A History of BPC: Lessons from our Past Informing our Future Directions

Madison Melton
mmelto21@charlotte.edu
University of North Carolina at Charlotte
Charlotte, NC, United States

Audrey Rorrer
audrey.rorrer@charlotte.edu
University of North Carolina at Charlotte
Charlotte, NC, United States

ABSTRACT

While there were previous efforts to increase the number of women and students of color graduating with a computer science (CS) degree, the establishment of the National Science Foundation's Broadening Participation in Computing (BPC) program in 2005 created an upsurge in this area of research. This program encouraged the creation and growth of many alliances that are still well-established today. While the CS field continues to grow drastically, with an increase of 300% in students earning a bachelor's in computer science since 2006, there is still much work to be done toward BPC efforts. When looking at intersectional groups such as Hispanic women and Black women, there is no significant change and a consistent decline in earned bachelor's computing degrees, respectively, within the last 20 years. Much of BPC research has become identity-focused, however, there is a dearth of research on intersectional identity groups. This paper presents a historic overview of BPC initiatives, research, and an overview of the seminal work being conducted about intersectional identity in computing. Also discussed are challenges specific to BPC research, opportunities to advance computing education research, and future avenues for advocacy of equitable computing education and BPC work.

CCS CONCEPTS

• **Social and professional topics** → **Computing education**.

KEYWORDS

Broadening Participation in Computing, Intersectional Identity, Computing Education

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1 INTRODUCTION

1.1 The BPC Program

Broadening Participation in Computing (BPC) is a term introduced by the National Science Foundation (NSF) that embodies the effort of those in the field of computer science (CS), and non-computing fields related to diversity, equity, and inclusion (DEI), to increase the representation of particular demographic groups in computing. In 2005, the NSF introduced the BPC program which aimed to "significantly increase the number of students who are US citizens and permanent residents receiving postsecondary degrees in the computing disciplines" [1]. The creation of this program may have been due to several issues affecting computing jobs in the early 2000s. This includes (i) a consistent decline (1999-2004) in college freshmen intending to major in CS, (ii) beliefs fueled by misinformation that most IT and computing jobs were being filled by workers overseas, and (iii) a decline in international student visa applications due to new procedures implemented after 9/11 [45, 89]. At the 2004 annual meeting of the American Association for the Advancement of Science, Shirley Ann Jackson (president of Rensselaer Polytechnic Institute) stated that a national commitment to broaden participation in science, technology, mathematics, and engineering was needed to resolve these issues [45]. The NSF's creation of the BPC program less than 2 years later was the first major step in broadening participation in the field of computing.

Progress has been made in the BPC field in the last 20 years with the increase in women and Hispanic students obtaining CS degrees. The typical approach to diversity studies and the language used by researchers has also developed during this time. However, ample opportunities remain to establish a computing field that is more inclusive and equitable. Although the number of CS majors has increased 300% since 2006 [10], the representation of several demographic groups within computing still is far from equivalent to their representation in the U.S. population. In order to move forward toward diversity, equity and inclusion in CS educational attainment, it's important to reflect on the history of BPC research and note how the field has developed since the establishment of the BPC Program.

1.2 Why BPC is important

The BPC program was initially established due to a workforce shortage in the computer science field. But this work has a more important purpose now, with the potential to reduce the presence of bias in technology, increase equitable access to computing, and provide economic mobility for a computing-literate society.

Bias in technology has plagued technology development, which could have been avoided with more diverse development teams. For example, racial/ethnic bias was demonstrated via the FaceApp

’beautifying filter’ that lightened the skin of Black users [60]. Facial recognition technology claims an accuracy over 90%, yet studies have found greater inaccuracy when looking at specific racial/ethnic groups [27]. Ableism bias has been demonstrated in cases where autonomous driving vehicles fail to recognize persons using wheelchairs [68]. Diverse teams bring diversity of perspectives and thought, long valued in business innovation [69]. Applying principles of BPC are essential in computing education.

When diverse groups have equal chances to engage with CS education from an early age, a richer, more inclusive learning environment can be fostered. BPC work that is focused on creating equity in computer science education [63] serves as a catalyst for cultivating a more diverse workforce in the field. By ensuring fair access and opportunities for all, regardless of gender, ethnicity, or background, future talent is cultivated and expanded. While crucial for excelling in the tech industry, computer science education is transferable across domains. The skills acquired through CS education, such as problem-solving, communication, and collaboration, are invaluable across diverse career paths and industries [88].

1.3 Evolution of BPC Terminology

The NSF’s original statement about the BPC program points to a specific demographic focus for "women, persons with disabilities, and minorities (African Americans, Hispanics, American Indians, Alaska Natives, Native Hawaiians, and Pacific Islanders)" [1]. Since the establishment of the BPC program, there has been a progression in the terminology used by researchers. Many early studies used “women” or “female” and “minorities” [47, 75], and evolved to using women and “underrepresented” students or minorities, also called URMs. However, this language fails to accurately represent and distinguish the very diverse groups of people that it aims to represent. In a blog post on Communications of the ACM, Tiffani L. Williams makes several important points about the racist and oppressive language people choose to use in diversity studies. Williams discusses 3 reasons why The term “URM” must be considered racist language because it objectifies groups of people, denies the autonomy to self-identify, disregards the differences among members within a demographic group, and affirms a hierarchical power structure between ’majority’ and ’minority’ groups [93].

A preferable term is BIPOC (Black, Indigenous, People of Color) or naming the specific demographic groups. ACM Transactions on Computing Education has updated the language guidelines for submissions and refer to Williams’ position [13]. These guidelines also indicate recommendations regarding gender labels. While terms like “men” and “males” or “women” and “female” are not to be used interchangeably, as sex and gender terms are not synonymous or binary [43].

While the NSF specified in their original statement of what is meant by “minorities,” it did not provide definitions for “persons with disabilities” [1]. In the 2023 Diversity and STEM report, the NSF discussed yes-or-no questions that the Census Bureau’s Current Population Survey (CPS) uses to label six disability types. The disability types are “hearing difficulty, vision difficulty, cognitive difficulty, ambulatory difficulty, self-care difficulty, and independent living difficulty” [37]. The National Center on Disability and Journalism has provided recommendations for appropriate language [9]. The terminology includes several broadly accepted terms, such as "disability," "disabled," "blind," "vision impaired," "deaf," "hard of hearing," "autistic," and "person with autism." These labels are far less sophisticated or nuanced than is reflected by the state of humanity, with mental and cognitive ability all but ignored.

More recent work in the BPC field often takes an intersectional approach to diversity studies. "Intersectionality," coined in the 1980s by Kimberlé Crenshaw [34], emerged from the groundwork laid by Black, Indigenous, and other women of color over decades of contemplation and activism [72]. This concept is focused on how different forms of inequality or disadvantage can intersect, creating barriers often overlooked by conventional ways of thinking. These intersections can exist between a person’s ethnicity, gender, economic status, sexual orientation, disabilities, nationality, or any other social categories. [21].

1.4 Overview of Early NSF BPC Alliances

By 2009, eleven alliances were part of the BPC program, including: A4RC, AccessComputing, CAHSI, CRA-WP, STARS, ARTSI, CAITE, El, GeorgiaComputes!, Into the Loop, and NCWIT [28]. NCWIT and CRA-WP were the only alliances to predate the BPC program. The missions and contributions of all of these alliances is beyond the scope of this work, therefore this section presents highlights aligned with major milestones for the BPC program.

The Computer Research Association’s Committee on the Status of Women in Computing Research (CRA-W) was established in 1991. Through the early 2000s, this alliance organized many programs (K12 and college) with the goal of increasing the number of women in computing. In 2008, it was established as a BPC alliance and renamed the Computing Research Association’s Committee on Widening Participation in Computing Research (CRA-WP). In 2020, the alliance reported results of graduate cohorts for women and "underrepresented minorities and persons with disabilities." Overall, improved sense of belonging in computing, self-efficacy in computing, and computing identity were observed for participants in each program [64].

The National Center for Women and Information Technology (NCWIT) is the second BPC alliance to predate the BPC program. With NSF funding beginning in 2004, the goal of this alliance was to increase the participation of girls and women in computing. In 2021, NCWIT published a paper about the online workshop designed to provide tools to foster an inclusive environment in undergraduate computing programs that recruit and retain diverse cohorts of students [18]. In the present day, the organization includes over 650 universities, corporations, and organizations working toward the goal of inclusive computing [7].

Students & Technology in Academia, Research, and Service (STARS) was an early alliance formed in the spring of 2006 [36]. In 2008, the STARS alliance included eleven academic institutions [36] and currently includes over 53 institutions [17]. The alliance builds a community of practice in support of faculty, students and community/K12 partnerships to build capacity for "taking action for diversity, inclusion, and equity in computing" [17]. STARS researchers examined the impact of the STARS program of computing-centered community service on persistence in computing for Black college students; findings indicated that a key component for persistence of Black students in computing is being able to develop networks and have colleagues and mentors with whom they identify [35].

The Computing Alliance of Hispanic-Serving Institutions (CAHSI) was established in 2006 through funding from the NSF's BPC program and included eight Hispanic Serving Institutions (HSI). The goals of the alliance are to increase the participation of Hispanic people in all fields of computing and develop competitive computing degree programs and research at HSIs [19]. CAHSI has been recognized by the White House Initiative on Educational Excellence for Hispanics and received further funding from the NSF as one of only five recipients in 2018 to be designated as a National INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discovers in Engineering and Science) alliance [87].

The Alliance for Access to Computing Careers (AccessComputing) was founded in 2006 and aims to "increase the representation of people with disabilities in a wide range of computing careers" [22]. It currently has over 100 partnerships with universities, organizations, and companies. The website provides resources on interventions that can be used to make computing programs more accessible to people with disabilities [12]. For example, a detailed checklist for making computing departments welcoming and accessible to all students is included [15].

2 LITERATURE REVIEW OF BPC

Improving the diversity of computing by increasing the number of women and people of color in computing was not novel when the BPC program began. Research in the 1980s suggested that software was designed for males, and challenged the current notion that computing was more difficult and less appealing for females[52]. In 1983, researchers [38] pointed out that advertisements contained stereotypes related to women and people of color using computers and that this depiction may discourage people from these groups from having an interest in computing. This section examines the representation of diverse demographic groups in computing from the late 20th century to recent years and covers the advocacy for increased participation of each demographic group in computing research. U.S. population statistics will be utilized as a benchmark; if a particular demographic's representation doesn't match its representation in computing, it is considered low [93].

2.1 Representation of Women in Computing

Before the BPC program, diversity efforts in computing largely focused on recruiting women. While other STEM fields had a steady growth of women awarded bachelor degrees from 1970 to 2000, the percentage of women earning computer science degrees began steadily declining in the mid-80s [31]. Between 1991 and 2001, the percentage of women intending to major in computer science in the U.S. dropped by almost 50% [31] causing researchers to search for causes. In 1999, Cohoon emphasized the potential influence of departmental structure on deterring women from the field [32]. Some researchers also found that women are more interested in computer science when they feel their work has a social impact [50, 86].

From 1995 to 2014, the representation of women earning bachelor's degrees in computing decreased from 28.5% to 18.1% [?]. By 2021-2022, this number only increased to 22.7% [81]. While an increase was observed, this is far from meeting the 50.4% of women that make up the U.S. population [11]. While all students in computing are affected by the high attrition rates present in the major, there is a much higher attrition rate among students who are women across STEM majors. Women majoring in STEM switch to a non-STEM major at a rate of 32% compared to 26% of men who switch [67].

2.2 Representation of Black Men and Women in Computing

Before the BPC program, limited research focused on students of color. Between 1955 and 1995, there was a consistent increase in Black men and women majoring in computer science [92]. Until the late 1970s, this was primarily at the original 6 Historically Black Colleges and Universities (HBCUs) whose policies were pushing for the growth of computer science programs. This was prompted by action from the Planning Commission for Expanding Minority Opportunities in Engineering to provide additional funding to HBCU6 institutions to expand and improve engineering programs. In the mid-1970s students graduating from HBCUs were equally as likely as a student from any other U.S. institution to have earned a computer science degree. By the late 1980s, parity in earning computer science degrees was seen among Black students at any U.S. institution, with HBCU rates doubling. In the 1960s, the original six HBCU campuses in the U.S. graduated around 2 women each per year, but by 1980 these same six campuses were graduating 100 women total between them each year [92].

By the 1980s, graduation rates for Black students in CS have been disproportionately dropping. The percentage of Black students graduating with computer science degrees dropped from 10.16% in 1995 [4] to 8% [10] in 2020. A decline can also be observed when looking at Black women earning computer science degrees (5.10% in 1995 [3] to less than 3% in 2016 [6]). Black Americans represent 12% of the U.S. population [37]. HBCUs continue to be fundamental to increasing participation of Black men and women in computing. Although HBCUs only represent 3% of universities nationwide they graduated 10% percent of Black CS majors in 2020 [41].

2.3 Representation of Hispanic Men and Women in Computing

In the 1980s, Burns [24] recognized that there was a clear underrepresentation of Hispanic students in technical fields. In the academic year of 1976-1977, Hispanic students represented 1.7% of bachelor's degrees awarded. Since then there has been a steady increase in the percentage of computer science bachelor's degree earners who are Hispanic. Hispanic student representation of earned computing bachelor's degrees grew from 5.31% in 1995 [4] to 9.8% in the 2021-2022 academic year [81] (18% U.S. population [37]). However, this increase is not observed when looking at Hispanic women; their representation changed from only 1.75% to 1.76% from 1995 to 2021-2022 [3, 81]. This is a very stark contrast when compared to the 9.2% of Hispanic women who are represented in the U.S. population [11].

2.4 Representation of Students with Disabilities in Computing

While there is a lot of demographic information relating to gender and ethnicity in computer science undergraduate students, it's challenging to find statistics about students with disabilities in computing because of reporting inconsistencies [80]. In 2017, a survey was conducted of computer science undergraduate students that included 9,591 participants. Of these participants, 7.9% reported that they had a disability [8]. In the NSF's 2023 Diversity and STEM report, the "Characteristics of the STEM workforce…" figure shows that the percentage of people in the STEM workforce who have a disability remained at 3% from 2011 to 2021. The NSF's 2012 diversity report indicated that almost 20% of undergraduate students with a disability enrolled in a STEM major and that this was a similar percentage to students without a disability [2]. As of 2020, less than 8% of undergraduate computer science majors had a disability [8] compared to the representation of 19% of all undergraduate students [5], as of 2018, and a representation of 13% in the U.S. population, as of 2021 [33]. These statistics indicate a clear need to increase accessibility and inclusion of students with disabilities. Additionally, addressing the challenge of identification and self-reporting for people with disabilities is needed.

It's clear there is still much work to be done to increase the representation of women, Black women and men, Hispanic women, and students with disabilities in computer science.

3 CURRENT BPC RESEARCH

While early work on diversifying the computing field focused on women and evolved to include men and women of color, current BPC work is evolving to include intersectional identities. There is research focused on women of color, Black women, Hispanic women, students with disabilities, LGBTQ+ students, and students with disabilities in K12. Many intersections that exist within computing remain unexplored. There has been a call to action for conducting diversity studies with an intersectional lens by many researchers in non-computing fields [61, 79] and in recent years in the BPC field by many respected computer scientists including Rankin and Thomas [71, 73], Washington [90, 91], as well as Rodriguez [77] and Ashcraft [20]. The dearth of research across intersectional groups is a barrier to achieving BPC goals of equity and inclusion. "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" [85]. Conducting research with a specific intersectional group at the forefront enables an understanding of the unique concerns and experiences of people across the complex landscape of identity.

3.1 Seminal Research about Intersectional Groups in Computing

3.1.1 Black Women. Research focusing on Black women has found that they experience isolation in computing [71]. Having communities and clubs on campuses focused on Black students or Black women in computer science or STEM majors can help with this isolation and increase persistence [71]. Black women face many other challenges in pursuit of a computer science degree, including expectations that are too high or too low, racism, sexism, discouragement, and job dissatisfaction [85]. However, these women are more likely to persist if they have a mentor, established personal and professional goals, and do work focused on human interaction [85]. Ways to make the field of computing more inclusive and welcoming to Black women include fostering communities for Black women that bring together undergraduate students, faculty, and/or those working in industry, such as Black Women in Tech chapters [49].

3.1.2 Hispanic Women. A study published in 2020, documents the experiences of 8 Hispanic women enrolled in engineering or computer science undergraduate degrees in a university near the U.S./Mexico border [65]. Several of these women reported the importance of having friendships in the courses, especially with other women, as well as family support and mentors. Other research also highlights the significance of support from parents and siblings, as well as community, extended family, and friends [74], as well as mentors and role models [48]. Rawhiya [74] also identified the importance of informal learning environments outside of school for cultivating a strong computer science identity for Latinas. There remains a lack of research on Hispanic women that is specifically about computing. Latinas' cultural perspectives vary a great deal depending on where they're from, whether that be the U.S. or any number of countries. To be inclusive and aware of all the multi-faceted perspectives across Hispanic cultures, a great deal more research is needed.

3.1.3 Students with Disabilities. 7.4 million K12 students nationwide have disabilities, representing 15% of all K12 students [46], yet there are few studies about students with disabilities in computing. While there are many studies about accessibility in undergraduate [25, 30] and K12 [56] computing classrooms, further exploration of students with disabilities in computing has been long called for [23]. This is an area that researchers should delve into more deeply, as well as the intersectional perspective of women with disabilities and LGBTQ+ students with disabilities.

3.1.4 Gender Identities. In recent years there has been an increase in research centered around LGBTQ+ students in computer science as well as LGBTQ+ researchers [40]. While research focused on women and girls, in general, has been established and prioritized for many decades, there is a need for BPC researchers to identify how the experience of people identifying as transgender and/or non-binary aligns with and diverges from cisgender students [66]. Some research in this area has focused on recommendations to adapt teaching methods and materials to be more inclusive to the LGBTQ+ community [78]. Other research has measured the sense of belonging of LGBTQ+ computer science students [82]. BPC research is expanding as researchers are called to understand intersections between gender, ethnicity, and belonging in the LGBTQ+ community as well as more specific LGBTQ+ identities.

3.1.5 Asian Women. One virtually unexplored area of students in computing is Asian women. While Asian women do not have low participation in computing (representing 8% of computer science degrees [81]), based on their representation in the U.S. population (Asian people represent 6.3% [11]) and number of bachelor's degrees earned (3.5% in 2018-2019 [14]), research has identified that they, like other women, deal with many hardships working in the field [84]. One study has found that women who are Asian-born, U.S.-educated Asian immigrants, and Asian-born, Asian-educated Asian immigrants earn less than white men in similar industry positions. Only U.S.-born, U.S.-educated Asian-American women did not tend to experience this [83]. Based on this finding, more work should be done focusing on the experiences of Asian women who are immigrants to the U.S.

3.2 Effective BPC Teaching Approaches

Many strategies for BPC have been demonstrated effective, such as pedagogical approaches like inclusive pedagogy and culturally relevant pedagogy. Inclusive pedagogy is an instructional approach proposed by Florian and Black-Hawkins [44] that acknowledges individual student differences but aims to prevent the marginalization that is often associated with differentiation strategies that solely address individual needs. In one study, based on research that women are more drawn to work benefiting humanity [62, 70] and are more dependent on social networking than men, the researchers created a Facebook discussion group among students of the class and replaced the traditional class assignments with ones that reflected current real-world issues [51]. Another study, considering students who may have no prior coding experience, proposes a new structure for a statistics course that begins with students using SCRATCH to learn basic programming concepts, instead of immediately learning R [59].

Ladson-Billings' model of Culturally Relevant Pedagogy [57] centers on three key elements: prioritizing student academic achievement, nurturing cultural competence for positive identity development, and fostering critical consciousness to recognize and challenge societal inequalities. Scott [**? ?**] designed a program that generated interest in computing for K12-aged girls. The girls are presented with a social justice concept and technical aspects of a form of media that they discuss applications for in small groups and then present to the class. In another study, young girls (7th and 8th grade) participating in a robotics programming workshop found ways to connect their unique identities with computing. For example, in one exercise they were asked to program the robot to greet them according to their culture [58].

3.3 Pipeline Strategies

Outreach programs are often used to plant an interest in computing at a young age and combat negative perceptions of computer science. Researchers in a study of Black and Latino middle school boys, point out several studies that highlight common perceptions of computing. Some of these perceptions are negative (isolating, difficult, geeky, etc.), however, even positive perceptions (smart, curious, making lots of money) did not have a positive impact on the students' ability to see themselves as a computer scientist [42]. Conducting outreach and building school programs with a focus on computer science also requires K12 teachers to partake in workshops and receive relevant training [29]. STARS [**?**] and NCWIT [16]are both BPC alliances with far-reaching pipeline programs.

As previously mentioned, mentorship serves as another effective pipeline strategy, especially for Black and Hispanic women [48, 85]. Several researchers [53, 76] have noted the lack of research into the possibility that mentorship may be more effective if the mentor and mentee share a similar intersectional identity. During the research process of this paper, information on all national and international fellowship programs that are focused on or include computing were collected. Out of about 60 programs, only half provide mentorship, and many that are specifically focused on selecting students who are women, LGBTQ, Black, or Hispanic don't include a mentoring element.

While improving diversity within the computing major will always be a primary goal of BPC, there is a need to demonstrate that a minor, concentration, or double major in CS can be a value investment to women and BIPOC already in a bachelor's program. While changing majors entirely may be unappealing to some non-computing majors, computer science is relevant to many fields and could be combined with their current degree program giving them an edge when applying to industry jobs. Northwestern University has a "CS+X" program that aims to provide undergraduate students in all majors throughout the university to CS courses that are relevant to non-majors. Initiatives like this have the potential to further diversity in the computing industry.

4 FUTURE DIRECTIONS FOR BPC WORK

Embedding diversity across the computer science curriculum could serve as another effective strategy in BPC. A lack of awareness that creators of some technology have of people outside of their own identities has proven to be a problem [27, 60]. Computing professionals need to have awareness to consider the diverse range of perspectives and needs of the people who will use the technology they create. Intersectional design discussions in human-computer interaction (HCI) [54] are not always covered extensively in undergraduate HCI courses, and many computer science students may finish their bachelor's without HCI coursework. Designing with every user in mind should be a concept that is as widely taught in CS courses as the importance of efficiency in programming. Diversity of thought and application is the ethical approach, not just an enterprise solution as is often the popular case made for diversity and inclusion.

While efforts to broaden participation in computing have empowered marginalized groups in some ways, addressing systemic and socio-political barriers remains imperative. A significant step in this direction is any integration of CS into K-12 curricula [39, 55]. This ensures universal access to fundamental CS education. This shift is one step towards embedding diversity, equity, and inclusion within education and society, alleviating the burden on marginalized communities to navigate systemic obstacles alone.

With the advent of artificial intelligence, AI is a tool that presents unique and exciting opportunities to expand pedagogical and pipeline approaches in BPC programs. Universities and industry are building partnerships to enhance CS education by training faculty, teachers, and offer classroom materials that are engaging, such as AI4All. The application of AI can be a pivotal tool for BPC in that AI provides direct link to exploring ethical issues about equity and inclusion, while providing the fascination that research shows to be essential to students [26, 94].

5 CONCLUSION

The field of BPC has come a long way since its establishment in 2005. While many demographics still require more representation in computing, researchers have made progress toward creating a more inclusive, accessible, and welcoming computer science field. In order to further progress, researchers must recognize the progress that has been made thus far and identify where research in BPC is lacking. Several areas that require further exploration have been discussed.

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