his job is to help people travel between the Nine Realms. You know Thor and his buddies have been doing a lot of realm-hopping...and Odin is getting annoyed. He wants to know which of his subjects has traveled between realms the most.

Write a function called BifrostAbuser that takes in one parameter, a list of tuples. Each tuple contains two items: the Asgardian's name and the number of times he or she has used the Bifrost. Your function should return the name of the Asgardian who has used the Bifrost the most.

Example:

```
bifrost_usage = [
   ('Fandral', 2), ('Hogun', 2), ('Sif', 5), ('Thor', 8),
    ('Volstagg', 2)
]

BifrostAbuser(bifrost_usage) => 'Thor'
```

Revised sample question.

Write a function called classAward that takes in one parameter, a list of tuples. Each tuple contains two items: a student's name and his/her total absences. Your function should return the name of the person with the lowest absences concatenated with a message. Assume the list is sorted by class average. If two people have the same amount of absences, the person who appeared first in the list wins the award.

Example:

```
studentAbsence = [
        ("Tyrone", 2), ("Tiffany", 0), ("George", 1),
        ("Lakeisha", 3), ("Vanessa", 5), ("Carlos", 0)
]
classAward(studentAbsence) => "Tiffany will receive a tablet for her excellent attendance in CS0"
```

The revised question did not elicit stereotype threat or threaten students' sense of belonging because the stereotype of CS majors as sci-fi geeks was removed. Most students could relate to the context of the question, because it was a task that they could realistically see themselves performing.

B. Symbolic Curriculum: Departmental Perspective

In order to improve the symbolic curriculum of our department, we have continually been doing an analysis of what the department values and what the environment communicates that we value. We have recognized that there are few artifacts in the environment that suggest what we value. This section discusses some of the areas that we recognize a need for improvement.

We have recognized a need to foster inclusivity and diversity. At the College level, there are many organizations formed to support women and African Americans (NCWIT[2], CRA-W[3], ACM-W[4], Anita Borg Institute[5] iAAMCS[6]) in CS. Our department has no relationship with any of the aforementioned organizations. We also realized that students were only recognized for academic achievement by the department and the college. In order to recognize students who contribute to the department outside of the classroom, we have created an annual BIT (Bison Innovation and Talent) award that recognizes innovation, technological achievements as well as membership in the discipline. Awards for membership in the discipline include recognition for mentoring, student leadership, activities that improve the sense of community, as well as social and technical professional development. Previous winners of the awards as well as other diverse achievements are given 'Spotlights' in the forms of posters and recognition in the weekly department emails.

In order to allow students to harness their diversity of thought and experience, we have designed and implemented two sequence courses in innovation and entrepreneurship that provide unique experiential learning opportunities that can be taken by students in their freshman year onward. These courses enable students to make deeper, more thorough connections between the theory that they possess and actual application while developing and launching a real product based on the Lean LaunchPad methodology [25].

In order to address shortcomings in our societal curriculum, we have begun creating media spotlighting students, alumni and underrepresented members of the CS community, and our industry partners who are diverse role models. Diversity includes but is not limited to ethnicity, gender, age, career paths and fields of work. We have begun developing mentorship chains and vertically integrated projects [26] where faculty will mentor graduate

[2] The National Center for Women & Information Technology: https://www.ncwit.org

[3] The Computer Research Association's Committee on the Status of Women in Computing Research: http://www.cra-w.org/

[4] ACM's Women in Computing: http://women.acm.org/

[5] Anita Borg Institute: http://anitaborg.org/

[6] Inst. for African-American Mentoring in Computing Sciences: http://www.hcc.cs.clemson.edu/~iAAMCS

students, and graduate students mentor upperclassmen, who in turn mentor underclassmen. We are actively seeking out partnerships with organizations where our students can be mentored or have a mentoring role.

In order to address social and psychological threats to belonging we have been working on increasing, awareness, our department's community interaction and creating physical spaces that promote interaction and community. We have partnered with industry partners to have events that go beyond traditional technical workshops and professional development. An example of this is a well-received workshop held by an industry partner that explores Impostor Syndrome.

IV. Results

Since the inception of the altered introductory class and the departmental initiative, we have seen a steady influx of internal transfers from other majors who have taken the introductory course. Of the CS students enrolled in the academic year 2015-2016, 17% comprised non-majors who have switched over after taking the introductory course. The registrar's office has also reported a program retention rate of 94 percent in the academic year 2015-2016, up from 74% in academic year 2014-205 and 66% percent in the academic year 2013-2014. We are still awaiting retention rates for the academic year 2016-2017. The pass rate for the subsequent courses in the curriculum, a C or better, has also increased from approximately 65% (2012-2013) prior to the change to 78% in the second course in the scheme and 87% percent in the third course in the scheme as of 2015-2016 academic year.

V. Conclusion

Culturally relevant pedagogical changes in our department have led to an increased retention of incoming students. Seventeen percent of our enrollment is due to students who transfer into our department after taking the introductory course and enjoying the experience. We have seen interest from other areas of engineering to find out how they can also create culturally relevant curriculum. Going-forward, we seek continuous improvement of our curriculum and look for ways to engage the larger CS community in helping to improve the experience of our students.

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Speaking Truth to Power: Exploring the Intersectional Experiences of Black Women in Computing

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***Abstract*—** This paper examines the narratives of 11 Black women in Computer Science (CS) to explore and understand their intersectional experiences (academic, professional, familial, etc.) in the field of Computing. We video-recorded the participants as they engaged in semi-structured interviews to explore and understand their experiences as Black women in Computing. Four coders engaged in content analysis on the video-recordings as well as transcripts of the video data in two rounds. Overall, our analysis revealed that the women in our study experienced discrimination, expectations from others that are too high or too low, isolation, sexism, and racism; yet they still choose to stay in the discipline. Remaining true to their personal and professional goals, having effective mentors, and inspiration from their fathers all contributed to their successful pathways and strategies of resistance.

Keywords—intersectionality, computer science, computing, black women

I. Introduction

On January 30, 2016, President Barack Obama unveiled an exciting new initiative, Computer Science For All, that would engage all U.S. students, K-12, to not only learn CS, but to also acquire and develop the computational thinking and problem-solving skills and capabilities to move from being solely consumers of technology to also becoming producers of technology [24]. The initiative called for providing $4 billion in funding for states to increase access to CS in K-12 through teacher training, curriculum development, and partnerships with $100 million provided directly for districts; over $135 million in investments over five years by the National Science Foundation (NSF) and the Corporation for National and Community Service (CNCS) to support and train CS teachers; and a call to action for state and city leaders, educators, philanthropists, creative media and technology professions, and others to get involved in supporting this initiative [24].

This announcement situates itself in the midst of a challenge that the U.S. has faced for decades in terms of who has access to CS education and computing- and technology-focused opportunities. The U.S. Census Bureau projects that by 2044, more than 50% of the population of the United States will be made up of people of color with no one race or ethnic group holding a majority [6]. At the same time, the U.S. anticipates significant job growth in the fields of Science, Technology, Engineering, Mathematics, and Computing (STEM+C). Although blacks make up about 13% of the U.S. population, the representation of Blacks in Computer Science is significantly low in all sectors. When looking specifically at Black women in CS, they comprise only 3% of all of the Bachelor's degrees awarded in CS in the United States [27], despite 2016 resulting in the highest number of Bachelor's degrees awarded in CS in the U.S. to women overall since 2002-2003 [27].

Examples of the significantly low representation of Blacks in CS range from the continually low numbers of blacks who choose CS as a major and receive Bachelor's degrees in CS in the U.S. [25, 26] to the start and sustained lack of diversity in the high-tech workforce, especially in Silicon Valley [25, 21, 16] with "unfairness-related turnover" costing the high-tech industry over $16 billion [16]. This trend is perpetuated, in part, by a false narrative of Computing being color blind and meritocratic, where the success of individuals is almost exclusively based on ability and talent. This notion of Computing being color blind and meritocratic suggests a level playing field as well as the notion of who is and is not "CS material" [14]. These false notions of a level playing field coupled with notions around who is or is not "CS material" often result in interventions where: a) the emphasis is on "fixing" the perceived deficiencies or characteristics that exist among groups who are under-represented in the field or b) the emphases is on helping them adapt to the "chilly" and often uninviting climates of Computing. The emphasis of these types of interventions often occurs in the absence of *also* fixing the institutional and organizational structures, behaviors, and culture that create and support those barriers and from which those challenges for women of color manifest. The lack of diversity in the high-tech workforce is also perpetuated, in part, by a lack of transparency around issues of diversity acquisition and retention [16] as well as by the history of racial and gender

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discrimination in the US, implicit biases and assumptions that a different look, path into or path through CS equates to deficiencies in CS that cannot be supported or addressed [17].

Without acknowledging the role of these factors, it can be easy to dismiss Black women's experiences that run counter to the dominant color blind, meritocratic narrative as anomalies. Additionally, a lack of acknowledgement and action can also lead to certain behaviors that result in marginalized groups acting in ways that appear beneficial from a professional, health, and mind/wellness perspective, but that can result in negative outcomes. For example, Black women often describe the energy required to constantly think about and monitor their actions to address stereotypes typically associated with blacks or women or being unsure whether an act of discrimination occurred because of race or gender and worrying about how to proceed [12]. Black women often enact performative identities [5] because of these stereotypes as well as trying to fit the mold of what the field says is required to be successful.

Efforts to increase the participation of minorities in computing – and by extension, black women, range from in-school efforts, such as CODE 2040 and Facebook's newly created TechPrep program, to career programs such as Intel's Diversity in Technology initiative. These interventions seek to promote, teach, and/or train black women throughout the pipeline. However, in spite of these efforts, as with STEM, the needle has barely moved on black women choosing CS as a major, and ultimately, graduating with a Bachelor's Degree in CS or pursuing computing careers [26, 27]. A review of the literature in broadening participation research in CS, and in STEM more broadly reveals that, while substantial research is being conducted focused on students of color (including black students) in CS, and women in CS, there has largely been little regards for the unique intersection of gender and race experienced by black women, described as the "double bind" [18, 19] and later, Intersectionality [9, 3, 4].

Computing has an opportunity to lead the way in challenging and addressing, head on, many of the challenges that women of color in computing currently face that often attempt to render us, as Dr. Lindsey Malcom (now Malcom-Piquex), and Dr. Shirley Malcolm have said "at once highly visible and invisible" [18, 19]. This simultaneous visibility, especially as it relates to our representation in CS, and invisibility within the field result in women of color having what Dr. Patricia Hill Collins calls a "curious outsider-within social location" that gives us a distinctive perspective onto and into the field [15]. These perspectives are critical to engage and learn from if the mission of making CS truly For All will be achieved.

There is a dearth of research that focuses on the double bind and other intersections that exist within the field that have and will continue to influence the impact of efforts to broaden participation in computing if they are not identified, understood, and addressed. What is needed is a more complex understanding of the experiences of marginalized groups in computing who live at various intersections of racism, sexism, classism, xenophobia, heterosexism, ableism, etc., an area of research we call ***Intersectional Computing***. As such, this study examines the narratives of 11 Black women in different computing contexts, such as the workforce, graduate school, government, and academia (professors). Their stories demonstrate counter-narratives to the perceived shared understandings of computing as a meritocratic level playing field that only requires addressing access to computing to successfully broaden participation. This study also contributes to the field because it will use intersectionality frameworks—Black Feminist and Standpoint theories to illuminate black women's experiences with power, oppression, and identity politics.

In this paper, we explore the following research questions:

1. What are the experiences (professional, academic, personal, familial, etc.) of black women in Computing?
2. What do these experiences tell us about their intersectional identities, systems of oppression, and forms of agency?

II. BACKGROUND

A. *Intersectionality*

Collins & Bilge [14] 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 [13], 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 [14]. 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. For example, Black women are, simultaneously, Black and female. 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" [14]. Although the term *Intersectionality* was coined by Kimberle Crenshaw [8, 9] 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 18th century [14].

Collins & Bilge [14] point out that the organization of power in our society can be examined through four distinctive lenses, including interpersonal, disciplinary, cultural, and structural. Interpersonal power helps us think about interactions between people and who is advantaged or disadvantaged within social interactions. Disciplinary power illuminates the ways people discipline themselves that puts them on paths that make some options viable and others out of reach. How messages about fairness of outcomes get communicated speaks to cultural power and finally, structural power highlights the discourse for ways intersecting power relations of class, gender, race, and nation, shape the institutionalization and organization of our various social institutions and policies. 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. [14], suggesting single-axes analyses (i.e., race or gender) as insufficient.

B. Black Feminist Thought

Black Feminist Thought (BFT) is an epistemology and politics that argues that the experience of being a black woman cannot be understood independently in terms of being Black and of being female. We invoke BFT for more granularity to focus on Black women in particular. The intersection of the two (i.e., race and gender) often reinforce each other and that intersection must always be considered when analyzing social injustices [15, 9]. BFT suggests that "African-American women's oppression has encompassed three interdependent dimensions": an economic dimension, a political dimension, and an ideological dimension [9]. The economic dimension of oppression illuminates the "exploitation of Black women's labor that has been essential to U.S. capitalism from the very beginning of slavery, leaving little room and opportunities to do intellectual work as it has been traditionally defined" [15]. The political dimension of oppression helps us see the historical and contemporary denial of rights and privileges to Black women that have been routinely extended to both White males and females. The ideological dimension of oppression refers to the historical and present-day control of images applied to Black women and the resulting ideas that are created and permeated about the interests (and disinterests) of Black women. Collins states [15], "Within U.S. culture, racist and sexist ideologies permeate the social structure to such a degree that they become hegemonic, namely, seen as natural, normal, and inevitable".

BFT asserts that Black women have a standpoint. They have a standpoint because of the distinctive perspectives gained from their *outsider-within* placement which began during slavery, but continued through historical legal and present day defacto segregation. Having a unique standpoint elevates Black women's intersectional epistemology expanding the notion of who is considered an "intellectual". Collins [15] calls for Black female intellectuals to engage in the knowledge production process in ways that clarify a Black women's standpoint for Black women. This does not promote essentialism, rather it identifies core themes or issues that come from living as a black woman.

C. Standpoint Theory

The previous discussion argued that black women have a standpoint and here we discuss the key ideas of Standpoint Theory more broadly. Standpoint Theory is an epistemology that argues that knowledge stems from one's social position within a society [10]. It rejects positivist perspectives that promotes objectivity, a perspective that regards the world as made up of observable and measurable facts [11]. For example, standpoint theory points out that to understand inequality, for example, begin with marginalized people who have "expert" knowledge in relation to experiences with interlocking systems of oppression [10]. Overall, standpoint theory, similarly to critical race theory, contends that experiential knowledge is legitimize "data" for analyses and should be used in order to advance feminist ways of thinking.

III. METHOD

A. Setting and Participants

The setting of this study took place at a conference for Black women in computing as well as a large research university in the Southeast. We videotaped the experiences of 14 black women. Among those fourteen, 3 of the women had backgrounds that were not CS-related (one was in arts/communications and the other two were in non-CS STEM areas). As such, this paper focuses on the remaining eleven Black women, all of whom are in Computing. The eleven participants were Black women in computing at various stages in their careers and across different segments of computing (i.e., industry, academia, entrepreneurship, etc.). Seventy-two percent of participants have a Ph.D. in Computer Science, while 9% have a Masters degree and 9% have a Bachelor's degree in Computing. All eleven Black women are currently working in Computing either as academics (63.6%), in government (9%) or in industry (18%).

Following the methodology of Standpoint Theory, we include a statement of standpoint of the research team. The research team included Black males and females who have strong interests in the disruption of hegemonic normativity in computing. We represent over 18 years of conducting research that aims to promote a more complex narrative of the ways Black women's bodies move through the world, and in computing particularly. Said another way, we have a posteriori knowledge about marginalization in computing and STEM spaces. We bracketed our various sets of assumptions by including all variation in the Black women's interviews, not rejecting those experiences that may have been divergent from our own.

B. Data Collected

We video-recorded the participants as they engaged in semi-structured interviews to explore and understand their experiences as Black women in Computing. We asked interviewees about demographic information (e.g., name, title, organization affiliation, etc.), background information including familial background and education, motivations for entering the field, and questions about their experiences as Black women in computer science including expectations, working in groups, the role of mentorship, and the trials as well as triumphs experienced in Computing. All of the video-recorded interviews were transcribed professionally resulting in typed (written) transcripts between the interviewer and the interviewees. Throughout this paper, we use the terms Black and African-American. Black is inclusive of people born of African descent across the diaspora, including Africa, the Carribbean, North and South America, Canada, etc. African-American refers to people of African descent who were born in the United States.

C. Data Analysis

Four coders analyzed the interview data. For each interview, coders first watched the video-recorded interview. As they watched, they took notes about the experience of watching the video including how the video made them feel and aspects of the video that triggered emotions for the viewer (e.g., affirmation, anger, sadness, confusion, etc.). Then, coders engaged in content analysis in two rounds. First, coders independently coded what black women actually said about their experiences, identifying particular phrases that the interviewees actually uttered that described their experiences as Black women in Computing. As coders identified actual phrases uttered by the interviewees, they then created a code descriptive of the phrases. That code was entered into a code book that contained all of the codes created along with the phrase itself that corresponded to the code. Next, the coders came together to analyze the code book and group phrases from the transcripts into additional categories for example, professional life, graduate school, expectations, etc.

IV. FINDINGS

The findings show that Black women have faced many challenges in their pursuit of their computing degrees and careers. Some of these challenges include too high or too low expectations, racism, sexism, discouragement, and job dissatisfaction. At the same time, many of these challenges were and are mediated through a variety of strategies. These strategies included advocacy by mentors, Black women staying focused on their goals and never giving up, having access to prestigious opportunities, and engaging in resistance. These women have attended public and private institutions across their careers. During their childhood and adolescent years, most of them were in advanced math courses, participated in internships, summer STEM camps, and attended STEM focused middle and high schools. They come from educated parents and families, but more importantly, parents who helped them see themselves as being able to accomplish anything. Over their careers, they have taken the initiative to demonstrate their skills and intelligence even in the face of peers or superiors having hidden agendas, as will be described using the actual words of these women. These Black women think that the collective of Black women can solve any problem because they have the "ability to look at problems in a different way and to solve them". In fact, one interviewee emphatically stated:

> *"I think that our experiences are unique…appropriate to be the most broadly thinking, systematic thinkers, innovative thinkers in computing. And so to not get into computing would be to rob the world of ground-breaking solutions that will truly impact lives."*

These women now serve in leadership, industry, and academic roles and have great advice for future Black women wanting to study computing and that advice is to for them to know that they are important and to hold themselves to their own standards in their own struggle. Below we discuss four of the many findings that helped us to answer the research questions about Black women's experiences in computing. As we discuss these findings, we will present quotes from the interview transcripts. However, we will not use the real names of the interviewees to maintain the confidentiality of their identities.

A. *Theme #1: I Am a Needle in a Haystack, but My Goals Keep Me Pressing*

Computing is a space that mainly consists of White and Asian males. The Black women in our study shared stories of being the only one, feeling isolated, even depressed; but they kept their minds and hearts on their long-term goals. Throughout their educational journeys, they were oftentimes the only Black female either in a graduate program, in the academy, or in industry. Mary Brown stated:

> *"I was at [large mid-atantic predominantly white] University and there were very few African-American women in PhD programs period and my particular engineering and computing program, I was the only African-American at that time. There had been some prior to me but at that time I was a lone wolf. So, I felt that isolation and I had to learn to deal with it and just always keep in mind what my goals were."*

Beverly Jones mentioned that she remembers being the only one in programming classes. She recalled:

> *"I look back and can see where I was the only one in the group or inserted myself into the problem set pairing up for coding, pursuing opportunities. But I've found groups along the way where I did not feel isolated whether it was intern programs that were encouraging minorities to be in the field and to have internship experience early on."*

This quote suggests that although she was the only one in many of her courses, Beverly found ways to mitigate the feelings of isolation by being involved with groups, outside of school, for which the focus was on supporting minorities in computing.

Deborah Coleman commented on the discrimination she experienced as a result of being the only Black in her company.

> *"Well, I've been in computers since 1982 beginning with my college career moving into Corporate America as one of the only ones in computer at a major organization such as IBM. AT&T built our labs; built communications, researched total system services ... So most of the time it's been like ... I'm the only one. What I mean by the only one is, I'm the only Black female working amongst white males, and then a few Asians. It was my desire to climb the*

corporate ladder and become that CEO. That didn't happen. I actually faced a lot of discrimination as a Black woman in computing…so an experience that I had as a black woman in computing where I felt discouraged was when I was actually at [a large tech company]. I would watch my counter-parts - when I say counter-parts I mean my white male piers - get promoted over me, I always wondered why they were promoted with less qualifications than I. I had my masters in computer science and I was not promoted…"

This quote suggests that even when Black women have high aspirations to advance into high power positions, they are often met with resistance.

B. Theme #2: Different Mentors in Different Spaces Champion My Success OR A Constellation of Mentors Ensure My Success

The Black women in our study had varied mentors, ranging from their parents, siblings, spiritual leaders, other Black women, White women, and even White men. For example, Allison Thompson discussed the benefits she received from different mentors across her educational journey. She stated:

"When I was first starting out in high school, it was my high school teachers, my math teachers, that were naturally already in my life. As an undergrad, it was my really good friend who was a math whiz. I had to learn calculus. I'm like, "Teach me this." It was research mentors from my different undergraduate experiences that said, "We'll write a letter for you. I'll write a graduate school recommendation for you." It's people who have given me information that I need to understand what the space looks like before I enter."

This quote suggests that a mentor can be proactive in sharing information with Black women about the culture and politics of computing. From an intersectionality perspective, the sharing of the computing culture and politics is imperative because it is a White and patriarchal space where Black women can endure low expectations, discrimination, racism, and sexism. Consequently, being prepared with some coping strategies can decrease the shock.

Dr. Deborah Coleman pointed out that her mentors were spiritual leaders: She commented:

"But then, I had this woman ... I call her a mentor because she was like a spiritual mother. When you're going through the PhD process or even working, you need someone to talk to. So I have this ... I call her my spiritual mother. She was out of Minneapolis, Minnesota, and she was the person that was really there; who was interceding and standing in the gap when I went through my tough times, and even when I didn't go through my tough times. Those two powerful black women were my mentors spiritually and in terms of my education."

Interceding and standing in the gap is a spiritual colloquialism in the Black community that means someone is praying and asking God to help, protect, provide, and watch over another. Deborah's spirituality is a part of her social identity and as intersectionality points out, it bleeds into her life as a professional for which she and others in her life draw upon to navigate computing spaces that may not necessarily support her advancement and success.

An important aspect of their mentoring experience was they felt that their mentors treated them like colleagues. Mary Brown stated:

"Her [dissertation advisor's] whole approach to my program and my education was one of a colleague. Never did I feel the professor-student relationship with her.*"*

Beverly Jones poignantly commented:

"When I met her [dissertation chair], it was an instant connection and synergy. Not only was she a female that had worked in industry and clearly was the standout in the room, and I felt that we matched in a lot of ways because she matched her clothing, she was stylish, she was personable, but she also knew her stuff. And being one in a room with many males and having to demonstrate your knowledge and capabilities, she got that. But in addition to that, she also recognized I am and was a black female. And it was a moment where she talked about some of the HBCs in the Atlanta area where I realized, oh, she's actually aware and knows of these universities and the prestige associated, which I would not have said many of her colleagues did. And that quietly set her apart for me and that she would recognize me as a complete person, a black female that was her student. And she has been advocate then and ever since, selflessly, from helping me find the opportunities that were best for me.

Whether it was the Graduate Research Fellowship award or the right research experiences in her lab, and now as a mentor in my later career. "

Intersectionality recognizes the latent power relations that exist in computing spaces, therefore Black women being perceived as equals and co-creators of knowledge disrupts the inequities.

C. Theme #3: Spending Time with My Father Inspired My Initial Interest for Computing

Black women in our study discussed the salience of interactions with their fathers as catalyst for developing their initial interest in Computing and Math. This was a surprising finding because their experiences present a counter-narrative to mainstream literature that often positions African American fathers as absent or not involved (i.e. [7]). According to a review of the effects of father involvement, a father is defined as involved if his relationship with his child can be described as being sensitive, warm, close, friendly, supportive, intimate, nurturing, affectionate, encouraging, comforting, and accepting [1]. In addition, fathers are classified as being involved if their child has developed a strong, secure attachment to them [1]. The ways in which the Black women in our study described their interactions with their fathers suggests they had loving, warm, and supportive attachments. Marie Thompson stated:

> *"From an early age, I loved to tinker. I'm a tinker at heart. I love to tear things apart and put them back together, have been that way all my life. I also like to follow my father around and my father was a natural builder. He could put things together to solve a problem and I think I picked up a lot from just hanging around him…So, I spent quite a bit of time with him and I think that helped me to formulate that problem solving aspect of my psyche."*

Marie's comments suggest that following her father around gave her time to watch and learn how to engage in the process of problem solving. This is an important skill to have as it supports individuals to think about how to define problems, how to generate alternatives, assess, evaluate, and select alternatives, and implement solutions. Biller [2] suggests that children with involved fathers have superior problem solving and adaptive skills, which are important for Black women in computing, given their experiences with low expectations, racism, sexism, and other negative aspects of their workplace and academic programs.

Black women in our study also discussed their fathers' natural endowment with numbers. While this perspective suggests individuals are gifted at birth with the capability for understanding math, we in fact reject this view; however, Janice Wilson internalized her father's propensity for math and finance. She recalled:

> *"My father had a gift for numbers and finance, so that translated into a passion for me, for math. I loved math and was taking advanced math from middle school on, which meant that I was able to get into this magnet program, a gifted and talent[ed] program and also science and technology focused school."*

Internalizing and developing a passion for math as a result of seeing her father's interactions with these ideas, Janice set herself on a pathway to success. This pathway clearly produced high self-esteem and self-efficacy because she continued to take more and more mathematics in her school trajectory. Some research contends that school aged children of involved fathers are better academic achievers [1], have better quantitative and verbal skills [22], and learn more and perform better in school [1]. From an intersectionality perspective, Black women need self-efficacy in the spaces where their intellect is constantly questioned and their goals for success are not always supported.

D. Theme #4: The Lows and Highs of Others' Expectations with No Middle Ground

Black women in our study discussed a constellation of expectations that others had of them in a range of computing situations and contexts. These expectations typically started out low, but in certain situations (for example, recognition that the black woman in question had a Ph.D. in Computer Science), the expectations became very high. Michelle Harris stated:

> *"I would say that at least primarily in the very beginning there were very low expectations of my contributions to projects, to the company, those kinds of things. I spent probably the first five to six years of my career trying to prove that I could be a contributing member, and that I was a valuable member of the team."*

Michelle's experience speaks not only to the low expectations experienced by Black women in Computing, especially in the beginning of their interactions and work within the field, but also the continued re-affirming of competency over extended periods of time that Black women have to do even after they have already shown, proven, and established their competency.

Natalie Shaw commented:

> *"It's frustrating to encounter someone that doesn't see how fantastic and capable I am. And try to limit [my] experience and exposure."*

Natalie’s comment describes not only the emotional impact of others’ low expectations of her, but also the professional or academic impact as others’ low expectations result in missed opportunities for Natalie to gain critical experience or exposure that can help her to advance and succeed.

Yolanda Pittman recalled:

> *“They expect me to either be able to do it all because I have had a wealth of experience, or they pretty much expect me to be there and just cosign to whatever it is they want to do. So, it's one extreme or the other, not much in the middle. I tend to operate a little bit better more in the doing it all space, but I know that most people, often the expectation is fairly low.”*

Yolanda’s comments reflect the stereotype of the “strong black woman” who can handle anything and “do it all”, no matter or stressful or strenuous. This stereotype that has roots in slavery where “sexist notions of real women as weak, and racist notions of Black women as not really women, have intersected to produce the *gender racism* of the strong Black woman, inferior to the pinnacle of womanhood, the weak White woman” (emphasis in [17]). Yolanda’s comments also provide a poignant example of the dimension of interpersonal power described by Intersectionality as well as the ideological dimension of oppression described in BFT around Black women. Black women’s experiences in these spaces highlight how both types of expectations disadvantage them. Expectations that are too high and unrealistic leave Black women saddled with unusually high amounts of work or responsibility as they “do it all”. Black women in Computing also described having learned how to function under those unrealistic high expectations, even when they place undue burden or stress (mental, spiritual, and emotional) on them. At the other end of the spectrum, expectations that are too low do not acknowledge the ideas, experiences or perspectives Black women bring to the table because of their unique positioning within the field. Instead, these low expectations position them, not as partners or innovators, but rather as “co-sign”-ers going along with the ideas of others without contributing to the formation of those ideas.

V. DISCUSSION AND FUTURE WORK

Our study aimed to understand the experiences of Black women in computing, creating a Black women’s standpoint in Computing, what we might learn from their experiences that illuminate nuances of their intersectional identities and the role of oppression. Overall, the women in our study experienced discrimination, low expectations from others, isolation, sexism, and racism; yet they still choose to stay in the discipline. The interviewees reported that remaining true to their personal and professional goals, having effective mentors, and inspiration from their fathers all contributed to their successful pathways and strategies of resistance.

We learned that many of them continue, or persevere, on the 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. From an intersectionality perspective, we also learned that while many of them have taken different pathways to get to the place of satisfaction and thriving in their work, it has come with a cost because they have had to negotiate spaces of simultaneous racial and sexual discrimination, something that groups such as White women and Black men do not face, as well as other negative experiences. For example, recent articles have cited the notion of “weathering”, or the chronic stress of facing racism and sexism at the same time as being a “significant factor in poor maternal outcomes” [20, 23]. This chronic stress may also cost Black women in other ways, especially when combined with the additional stress that comes with pursuing a degree or career in Computing – further research is needed to explore exactly what cost Black women in Computing pay and how it manifests itself. What Black women in computing appear to lose are aspects of their personhood and humanity because computing spaces can reject their Blackness and womanhood. The culture of computing is competitive, male, and largely White; consequently, Black women receive implicit and explicit messages that they do not belong in computing.

The Black women in our study experienced complete isolation in that on the one hand, computing is a field dominated by males, and on the other hand, Blacks are not represented in computer science. The ambiguity of experiences suggests that Black women may not understand if they are experiencing negativity because of their gender or their race; however intersectionally argues that these two identities cannot be divorced, therefore, the discrimination happens at the intersection.

There is still much work left to do to understand these issues. We call for research that continues to examine the intersectional experiences of women of color as well as other marginalized groups within computing. For example, more research is needed around not only why Black women leave Computing, but also why they persist. Most work in this space focuses on why women or minorities leave the field, with little focus on the intersectional experiences of women of color (or of particular groups of women of color) in the field and what causes them to leave or persist. We plan to continue to collect digital narratives of Black women in Computing and continue to refine our understanding of their intersectional experiences. Additionally, we are working on constructing an instrument to allow us to assess the intersectional experiences of Black women in Computing, Mathematics, and STEM more broadly.

ACKNOWLEDGMENT

We thank the National Science Foundation for their generous support of this work.

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The Role of Relationships in Engaging Latino/a High School Students in Computer Science

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Abstract— **Latinos are the fastest growing ethnic minority population in the United States but are underrepresented in computing-related majors and fields. Most efforts to broaden participation in computer science lack a cultural and contextual perspective, and focus on building individual competencies and motivation. In this paper, we propose that a greater understanding of relationships is critical to inform efforts to increase the interest and build the computational skills of Latino/a youth to enter and persist in a computing education pathway. The focus of this study is on a community technology center that serves primarily Latino/a youth in an agricultural region of California. The primary research question was "What is the role of relationships in Latino/a students' interest in computer science?" Data were collected from high school students (97 surveys and 20 in-depth interviews), and from center staff (6 in-depth interviews). The findings show how relationships help students connect computer science to cultural values by forming communities of practice around CS with similar peers and mentors.**

Keywords— Latinos, Relationships, Informal learning environments)

I. Introduction

Latinos are the fastest growing ethnic minority population in the United States. They accounted for over half the growth of the U.S. population between 2000 and 2010 [1]. Despite the growing numbers, Latinos are vastly underrepresented in computing-related fields; in 2010, they made up only 4.6% of computer and information scientists in the labor force [2]. Latinos are 16% of AP test takers, but only 8% of the AP CS test takers; those that took it scored far below their peers [3]. Although Latinos make up 19% of all US college students ages 18-24 [4], they earned just 6% of CS bachelors degrees; less than 2% of students who enrolled or completed a PhD in CS were Latino/a [5]. The term "Latino" includes a heterogeneous group of people in the US; in this paper we focus on a population that has low levels of formal education and retains strong ties to Mexico.

Most efforts to build the computational skills of Latino/a youth to enter and persist in a computing pathway lack a cultural and contextual perspective. They are often self-contained classes or programs that focus on skill building, rather than an ecological and relational approach that recognizes the factors that are most salient in the lives of Latino/a youth [6]. These factors include identity exploration, navigating challenges associated with balancing future goals with family and cultural values, pressures to assimilate, and friendships and romantic relationships [7]. Cultural values common in Mexican-descent families include a high priority on education and responsibility for financially supporting one's family rather than self advancement [8,9].

Despite their interest in computing fields [10], few pursue them, perhaps due to a perceived mismatch between student cultures and the values widely associated with CS. Increasing Latino/a students' motivation and capacity to pursue CS requires strategies that respond to culture [11] and make connections to students' values [12]. Examples include helping students see the relevance of a computing career [13], building connections to their identity and culture, and addressing the economic needs of their family and community [14]. Thus, efforts to engage Latino/a youth in CS would be strengthened by helping youth navigate relationship challenges and opportunities to gain the skills and experiences that will prepare them to pursue computing-related courses and careers while maintaining their cultural identity.

Efforts to engage K-12 students from underrepresented minority groups in computer science typically focus on the individual, rather than on the relational and institutional factors that play a significant role in decision making. However, decades of research have identified the importance of relationships in Latino/a students' educational pathways. For example, successful college-bound Latino/a students establish relationships with cultural brokers, often slightly older youth, that provide direct guidance and resources needed to meet their

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academic and career goals [15]. Despite the importance and pervasiveness of relationships during this time period, the role of peers and mentors in Latino/a high school student pathways to CS education has not been investigated.

In this paper we propose that efforts to increase equity and inclusion in CS require a better understanding of how relationships influence the pathways of Latino/a youth into CS education in K-12. The paper builds on theoretical frameworks that show how learning and engagement are a result of interactions with one's environment and relationships [8]. Qualitative and quantitative data collected at a community technology center are used to show how relationships with mentors, peers, and family play a role in how Latino/a high school students enter and whether they persist on a CS pathway.

A. *The Role of Informal Settings in CS Education*

Community technology centers (CTCs) are a key resource in the effort to prepare youth for CS education and careers because they increase access to technology in low-income communities that have few high tech classes or role models. Their community-based and sustainable model offers more than the typical "outreach" (e.g., one-time presentations or a week-long class or camp for highly motivated and resourced students). In addition to technology access and experience, they foster social capital by expanding their networks (with peers, mentors, and other adult community members), and offer opportunities to design, create, and contribute to their communities [16]. To promote learning that is connected to the local values and culture, CTCs must provide opportunities for creative production; build sustained social relationships with peers and mentors; provide ongoing learning opportunities for mentors and youth leaders; disrupt patterns that favor one group of learners, and use research to inform cycles of revision [17]. Despite the large body of research on how informal settings create opportunities and supports, little is known about their role in students' decisions to pursue computer science.

B. *Theoretical Perspectives.*

This study is informed by two theoretical perspectives. The first, the Contextualized Model of Learning, has been applied primarily in out-of-school settings [18]. It suggests that learning and engagement in STEM (science, technology, engineering, and math) fields are the result of the complex interactions between the personal, social, and physical contexts. In this model, those interactions are influenced by the student's identity, interests, and perceived abilities [18]. The second set of theoretical perspectives includes social constructivism and communities of practice. These models suggest that learning is fundamentally social, and occurs in the context of a community that has its own set of goals and expectations [19]. These interactions take place as part of a community that involves participants from different ages and skill levels. Research suggests that meaningful participation in learning communities may be a more important part of education than the acquisition of knowledge or facts [20], and thus there is a need to understand how youth move from being peripheral or less engaged members of a community of practice to become more active members who develop an identity as someone that knows or likes to do a particular activity [19].

These frameworks are relevant to the field of CS education in several ways. First, efforts to broaden participation would benefit from understanding the structures and processes that scaffold CS learning and identity formation in informal environments. Thus, we need to go beyond knowledge of individual level learning to also measure who they interact with, their identities or beliefs about their capacities and possible futures, and group and community-level processes for sharing knowledge and skills. These include the relational supports and barriers that can drive or undermine students' interest and confidence in CS. The current study of a community technology center (CTC) is designed to address this need. The following research question is addressed: What is the role of relationships in high school students' CS interest?

II. METHODS

A. *Sample*

The CTC is a non-profit entrepreneurship and technology workforce development center located in a low income and rural community in Central California. It provides primarily Latino/a youth and young adults with the resources and supports to develop the motivation and skills needed to pursue and succeed in the technology workforce. It offers free access to computers and other technology, wifi, food, and a variety of classes and events. It is organized into six core member groups (e.g., Tech Squad, Connect Crew, Media Creators), which are each overseen by an adult staff member. Over the period of one year, the high school aged members were invited to participate in a study that included taking three surveys and possibly a one-on-one interview. A total of 97 high school aged members completed the first survey, which is the focus of this paper. Most (89%) identified as Hispanic/Latino, 93% speak another language at home besides English, 42% were female, and one third have a mother who did not complete a high school education.

A subset were invited to participate in an interview about their experience at the CTC. They were selected based on being moderately or highly involved in the CTC; the goal was to get an equal representation of male and female members and a distribution across core member groups. Twenty students were interviewed; 40% were female, 75% were Latino/a, and they ranged in age from 15-18 years old. The six primary line staff members participated in a one-on-one interview. All identify as Latino/a, and four identify as female. They range in age from 24-30 years old. Four grew up in the local community, none have a CS degree, and they had worked at the CTC between 1-4 years.

B. *Measures & Analyses*

Survey data on the role of relationships in CS motivation. Data used in this paper include four scales that were based on prior research. They include the CS Motivation scale [21], the Perceived Support for CS scale [22], and the Family Support and Friend Support scales, which were adapted from an existing survey [23]. The items and reliability information are summarized in Table 1.

TABLE 1. SURVEY SCALES

This work was supported by grant 1543001 from the National Science Foundation.

Scale	Items	Response Range	Alpha
CS Motivation	Developing computing or technology skills will help me achieve my career goals. Knowledge of technology will allow me to secure a good job. My career goals require that I learn computing skills. Knowledge of computing skills will help me secure a good job. I am comfortable with learning computing concepts. I have self-confidence when it comes to computing courses. I can learn to understand computing concepts. I can earn good grades in computing courses. I am confident that I can solve problems by using computer applications. I can solve problems by using computer applications. I would take computer science courses if I were given the opportunity. I hope that my future career will require the use of computer science concepts. I like using computer science to solve problems. The challenge of solving problems using computer science appeals to me. I think that computer science is interesting. I would voluntarily take additional computer science courses if I were given the opportunity.	Strongly agree (1) to Strongly disagree (4)	.87
Perceived Support for CS	There is a mentor or staff person who encourages me to learn about computers and technology. My friends are interested in the work I do with computers and technology. Other students at the CTC have encouraged me to learn about computers. Other students at the CTC are interested in what I know about computers and technology.	Strongly disagree (1) to Strongly agree (5)	.80
Family Support	People in my family want me to learn more about computers and technology My family is enthusiastic about what I am learning at the CTC. My family has encouraged me to come to the CTC. My family is interested in what I am doing at the CTC.	Strongly disagree (1) to Strongly agree (5)	.87
Friend Support	My friends think it's cool to learn more about computers and technology My friends are enthusiastic about what I am learning at the CTC. My friends have encouraged me to come to the CTC. My friends are interested in what I am doing at the CTC.	Strongly disagree (1) to Strongly agree (5)	.86

Interviews with members about the role of mentors and friends. One-on-one interviews were conducted with 20 high school age members. The questions related to this paper are: When you first heard about the CTC, what did you hear? Why did you decide to become a member? Have you thought about studying computer science or engineering? What types of help have you gotten from the CTC to reach your future goals? Are there important people in your life that you talk to regarding your future, including school and your future career? Do you have a mentor at the CTC?

Interviews with CTC staff on their mentoring strategies. One-on-one interviews were done with six staff members who work directly with the youth at the CTC. Questions included: What are your goals for working with your mentees? How do you know whether or not you have been successful? How would you describe the strategies you use when you mentor? How do you adapt your approach for different kinds of youth?

Data analyses. Survey data were analyzed using simple correlations. Both sets of interviews were analyzed using the constant comparison method [24]. The analysis was guided by theory but allowed for the emergence of other factors. First, open-coding of responses for each of the interview questions was used to name the conceptual categories into which the words or phrases seem to be grouped. Second, each response was coded for more specific, word-level replies; specific examples were grouped by key factors, such as the different ways that mentors support youth. As new codes emerged, the coding scheme was revised and transcripts were reread and coded according to the new structure. Saturation was achieved when no new codes were identified; similar codes were moved into categories, then developed into themes, and finally a matrix of themes was analyzed across all interviews [24].

III. RESULTS

Responses to the survey questions are summarized in Table 2. They show that levels of CS motivation varied, but on average the students reported low interest in pursuing computer science. They reported partial agreement that others support their learning about computers and technology. And on average, the students somewhat agree that their family and their friends support their interest in computers and technology

TABLE 2. SCALE STATISTICS

Scale	N	Min	Max	Mean	St Dev
CS Motivation	95	2.06	4.00	3.05	.39

Perceived support for CS	94	1.00	5.00	3.39	.75
Family Support	97	1.00	5.00	3.46	.91
Friend Support	96	1.00	5.00	3.37	.81

Simple correlations of data in the student surveys show several significant results. Students are more motivated to pursue CS when they perceive greater support from other students, friends, and a mentor to learn about computers and technology ($p<.01$). CS motivation was also significantly correlated with perceived support from family members ($p<.05$) and from friends to come to the CTC and learn about computers and technology ($p<.05$). Correlations between CS motivation and support from a romantic partner were also explored but were not significant; this may be due to having only 22 students who reported having a boy/girl friend or equivalent.

Interviews with six staff members were used to understand the roles that these mentors play in students' CS pathways. The results suggest a great deal of variation in staff members' confidence or interest to support students' interest in computer science, and in the ways that relationships influence students' CS-related decisions. Among those members that did talk about how they support CS pathways, there were a range of strategies to: 1) increase access to experiences that build CS knowledge, 2) support the development of a CS identity, 3) build their confidence, and 4) inform them of education and career pathways. These included telling the students how it is possible to work in tech even if they are not programming, as well as taking them on field trips to see different kinds of tech work environments and to meet people who work in a range of computing fields. Some staff members described how they use their own experiences (e.g., not earning a CS degree) to motivate youth, and providing "emotional support and more cheerleading for them to stick with a program or to learn on their own because it takes a lot of self-discipline to learn a programming language. It takes a lot of 'oh you failed and now you have to try again' those things I think are the most important things to have." Other staff say they do not personally know anything about computer science, but that they help youth understand that working in the tech industry does not always require a college degree. By introducing alternative pathways, their goal is to give options to youth who cannot afford college or cannot leave their family.

Interviews with youth reinforce these findings by showing how they perceive the benefits of relationships with mentors. Students said that their mentors helped them prepare for college, gave them opportunities to take on leadership roles and have real-world experiences, and provided them with connections to professionals (e.g., game designers). Some students also talked about receiving emotional support and help dealing with challenges.

Two case studies show the different ways that high school students develop an interest in CS, and the role that relationships play in sustaining that interest. The first case is 16-year old Juan (not his real name) who talked about how he first started coming to the CTC because it was a safe place to do homework, there was free access to a laptop and wifi, and it was a place he could do volunteer hours. His interest in CS grew with the opportunity to take classes in game programming and development. He has since talked to the CTC teacher about additional opportunities, such as participating in or attending video game competitions. He describes staff as mentors that give him encouragement to stay on his chosen path, create opportunities for him to meet people who do coding, provide information about what college is like and how game programming could fit into it, and give him something to strive for by being the kind of successful and open minded people he can look up to. Juan also cited his family as playing an important role in his future goals, and wanting to outdo his brothers as a motivation to succeed.

Another case study shows a different entry point into CS. Sixteen year old Carmen (not her real name) first came to the CTC for the free computers and wifi, and the free food. She eventually joined the core member group that plans events and does not focus on building technical skills because she felt a strong connection to the staff member leading that group. As a result of her involvement, she learned how to work with different types of people and how to express herself. Over time, as she built confidence and leadership skills, she took some workshops at the CTC that gave her technical skills, such as making a customized filter on Snapchat. At the time of the interview, she talked about wanting to major in business in college, but was interested in studying computer science or engineering because she sees those skills as essential for the future. She described the staff mentor as someone who tells her about different pathways and talks about the importance of diversity in tech. This relationship has shaped her desire to take a leadership role in the tech industry to get more Latinos and women into technology: "…that's why I said…that I want to change diversity and empower women in technology."

IV. Discussion

Efforts to engage Latino/a youth in computer science typically focus on building their knowledge or increasing their interest and motivation. The findings from this study show the important role that relationships can play in whether and how Latino/a youth in a community technology center enter and persist in computer science-related activities. The data suggest that CTCs can play an important role by providing the opportunities and supports that some young people need in order to develop an interest in the field of CS. Relationships with mentors and peers help Latino/a youth experiment with a CS identity that is consistent with their cultural values and show them how CS is connected to the real world. In addition, relationships with mentors, family, and friends provide opportunities and encouragement, and the support to form communities of practice.

This study is unique in its exploration of how relationships and informal learning settings can play a role in getting students from underrepresented minority groups on a computer science pathway. The results can inform efforts to broaden participation in CS by calling attention to the social factors that influence individual decision making. More research is needed to understand the role that informal learning settings that are not staffed by adults with computer science expertise can support youth to pursue CS. In addition, more research is needed to understand how relationships can undermine interest or persistence, particularly for women and underrepresented minorities.

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Applying the Engagement, Capacity and Continuity Trilogy for Computing Undergraduates at Johnson C. Smith University

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***Abstract*—The Johnson C. Smith University (JCSU) Computer Science and Engineering (CSE) department is a leading producer of African-American graduates in Computing with retention and graduation outcomes far exceeding the national average. This experience paper describes the partnerships, programs and activities conducted within the JCSU CSE department and how they collectively contribute to such positive impacts. It will provide an overview of how the College of STEM has applied the Engagement, Capacity, and Continuity (ECC) Trilogy framework. This paper also gives suggestions on how understanding its system of interdependency can improve outcomes.**

I. Introduction

Johnson C. Smith University (JCSU) is an independent, private, coeducational Historically Black College and University (HBCU). As of Fall 2016, 1,428 undergraduates were enrolled at the institution. The Department of Computer Science and Engineering (CSE) is part of the University's College of Science, Technology Engineering, & Math (STEM) and represents approximately 14% of the overall student population. The JCSU computing program has been ranked in the top 30 of all universities nationally as a leading producer of African-American graduates in computing. Computing majors have maintained an 85% retention rate and 61% graduation rate, which far exceeds the national average.

According to a report from the Center on Education and the Workforce at Georgetown University, African-American students are highly concentrated in service-oriented majors: Humanities, Education and Social work [1]. African-Americans received just 7.6% of all STEM bachelor's degrees and 4.5% of doctorates in STEM [2]. In 2011, 11% of the workforce was black, while 6% of STEM workers were black [3]. The 2014 freshmen survey data at JCSU reported characteristics of the students' initial major choices. The most popular STEM major is Biology (16.6%). Only 2.9% of freshmen choose Mathematics or Computer Science as their intended major.

The demographic disparities in computing education may affect equality of opportunity in these critical jobs of the future. Although there is no singular reason for the racial disparities within the college major choices, literature suggests that the barriers exist, which include academic under-preparedness, lack of mentorship, and negative race and gender stereotypes regarding the ability to succeed in STEM fields. Additionally, students do not perceive STEM careers as socially and culturally relevant [4], [5], [6]. Today, college students have great interests in societal issues like sustainability, environmental justice, and community resilience. Therefore, programs addressing these interdisciplinary issues provide great opportunities to attract and retain students in STEM disciplines. This paper outlines the JCSU Department of Computer Science and Engineering's programmatic approach to student recruitment and retention challenges system in a variety of programs and then discusses outcomes and implications.

II. The ECC Trilogy at JCSU

A 2005 study conducted by the Southern Education Foundation, Igniting Potential: Historically Black Colleges and Universities and Science, Technology, Engineering and Mathematics, provides an outline for "best practices" for HBCU STEM programs. This are inclusive of, but not limited to: strong advisement, meaningful research experiences and internships, and hospitable campus climates and caring learning environments. JCSU has a history of providing a nurturing campus climate and a caring learning community.

Over the past few years, the College of STEM utilized "Engagement, Capacity, and Continuity: A Trilogy for STEM Student Success" [7] as its conceptual framework for delivering an excellent educational experience. The ECC Trilogy suggests that there are three broad interconnected factors which are essential to the persistence of students in STEM disciplines. These include engagement (that which attracts the student to study), capacity (possession of the required knowledge and skills), and continuity (a pathway for advancement). Table I provides a summary of some of the implemented ECC activities at JCSU.

TABLE I
ECC PROGRAMS AT JOHNSON C. SMITH UNIVERSITY

Engagement (attract)	**Capacity (cultivate)**	**Continuity (advance)**
Service-Learning: Outreach programs such as Ignite CS; STARS Computing Corps	Undergraduate Research: Socially relevant projects; Rigorous inquiry; Conference publications and presentations	Mentoring: Faculty-Student teams; Alumni advisement and involvement
CS Community Engagement: Student and Faculty travel to conferences, workshops, summits, and competitions; Hosting campus events	Experiential Learning: Pre-College HBCU; Applied CS; Faculty-in-Residence; Hackathons	Career Development: Internships; Mock interviews; Resume and application review
Leadership Development: Student involvement in professional groups and campus organizations	Curriculum Enhancements: Interdisciplinary programs; Market-driven courses	Industry Partnerships: Campus recruiting; Industry-sponsored forums

A. Engagement

Student engagement is the best predictor of their learning [8], [9] and promotes a reduced gap between students with different ability level [10]. JCSU students and faculty were behaviorally and emotionally engaged [11] through targeted activities which occurred at various intervals throughout the entire academic year. Notable engagement activities include service-learning programs such as Ignite CS, CS community engagement through travel opportunities or campus events, and leadership development opportunities such as student involvement in professional organizations.

Ignite CS was a two-week outreach program, led by JCSU students, that provided high school students hands-on opportunities in web development. The JCSU CSE department also advised and directed two campus student groups: a student chapter of the National Society of Black Engineers (NSBE) and most recently The Women in Information Technology Science and Engineering (WISE) Program. The gender distribution of computer science and engineering majors at JCSU is 20% female and 80% male. The WISE Program is relatively new, but worth mentioning here as a strategy to engage more women. In both instances, students are encouraged to develop their leadership potential through student-driven activities and events.

Additionally, the CSE department promoted, encouraged, and at times funded several student and faculty opportunities to engage with the wider CS community through events such as the NSBE National Conference, the HBCU Innovation Summit and the ACM Richard Tapia Celebration of Diversity in Computing. The JCSU College of STEM hosted a wide range of local computing community events including Leadership Lyceum, CIO/CTO forums, STEM Conferences, Tech Talks, and Start-up Weekends.

B. Capacity

In 2012, the JCSU CSE department adopted strategic priorities to cultivate the culture for undergraduate research and market-driven curriculum. This commitment placed emphasis on the development of new interdisciplinary programs, experiential learning programs and socially relevant course content therein. This section briefly describes the hands-on approach used at JCSU to build students' fundamental and advanced knowledge of computing concepts and resultant capacity.

1) JCSU Undergraduate Research Programs: Two of the JCSU College of STEM's signature undergraduate research programs include: Faculty and Student Team (FAST) and Collaborative Research for Undergraduates in Science and Engineering (CRUISE). With the explosion in the number of new discoveries and technologies in today's global scientific community, it is becoming increasingly imperative that faculty keep abreast of cutting edge research and discoveries, as they update existing courses and plan for the infusion of new curriculum enhancements. Additionally, being prepared to expose students to these new discoveries and to incorporate this new knowledge as a part of their learning regimen will better prepare students for graduate or professional schools and for the scientific workforce.

The FAST undergraduate research program provided rich learning opportunity for students to gain first-hand knowledge of the methods and challenges of scholarly research. These collaborative projects were designed to be of such quality that they might lead to publication, exhibition, or performance. The CRUISE undergraduate research program was a summer research project institutionalized with several other universities and institutions for computing students.

2) JCSU Curriculum Updates and Experiential Learning: JCSU supports knowledge and skill development through curricular innovation, experimental learning, and interdisciplinary collaboration. Since 2012, the CSE department has introduced two new minors: Cyber Security and Bioinformatics, three experiential learning programs: Pre-College HBCU, Applied CS, and Faculty-in-Residence and several special topics courses in mobile application development, wireless networking, and data analytics.

Pre-College HBCU was a 3-week summer residential program for incoming freshman students hosted at JCSU. The goal of the program was to immerse students in Computer Science, using a rigorous curriculum designed and taught by Google Engineers and University Faculty, and to prepare them for internships after their freshman year. Through this 120-hour immersion experience students learned about front-end development (HTML, CSS, JavaScript, and Python) while building their soft skills. The Applied CS Program was a

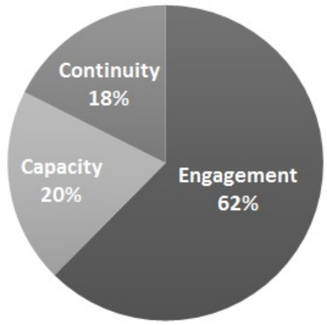

Fig. 1. Percentage of ECC Factors within the JCSU College of STEM

flipped classroom approach for students to apply advanced Java programming skills. This six-week program, held on consecutive Saturdays, was intended to compliment the knowledge of students who have taken Programming II and Data Structures courses. The Faculty in Residence program was a six-week summer immersion experience for two JCSU faculty to learn about the current workforce needs in high-tech companies. Faculty could develop curriculum and projects for implementation into courses.

C. Continuity

Among the three factors in the ECC Trilogy, academic departments have tremendous influence on the availability and effectiveness of its educational programs and pathways. It is through such institutional systems that continuity is established [7], therefore allowing students to advance to completion. JCSU provides information an academic support (continuity) through mentoring, student career development, and industry partnerships. The student-faculty ratio at JCSU is 11:1, and the school has 77% of its classes with fewer than 20 students. Thus, providing a climate upon which to build opportunities for faculty-student mentoring.

The JCSU College of STEM has leveraged over a dozen industry partnerships to provide career development and professional pathways to students. Industry partners have visited the campus to provide information about their companies and to conduct on-site interviews. To help students feel prepared to advance in their careers, they were provided with mock-interviews, access to a professional clothing closet, and faculty feedback and encouragement as new opportunities arose. Alumni also participated in this process of continuity as representatives of their companies, and facilitators in access to information about internship and job opportunities.

III. Interdependency of ECC Factors

The ECC Trilogy was developed using a systems approach to describe how individuals can achieve success in STEM [12]. Systems theory is a concept broadly used to describe the interdependence, or mutual dependence, of relationships created in communities and organizations [13]. One of the essential components to utilizing the ECC framework, is an understanding of the interdependency between the three factors. Yet, methods to do so are largely unexplored. Furthermore, while most HBCU institutions offer programs, activities, and events like what has been described in this paper, it remains unexplained as to why they don't experience more growth. This section describes some examples of occurrences of interdependency of ECC factors at JCSU, and then offers the use of Network Science as a possible tool for examining such occurrences.

1) Continuity Builds Capacity and Engagement: In 2015, JCSU completed construction of its new Science Center. This four-story, 62,000 square-foot academic facility was built to support students' preparation as global competitors for careers in STEM. This new facility allowed the College of STEM to expand its programs and house two new education centers: The Center for Bioinformatics and The Center for Renewable Energy. Furthermore, the facility's 250-seat tiered lecture hall and atrium has been used to accommodate dozens of guest lecturers, five STEM conferences and over 100 multi-purpose events for the campus and community since its construction. The access to a new facility (continuity) built the capacity to deliver more classes, programs, and events (capacity), which supported the engagement of students, faculty and the community.

Since 2015, the college has been able to engage with broader audiences, providing significant improvements in the college's brand visibility. There was a significant increase in the numbers of experiential learning opportunities for students, collaborative research opportunities for faculty, and philanthropic donations. As shown in Figure 1, engagement factors were a significant area of focus for the institution, representing a majority (62%) of the college's programs.

2) Engagement Shaped Continuity: When students traveled to conferences (engagement), participated in research experiences (capacity), and other campus computing events, they were able to shape the development of social capital (continuity) [14] and broaden their professional social networks. Additionally, students received mentoring and guidance (continuity) through their informal exchanges with faculty. This increased frequency of interaction outside of the traditional classroom setting made it easier for students to approach faculty for internship or job references, and for those references to be strong. Working closely on research with a faculty member helped more students identify as a colleague, which supported the students' willingness to ask questions and offer ideas [15]. Hence, as the ECC model suggests, there was interdependency between all three factors.

3) Insight from Network Science: Network Science is concerned with understanding and modeling the behavior of real-world networked systems [16]. A single network is simply a collection of points joined together in pairs by lines. The points are referred to as nodes and the lines are links. The interdependency of the ECC Trilogy creates a vulnerability in that if one factor, such as continuity is unsuccessful, it could lead to failures such as low engagement and diminished capacity throughout the entire system. Therefore using the lens of Network Science, the phenomena of ECC interdependency can be characterized as a network of networks. This multiplex network holds additional properties of two distinct types of links: connectivity and dependency links [17]. Connectivity links in multiplex networks function similarly to links in single networks in that they enable single nodes to function collaboratively as a network. Dependency links in multiplex networks are used to bind the success and failure of one network to elements in another network. Thus, research has found synergy between the failure of dependency links and cascading failures which can ultimately damage network stability [18]. With the help of Network Science, one could gain a unique understanding of the structure of ECC systems as well as the impact of network structure on system vulnerabilities.

IV. Conclusion

Overall, the ECC Trilogy framework has helped the JCSU College of STEM understand its strengths as well as those areas for improvement around curriculum and student engagement. The use of this framework is still in its infancy and will be leveraged to compliment other college-wide programmatic activities.

In 2015, JCSU hired a full-time Director of STEM Innovation to help facilitate and manage its ECC efforts. This additional staff has been pivotal in the college's ability to provide coherence between programs and beneficiaries. However, assessing the degree to which students received appropriate amounts of each of the three ECC factors has remained a challenge.

For ECC efforts to be successful, it is necessary to assess the degree to which each student has needs in each of the three factors and to provide opportunities to meet those needs for everyone. Consequently, the JCSU College of STEM is eager to advance its understanding of the ECC Trilogy at the individual student level. Smaller universities offer the appropriate environment for such an individualized approach, but could become even more equipped for this level of analysis with more cross-campus collaborations. Much can be learned from the examination of successful cases.

As the college continues to innovate, there will be a greater focus on collecting the ECC assessment data and appropriate indicators to best drive students' engagement, learning outcomes, retention, graduation, and employment. Additionally, such indicators will also help to further understand the impact of the programs, activities, and opportunities on non-cognitive factors, particularly motivation and self-efficacy.

Furthermore, within the ECC Trilogy, there is a focus on the individual student's experiences and capacities as the unit of measure, but for continuity, the measures are of the system and individual student access to the aspects of it [7]. It is in this area where Network Science could be applied to provide insights into the strengths and weaknesses of interdependent academic support systems. The college seeks to delve more deeply into understanding how to leverage partnerships to support the interdependency of ECC factors. Ideally, it would be helpful to discover what is happening in the computing departments on other HBCU campuses, and how institutions of similar size and structure could use the framework to collaborate, strategize, and build best practices for minority student success.

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RESPECT 2018 Panel Session on Revolutionizing the Culture of Computer Science

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Categories and Subject Descriptors

• Social and professional topics → Professional topics → Computing education → Model curricula • Social and professional topics → Professional topics → Computing profession → Employment issues • Social and professional topics → Professional topics → Computing profession → Codes of ethics

Keywords

Culture; gender; social justice; diversity; change theory; industry; students; faculty.

1. SUMMARY

This session will explore the role that academic institutions and computer science departments can play in creating a revolutionary, real, and lasting change in the culture of computer science to create and promote an inclusive culture that values diversity and promotes social justice.

2. OBJECTIVE

It is well-documented that women and members of other groups are not well-represented in either education or professions related to computer science [1]. Research has shown that many popularly-held notions accounting for the disparity are inaccurate or simply false [2]–[7].

While several topical cases at Uber and Google [8]-[10] have re-energized this discussion in the news, in higher education and in industry, it is not a new phenomenon [11]. The phenomenon underpinning these issues reflects historical social barriers, but at the same time the costs of these issues to the future of computer science and society in general are very large [12].

The objective of this special session is to discuss the role of academic institutions and computer science departments in propagating positive, revolutionary change to this culture, and creating and extending research on how it can be done sustainably and in a manner that works within, but extends, existing organizational structures with existing faculty.

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RESPECT 2018, Feb 21, 2018, Baltimore, MD, USA.

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DOI: 10.475/1234

3. OUTLINE

The participants in this special session are computer science departments who are recipients of the NSF IUSE: Revolutionizing Engineering and Computer Science Departments (RED) grant, each working to transform computer science education and spread this revolution to other computer science departments and fields. The institutions represented in this session are the University of Texas El Paso, the University of North Carolina Charlotte, East Carolina University, and Boise State University. Each team will give a short presentation on how their project is working to promote inclusion and transform the culture of computer science, followed by a 30-minute brainstorming session where ideas can be discussed and where teams can answer questions.

UTEP's project, "A Model of Change for Preparing a New Generation for Professional Practice in Computer Science," aims to foster understanding and appreciation of benefits of diversity in computer science. The first year of the project implemented training to facilitate (a) shared purpose and goals to create cultural competence and inclusive environments; (b) reflective dialog to produce a professional learning community; (c) strategies for accepting and integrating differing perspectives; and (d) asset-based approaches to engage students. In spring 2017, the evaluation team presented student climate-survey data, sparking dialog on the impact of student experiences. In May, faculty attended a workshop where they (a) heard summaries from a survey of all students, (b) received packets of raw, de-identified data representing differences across student populations, (c) participated in real-time analyses of questions of interest as they interpreted the data. This led to additional questions for follow up research. Surveys of faculty following the workshop indicate a value for interactive interpretation of student data, and willingness to engage in similar activities. Highlights of the project are collaborations with Google, New Mexico State University, and California State University Dominguez Hills to create one-credit hour courses focused on problem solving; collaboration with the Army Research Laboratory resulting in monthly cybersecurity workshops for all students; and a film series to trigger discussions on diversity and inclusion.

At the University of North Carolina, Charlotte, the Connected Learner project seeks to transform undergraduate education through a pedagogy that emphasizes learning from peers, learning through service to the community, and learning from real world problems in the profession. The research team includes faculty from CS and Organizational Science Departments, ensuring a multidisciplinary approach to organizational change. The project has transformed the introductory CS courses by using lightweight teams and flipped classrooms, resulting in students' perception that they feel part of a community by the end of their first semester[13],

[14]. Preliminary analyses of student data show that the project achieved significantly higher levels of retention of women and under-represented groups. New approaches to pedagogy are shared with faculty through the Summer Institute and by extending the changes to community service learning and learning from the profession.

At East Carolina University, Programmers to Professional Software Engineers aims to transform undergraduate Computer Science (CS) education through a set of complementary approaches. They include transform programming-centric computer science education approach to a systems-oriented and software engineering-centric one using open-source software, development of non-course-centric curriculum, infusing professional skills development processes into the entire curriculum, and dramatically increasing retention and graduation rates through inclusive pedagogy and personalization of teaching and learning[15]. We are currently developing personalizable teaching and learning materials for an introductory CS course.

At Boise State University, the "Computer Science Professionals Hatchery" seeks to transform undergraduate education by replicating the best elements of a software company environment, layering in moral, ethical, and social threads with entrepreneurship and professional skills. We have developed a - credit Foundational Values course for first-year students where case examples of bias in interpersonal and corporate interactions, and as reflected in products of computing professions are analyzed in a series of team-based activities guided by rubrics based on the social-justice theories of John Rawls [16]. This course will provide a consistent and usable scaffold of values and practices that can be adapted to other courses, further distributing the content through the curriculum, and further helping students become agents of change through computer-science education and professional practice.

At the conclusion of the presentations by the four RED teams, we will transition to a question and answer session followed by a group discussion of how to best approach achieving sustainable cultural change in computer science departments to include and support a diverse range of students.

4. EXPECTATIONS

The intended audience is members of computer science departments and any others who are interested in improving the culture of computer science. Attendees should learn about the latest research and approaches for creating lasting and meaningful changes in the culture of computer science.

5. SUITABILITY FOR SPECIAL SESSION

Most of the NSF RED projects are changing engineering departments and reporting to Engineering Education conferences. With this session we plan to bring the CS RED projects to a CS education conference. Our goal with this session is to encourage participants to begin their own thought processes on how they can approach the issue of cultural transformation within the context of their own institutions, and begin to build a community of like-minded practitioners committed to making computer science a more inclusive discipline.

6. Acknowledgements

In addition to the listed authors, the following additional members of the CS RED project teams will participate in this session: Boise State University: Timothy Andersen, Amit Jain, Dianxiang Xu; Easter Carolina University: Qin Ding, Nasseh Tabrizi and Mark Hills; University of North Carolina, Charlotte: Mary Lou Maher, Audrey Rorrer, Larry Mays, Steven Rogelberg; University of Texas, El Paso: Elsa Villa, Martine Ceberio, Salamah Salamah, Natalia Villanueva Rosales, Christine Convertino.

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