

Review

# Women of Color Leveraging Community Cultural Wealth to Persist in Computing and Tech Graduate Education: A Qualitative Meta-Synthesis

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**Abstract:** This paper synthesizes 20 years (1999–2019) of empirical research on women of color (WOC) in computing and tech graduate education. Using complementary theoretical frameworks of social pain and community cultural wealth (CCW), we identify factors in the research literature that affect WOC's experiences, participation, success, and persistence. This qualitative meta-synthesis employed systematic literature search and selection methods, a hybrid approach to coding and thematic analysis. Findings include the ways in which social pain from isolation, exclusion, and hostility from peers and faculty negatively affected WOC's experiences in their graduate programs. Often, WOC's motivation to persist and succeed in computing came from key social actors, such as mentors and families, and from individual and social strategies, such as seeking counterspaces, that leveraged their CCW. This meta-synthesis contributes to the knowledge base about the mechanisms that support and hinder the persistence of WOC in computing graduate programs and provides recommendations for institutions and for further research.

**Keywords:** computer science education; equity in higher education; graduate education; women of color; meta-synthesis; community cultural wealth; social pain



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## 1. Introduction

One of the fastest growing professions in the United States is within the field of computer science (CS) and related fields, typically offering high salaries and promising job security, especially for those with graduate degrees [1]. However, women of color (WOC) in the U.S. are significantly underrepresented in CS graduate education relative to their presence in the U.S. population. In 2018, WOC represented 21.2% of the population, while representing 16.8% of CS master's and 8.5% doctorates in the same year [2,3]. According to the data, women who are Black/African American, Hispanic/Latinx, American Indian and Alaska Native, and Native Hawaiian and Pacific Islander are especially underrepresented (see Table 1). The only exceptions are Asian/Asian American women, who are not underrepresented in CS graduate education. However, once in the workforce, they are less likely to be in positions of leadership than white women [1]. For this reason, they are included in this meta-synthesis.

Research shows that WOC, who live at the intersection of two minoritized identities (being both a person of color and a woman), tend to experience additional challenges in STEM compared to white women, white men, or men of color (e.g., [4,5]). In a previous study synthesizing literature on WOC in STEM prior to 2009, Maria Ong, Carol Wright, Lorelle Espinosa, and Gary Orfield [5] wrote:

The existing empirical work on graduate experiences overwhelmingly identifies the STEM social and cultural climate—that is, the interpersonal relationships with other members of the local STEM communities and the cultural beliefs and

practices within STEM that govern those relationships—as the leading challenge to the persistence of women of color in STEM career trajectories.

(p. 192)

Other factors at the STEM graduate level affecting WOC’s persistence that the study found included the availability of financial aid and other funding; the availability of mentors and role models; support (or lack thereof) of faculty and family members; and opportunities to do community outreach. However, their work [5] identified only six works published between 1970 and 2008 that focused specifically on the experiences of WOC in “computer science/technology” (p. 179) at the graduate level, and their findings were not reported in the synthesis by discipline.

**Table 1.** Representation of Women of Color in the U.S. Population and Earned Graduate Degrees in Computer Science (2018) <sup>a,d</sup>.

	% of Total Population	% Master’s	% Doctorates
Women of Color	21.2%	16.8%	8.5%
Black/African American	6.7%	4.8%	2%
Hispanic/Latinx	9.2%	2.2%	1.8%
American Indian & Alaska Native	0.4%	0.1%	D <sup>b</sup>
Native Hawaiian & Pacific Islander	0.1%	n/d <sup>c</sup>	0.0%
Asian/Asian American	3%	6.2%	4.7%

<sup>a</sup> Elaborated with data from the U.S. Census Bureau (2018) and the National Science Foundation (2018).

<sup>b</sup> D = suppressed to avoid disclosure of confidential information (National Science Foundation, 2018).

<sup>c</sup> n/d = data not available because data on Pacific Islanders was reported as part of the Asian classification.

<sup>d</sup> Table originally published in Jaumot-Pascual et al. (2021) © 2021 IEEE.

More recently, a few studies have focused on related topics, such as graduate students of color (both men and women) in CS and engineering [6], WOC graduate students in general STEM (e.g., [7,8]), and African American women transitioning from undergraduate programs in historically Black colleges and universities (HBCUs) to graduate programs in STEM in predominantly white institutions (PWIs) (e.g., [9]). The majority of recent research on WOC in computing and tech has focused on the undergraduate level (e.g., [10,11]). Across these related studies, consistent themes arise, including perceived messages of not belonging; negative interactions with faculty and peers; experiences of invisibility and hypervisibility; feelings of exclusion, isolation, or being tokenized; experiences of impostor syndrome; and exhaustion from the emotional toll from coping with these stressors. Joseph’s [9] study additionally described the chilly climate experienced by Black women in STEM doctoral programs at PWIs and a series of strategies for success that ranged from resistance and navigation strategies (e.g., refusing to give up, seeking mentors), to strategies directed towards their departments (e.g., asking faculty for help, becoming involved in departmental activities), to social strategies (e.g., seeking counterspaces on and off campus). Despite the growing knowledge base on students of color in computing and on WOC in STEM, it must be noted that *WOC in computing and tech graduate education* remains a severely understudied population. The purpose of this paper is to bring together and synthesize findings from eleven empirical research studies published between 1999 and 2019 and to suggest a research agenda and policy reform to better understand and advance future WOC in computing and tech.

## 2. Theoretical Framework

The themes of struggle and strategies for success described above were resonant with findings in the present meta-synthesis of the literature, discussed below. In this

meta-synthesis, we frame these themes in two complementary theoretical frameworks that encompass them.

### 2.1. Social Pain

We bring together themes related to struggle in computing and tech fields due to social experiences under the social pain framework. Maria Ong, Nuria Jaumot-Pascual, and Lily Ko [12] adapted the psychology term *social pain* to refer to a set of experiences related to rejection and a lack of belonging in STEM. Citing the work of Eisenberg and Lieberman [13], Ong and colleagues explain:

When a human experiences social pain—including rejection, feeling left out, or feeling like one does not belong—it triggers a neural reaction that may be analogous to a reaction to physical pain. A physiological alarm goes off, interrupts current tasks, and focuses attention on mitigating the pain.

(p. 595)

Experiencing social pain itself and managing one's reactions to social pain often take an emotional toll. Furthermore, they divert cognitive resources toward managing the social situation and away from other areas, such as engaging in graduate education. The four types of social pain identified by Ong and colleagues [12] included: being the only one, being made invisible, stereotype threat and being spotlighted, and discrimination and harassment. Oftentimes, those experiencing social pain felt as if they did not belong. These experiences overlap with the experiences identified for the present synthesis. Moreover, in a related STEM report on identity-based harassment (denigrating behavior targeting individuals due to their social group membership(s)), Herbers et al. [14] reported that subtle, repeated harassment such as gaslighting or microaggressions may create “hostile environments and can be more damaging than a single more egregious event” and that individuals with multiple marginalized identities, such as women of color, experience more frequent and more severe instances of harassment (p. 9). It is imperative to note that experiences of social pain are not benign; previous syntheses—e.g., [5,12]—have shown that they are key reasons for attrition from STEM and engineering. Therefore, resources and strategies for navigating and mitigating experiences of social pain are major reasons for persistence.

### 2.2. Community Cultural Wealth

In this paper, under the community cultural wealth framework, we introduce several strategies for navigating and mitigating social pain to persist in STEM and computing fields. Yosso [15] developed the community cultural wealth (CCW) framework within the tradition of critical race theory as applied to education [16,17]. In this framework, she challenged the traditional, deficit-based interpretations of cultural capital in communities of color. She integrated the knowledges of communities of color in a framework that centers and acknowledges them with the goal to transform the process of schooling. This framework includes six capitals: aspirational, linguistic, familial, social, navigational, and resistant capitals. See Table 2 for definitions of these capitals.

Several scholars have fruitfully applied the CCW framework in STEM education (e.g., [18,19]) and in disciplines such as engineering (e.g., [12,20]). Denton et al. [21] conducted a systematic review of how CCW has been applied in STEM education research. Of the 33 pieces they identified, most were focused on the undergraduate level and in the discipline of engineering, and the majority of studies were qualitative and relied upon student interviews. Denton and colleagues [21] raised especially intriguing claims about resistant capital within STEM education. Namely, they claimed that participation in volunteering opportunities to encourage interest in STEM among younger students of color was a form of resistant capital that appeared in the literature they reviewed, and persistence in a field such as engineering that is not set up to include WOC was, itself, a manifestation of resistant capital. Although we focused on the graduate level in computing

and tech, our synthesis resonated with many of the points Denton and colleagues made, and we will return to them in the Findings and Discussion.

**Table 2.** Definitions of Community Cultural Wealth [15].

Type of Capital	Definition of Capital by Yosso (2005)	Example
Aspirational capital	“Ability to maintain hopes and dreams for the future, even in the face of real and perceived barriers” (p. 77)	Desire to succeed
Linguistic capital	“Intellectual and social skills attained through communication experiences in more than one language and/or style” (p. 78)	Storytelling, art, communication skills
Familial capital	“Cultural knowledges nurtured among <i>familia</i> (kin), that carry a sense of community history, memory and cultural intuition . . . expands the concept of family to include a more broad understanding of kinship” (p. 79)	Parents’ words of encouragement, community support, kin modeling success
Social capital	“Networks of people and community resources” (p. 79)	Counterspaces such as student groups, affinity groups
Navigational capital	“Skills of maneuvering through social institutions” (p. 80)	Receiving mentoring, engaging in networking
Resistant capital	“Knowledges and skills fostered through oppositional behavior that challenges inequality” (p. 80)	Oppositional behavior, teaching others how to resist and persist in a hostile environment

As Yosso [15] highlighted, “These various forms of capital are not mutually exclusive or static, but rather are dynamic processes that build on one another as part of community cultural wealth” (p. 77). As such, these capitals often overlap, support, and build onto each other as in the following example provided by Yosso. Family members who provide stories and advice to navigate an oppressive educational system to motivate youth to obtain a formal education, support community cultural wealth through several capitals: storytelling and advice using linguistic capital; the strategies embedded in the stories and advice provide access to navigational capital; and the motivation to obtain a formal education accesses aspirational capital. Through this statement and example, Yosso provides a powerful way to understand the dynamism of intersecting or overlapping capitals towards persistence in environments not set up for minoritized individuals’ success. Most researchers identify how the individual capitals appear in their research but may ignore or overlook how several capitals may overlap and be activated at the same time [21].

The present meta-synthesis study is unique as it addresses the dearth of published literature and synthesizes nearly 20 years (1999–2019) of empirical research to emphasize, through the lens of CCW, elements contributing to WOC’s persistence in computing and tech graduate education in spite of elements of social pain that hinder them. We pay particular attention to how the different capitals overlap in the literature and how CCW provides an antidote to the social pain experienced by WOC in computing and tech graduate education. We also provide recommendations for leaders in computing and tech graduate education and research. This synthesis study addresses the following synthesis question: According to the literature from the last two decades (1999–2019), what factors affect the experiences, participation, advancement, and persistence of WOC in computing and tech graduate programs?

### 3. Materials and Methods

The methods description in this paper was originally published in Jaumot-Pascual et al. (2021) © 2021 IEEE. We followed Tomas and Harden’s [22] overall methods for conducting a thematic synthesis, which is a type of qualitative meta-synthesis, that uses systematic

methods for the search and selection of the literature and thematic analysis to develop meta-findings. We provide an overview of the methods our team used to search, select, and analyze the appropriate literature for this qualitative meta-synthesis. For a more detailed explanation of our methods, please refer to Ong et al. [12]. Given that this work is a meta-synthesis and not a systematic review, it does not follow the PRISMA guidelines.

### 3.1. Stage 1: Pre-Search & Start Set

Before the identification of relevant empirical research literature, we conducted the pre-search activities necessary to lay out the parameters of the search and selection of literature, established and detailed in our previous meta-synthesis study [12].

#### 3.1.1. Pre-Search Activities

We first created a list of criteria to select studies to include in the synthesis. We sought empirical studies published between 1999 and 2019 (when our search phase ended) that reported research on WOC in computing and tech graduate education and applied critical appraisal criteria, which determined basic methodological elements necessary for a research study's inclusion.

We conducted a comparative test of 16 search engines to find the best tools for our search process to identify those with the most optimal yield in terms of number of results, diversity of types of publication (e.g., dissertations, conference proceedings, peer reviewed, books, reports), and relevance of results. Once the test narrowed the engines down to seven, we learned their Boolean rules to do our searches. We created a list of search terms matching the content fields in our criteria and built "search strings" by creating all the possible combinations of our search terms using the engines' Boolean rules.

#### 3.1.2. The Start Set

We then proceeded to establish the start set, which is the initial group of full-text primary research reports that become the basis for the subsequent literature searches through snowballing. We entered the search strings and publication range into the search engines and conducted the searches. Our team then identified which references to keep by applying two filters and a critical appraisal. In Filter 1, we sifted through titles and abstracts for a first yield of the literature. In Filter 2, we read the remaining full pieces to ascertain that they fulfilled the criteria. In the critical appraisal, we determined whether each study included the preselected basic elements of a research study. The studies that remained after the three screening steps became part of the start set. Throughout these steps, the literature was tracked and catalogued.

### 3.2. Stage 2: Forward and Backward Snowballing

Forward and backward snowballing [23] were used to identify additional literature. Forward snowballing involved finding the literature that cites each of the pieces in the start set, which results in more recent pieces. Google Scholar's "Cited by" feature is the tool we used for this purpose. Backward snowballing involved reviewing literature that was cited in the bibliographies of the pieces in the start set, thus resulting in older literature. We then repeated the same three screening steps and tracking and cataloguing processes described above. The start set, combined with snowballing, resulted in a total of eleven pieces for this meta-synthesis (see Table 3).

**Table 3.** Empirical Research on WOC in Computing Graduate Education Included in the Meta-Synthesis <sup>a</sup>.

Author/s and Year	Literature Format	Methodological Stance	STEM Field	Race/Ethnicity and Gender Descriptors <sup>b</sup>
Agbenyega (2018)	Dissertation	Qualitative	Computer sciences & engineering	Latina/Hispanic women
Ashford (2016)	Dissertation	Qualitative	Computing disciplines	African American women
Charleston, George, Jackson, Berhanu & Amechi (2014)	Peer reviewed journal article	Qualitative	Computer science	African American women
Herling (2011)	Dissertation	Qualitative	Computer science	Hispanic women
Hodari, Ong, Ko & Kachchaf (2014)	Conference proceedings	Qualitative	Computer science	African American/Black, Asian American, Latina, White, Arab, Native American, mixed race women
Hodari, Ong, Ko & Smith (2015)	Conference proceedings	Qualitative	Computing disciplines	Asian American, Latina, Black women
Hodari, Ong, Ko & Smith (2016)	Peer reviewed journal article	Qualitative	Computer science	Asian American, Black, Latina, Native American, Arab women
Middleton (2015)	Dissertation	Mixed methods	Information technology	African American women
Murray-Thomas (2018)	Dissertation	Qualitative	STEM (e.g., computer science, veterinary science, environ. sciences)	Black females
Thomas, Joseph, Williams, & Burge (2018)	Conference proceedings	Qualitative	Computer science	Black women
Tran (2011)	Dissertation	Qualitative	STEM (e.g., computer science, biological sciences, chemical science)	African American, Latina/o, and American Indian men and women

<sup>a</sup> Table originally published in Jaumot-Pascual et al. (2021) © 2021 IEEE; <sup>b</sup> descriptors listed originate from the authors' respective pieces of literature.

### 3.3. Stage 3: Iterative Analysis

Following the establishment of our literature set, we established a codebook and analyzed the literature pieces as data in an iterative process.

#### 3.3.1. Establish Codebook

We created a codebook through a hybrid approach to coding in thematic analysis [24] that used both deductive [25] and inductive [26,27] coding. We then brought together the two sets of codes to consolidate them in a single codebook, which was treated as a living document, periodically updated, and refined by team consensus [26,27].

#### 3.3.2. Analysis Steps

We analyzed the resulting pieces of scholarship through iterative analysis based on team check-ins and consensus to solve coding disagreements and to achieve consistency across the team. Analysis included the following steps: (1) creating analytical memos for each of the studies, which synthesized their main findings; (2) using the codebook to code the memos; (3) conducting thematic analysis to create the synthesis meta-findings; and (4) discussing findings through the lens of the theory in our conceptual framework.

### 3.4. Positionality Statement

The four authors of this meta-synthesis identify as women who are minoritized due to their intersecting identities and/or their national origins/cultural backgrounds. As such, the team is interested in highlighting the experiences of WOC in computing and tech and diversifying computer science and related fields as social justice issues that will help in providing WOC with access to careers with growth and high pay potentials.

## 4. Results

Below, we organize the major findings in our meta-synthesis of literature on graduate WOC in CS and related fields using the concepts of our theoretical framework: social pain and CCW. The first section shows instances where WOC contend with different types of social pain in predominantly white institutions (PWIs) and how these redirect their energies away from their graduate studies. These findings around social pain ground the need for the implementation of the CCW framework, where WOC leverage the different capitals that serve as sources for persistence in hostile computing and tech environments. It is important to note that, in each thematic section, we provide only a few illustrative examples of the experiences of WOC in graduate computing education, which are representative of others not cited here.

### 4.1. Social Pain

Throughout the synthesis literature, it was evident that WOC who pursued computing and tech in graduate school in PWIs often faced social barriers that triggered social pain, which hindered their ability to persist and succeed in computing-related fields by divesting intellectual and emotional resources from their academic work and toward the negative social situation at hand. WOC often experienced social pain through a culture of exclusion and hostility which manifested in various ways. This included unwelcoming environments, exclusion, and isolation from classmates who were predominantly white male peers [28–32]. These elements were exacerbated by the absence of institutional support for WOC and members of other minoritized groups [29]. As WOC navigated this culture of exclusion and hostility, they encountered various stereotypes that contributed to feelings of not belonging and social pain. The major contributors (or enforcers) of these negative experiences were professors who, at times, publicly humiliated and expressed hostile attitudes towards WOC in front of the WOC's classmates [28,29,31,32]. For example, Maddie, an Asian American woman pursuing her Ph.D. in CS in Hodari et al.'s [31] study, described how her graduate advisor doubted her scientific abilities and then stopped speaking to her altogether.

[After] an unsuccessful presentation, [Maddie's] advisor expressed extreme disappointment in her, saying he had "serious doubts about [her] scientific abilities". Furthermore, rather than discuss Maddie's performance, he stopped communicating with her for months. Maddie explained the harmful effect this had on her motivation to pursue computing: "It was kind of, unfortunately, a defining moment which probably pushed me away from science . . . I eventually got a thesis and defended [but] we never really spoke about that again . . . He said he was relieved to know that I wasn't completely clueless, but it was really upsetting, because his first assumption was that I was clueless."

(p. 87)

In Ashford's [28] study on African American women who had obtained Ph.Ds in a computing discipline, one of the participants recounted how a white male professor in her master's program told her she was not "creative or intelligent enough to get a Ph.D." but was "an excellent affirmative action candidate" (p. 116). Likewise, in Charleston et al.'s [29] study, an African American participant shared how a faculty member undercut the success of another African American woman graduate student in CS. The faculty member was reported as saying:

I don't think she has talent. I think White professors gave her grades because of her race and they felt bad about slavery. I don't think there are any real computer scientists who are Black, and maybe she can be the first.

(p. 172)

Although this last comment was about a specific individual, it potentially caused pain to minoritized others within earshot due to its denigrating nature that racial guilt, and not intelligence or hard work, must be the reason for her good grades. Further, potential pain

could be experienced by students who overheard, but were not in positions to correct, the professor's ignorance about the facts that Black women have been earning Ph.Ds in CS since the late 1970s and have played "real" key roles as human "computers" and computer scientists at NASA, IBM, and elsewhere since the 1950s [33].

Social pain caused by professors' hostile conduct did not stop at just words but, for some, included physical assaults and threats. One of Ashford's [28] participants, an African American woman named Susan, disclosed how a white male professor physically assaulted her during a class discussion she was leading by hitting her over the head with a stack of papers in front of the entire class. Susan also shared how there would be periodic appearances of the Ku Klux Klan (KKK) at her school's campus, contributing further to a heightened presence of racism on campus as she pursued her CS Ph.D.

Now we were in [the deep South]. It was already hard enough to come to school every day with the KKK out on the lawn. Then, you're going [to hit me on the head with a stack of papers]. That was just so demeaning. You don't do that to adults. [He treated me] like I was just a dog . . . I do not know how in the world I even continued. I was completely caught off guard. I would have never expected anything like that. Of course, I made it through the class. Then right after the class, I cried a flood of tears.

(p. 120)

Experiences of social pain due to a culture of exclusion and hostility were not limited to interactions with professors. The literature shows that peers also played key roles. Participants in Charleston and colleagues' [29] study shared how Black women in computing and tech had to contend with negative stereotypes related to their academic and intellectual abilities. One participant in their study declared, "There are often assumptions that I am supposed to act a certain way because I am a Black woman" (p. 171). The researchers added of this participant, "She continued to describe how she felt others expected her to get upset or defiant when events would occur that were not particularly in her favor" (p. 171). In this study and others [28,30,31,34], researchers noted that participants widely shared experiences of isolation and having their academic competence questioned.

Beyond racial stereotyping, WOC also experienced social pain due to exclusion. WOC did not fit the nerd stereotype that is often associated with men pursuing computing and tech [30]. In Herling's [30] study on Hispanic women in computing, participants discussed "not fitting in because they had different interests and did not speak the same 'language' as their male classmates" [30] (p. 65). These participants could not relate to their male peers' humor or taste in gaming, often making it difficult to feel as if they belonged or to have conversations with their male peers.

As we will see in the next section, one way WOC coped with the different types of social pain in their computing graduate education was through the enactment of their community cultural wealth.

#### 4.2. Community Cultural Wealth

Although WOC encountered many instances of social pain, we identified several ways WOC mitigated the effects of social pain using their CCW. We organize this section's findings according to the six types of capital that Yosso [15] defined. As noted previously, these capitals were often leveraged in an overlapping fashion with other capitals. Thus, after providing examples for the six types of capital, we include examples from the literature where more than one type of capital was activated.

##### 4.2.1. Aspirational Capital

WOC accessed their aspirational capital to navigate and resist the social pain inflicted by the culture of exclusion and hostility they encountered in their CS and tech graduate education by maintaining their desire to succeed in institutions that were not designed with them in mind. Their aspirational capital helped them resist negative stereotypes and persist to complete their graduate programs [28,32]. The desire to succeed was apparent

among participants in Ashford's [28] study. Three African American women resisted the negative stereotypes imposed on them by white male graduate professors. Such was the case of Bianca, who was pursuing her master's at the time. She had a professor who told her and other African American graduate students that they were not Ph.D. material. Despite being discouraged by his words, Bianca felt determined to complete her master's and, afterwards, pursued a Ph.D. and became a professor.

Jasmine, an African American woman in a computer science Ph.D. program in Tran's [32] study, recounted that during an undergraduate internship, she learned from her boss that, in order to be respected for her analytic thinking and to have a front-row seat in company decision-making, she needed to obtain a doctorate. Instead of discouraging her, this realization motivated her to pursue the degree.

Aspirational capital was not only accessed as a response to negative experiences. In some cases [35,36], WOC's aspirational capital was a positive force that encompassed their desire, ambitions, expectations for a better life, and the desire to belong to a valued community. These helped WOC persist and complete their graduate programs. Such was the case of one African American woman in Middleton's [35] study, who shared how her own ambition and determination motivated her to pursue her master's degree:

It was just ambition itself . . . I was the first in my family to get a master's degree . . . I wanted to be successful. I wanted to have a career, something I could be proud of. I wanted to make my mom proud. I've learned just over the years growing up that, you know, that I have to do well in school . . . it just kind of motivated me.

(p. 107)

In Murray-Thomas's [36] study, older peers helped inspire some WOC to pursue graduate school, as was the case for Nikki, a Black woman pursuing an advanced degree in CS. Nikki recounted how her peer network motivated her because she wanted to be a part of the same community as them.

I have friends that have advanced degrees. . . . (I) just wanted to be a part of that community. It was just set in my mind to; this is what I want to do. This is what I have to do. If it meant sacrificing, not going to something, that's what I had to do. . . . With me doing it, it would get me a better job. Not necessarily the case, but that was my mindset. That it would advance me in my career.

(p. 73)

The examples of Bianca, Jasmine, and Nikki show how aspirational capital provided them with the motivation to not only persist, but to succeed and aim higher in their careers.

#### 4.2.2. Linguistic Capital

In this synthesis, we identified instances where linguistic capital was enacted in areas that include various communication skills to interact with different audiences, cultural knowledges and values, and taking the initiative to connect with others [30,37,38]. These areas are usually referred to in CS and tech as nontechnical or soft skills and tend to not be as valued as technical skills. WOC in the literature used the development of these nontechnical/soft skills as a way to navigate and persist in their graduate education.

Hailey, a Middle Eastern doctoral student in information technology [37], enacted her linguistic capital by using her communication skills and extroverted personality to take the initiative to introduce herself to others and find mentors both in the corporate world and in her program. She explained,

Everywhere I go, I pretty much look for mentors. When I was at [corporation name], I found a few that mentored me. It's kind of funny because if you go out and you're like, 'Listen, I'm new here.' And you just kind of put yourself out there, right? And then of course in academia I have a couple [of mentors], and my undergraduate mentor is where I started, and we still talk.

(pp. 4,5)

In a related study, Hodari and colleagues [38] reported that good communication skills gave Sadie, a Native American doctoral student in informatics, the ability to build and strengthen her relationship with her advisor and their understanding of the perspectives that she brought to their work:

It's been this process of learning how to communicate most effectively with him. . . . That has taken effort to get him to consciously think about, as a Native American woman, this is how I would think about it, but as a graduate student, this is how I think about it. Then, as a cultural ambassador, this is how I think about it. We went through this whole year of that process where I was like, "Yo, dude, time out. We have to work on your Navajo etiquette."

(p. 65)

In addition to her communication skills, Sadie also leveraged her cultural knowledge of how to behave with others from a Navajo perspective and her desire to bring knowledge of her Native culture to others to build her relationship with her advisor equitably, where her perspective was valued and respected.

The literature also showed that WOC did not always access their linguistic capital in such positive and productive ways as the two instances above. In the case of participants in Herling's [30] study, seven out of the ten Hispanic women in computing were not able to access their linguistic capital because of differences in culture, language, and interests with their male classmates, which made it difficult for them to fit in. Mary, for example, expressed a lack of interest "in the hard-core, nerdy stuff like over-clocking CPUs or modding games or operating systems kernels", whereas Gloria experienced "just not fitting in with the guys, especially trying to find their humor funny, which to be honest it wasn't but at the time I had to think those things were funny too" (p. 65). Mary and Gloria's examples show that, though they were aware that using their linguistic capital may have helped them fit in with the guys, they did not always enact their linguistic capital, or their efforts were not met by their male peers. This was due to the fact that their efforts were often unidirectional and unmatched by their male peers, emphasizing their feelings of not belonging.

#### 4.2.3. Familial Capital

WOC in the literature included in this synthesis carried "a sense of community history, memory and cultural intuition" and had a "commitment to community wellbeing" [15] (p. 79). Several studies included in this synthesis [28,32,34–36,38,39] included examples that "described how family was supportive in broad ways, such as encouraging students to persist, showing pride in their accomplishments, supporting STEM as a desirable career choice, telling stories of resilience, and setting expectations for doing well in school and being respectful of teachers and professors" [21] (p. 13).

Rosa, a Hispanic doctoral student in Agbenyega's study, was encouraged by her mother to pursue her education [39]. She explained, "when I started my Master's, my mom passed away and one of the things that she wanted was for me to actually finish school and that's ultimately what kept me focused on actually finishing up my degrees and, and just doing what I had to do" (p. 163). Her mother's encouragement contributed to supporting her persistence, even after she was not there to provide this support in person anymore.

In the case of Suzanne and Jacquelyne, Black graduate students in CS-related degrees in Murray-Thomas' [36] study, they received support from their families through high expectations, hand-picked schools, and general support. Suzanne remembered her family's regular meetings where they talked about her and her siblings' future. She recalled, "We

definitely had conversations about our world, ‘What’s next? What you’re going to be doing?’ As long as you go and do it, your family will be there to support you” (p. 68). Jacquelyne recalled that “there was this expectation”, it was “part of their fabric” (p. 69) that she would attend college and achieve excellence. Additionally, they were expected to contribute to their families’ familial capital by expanding their educational legacy, which would contribute to their history and cultural knowledges related to education for present and future family members.

In some cases, family members provided support beyond general encouragement and pride by modeling lessons of occupational consciousness and engaging in direct support of WOC’s efforts to persist and succeed in computing and tech. A participant in Middleton’s [35] study shared how her aunt, who worked in the computing field, helped her secure an internship.

When I reached out to my aunt who was working actually at Company X, and I asked her, you know, can I get any help—can you help me get an internship? And she said, well, you need to get some experience. I’m, like, that’s what I’m trying to do, get some experience. But she said, you need to get some experience before you get your experience at Company X. And that, kind of, helped me drive to go and get internships with Company A and B.

(p. 102)

Her aunt’s involvement provided more than access to an internship, but occupational consciousness by teaching her how the field works, and even transportation to potential internship sites.

In the case of Bianca, the Black woman who earned a Ph.D. in CS and went on to become an associate professor in Ashford’s [28] study, familial capital extended beyond the concept of family when she became an early role model in her home community and other parents became invested in her success. Community members told Bianca’s mother to “make sure you let us know if you need any support” (p. 107). As she recalled,

When I was bused to the ninth grade for that math program, I was the only Black child for that one that they took from the middle school to the high school for that math [Pre-Calculus program]. . . . I remember that the other parents were telling my mom ‘Make sure she does this and does it well.’ Like I was going to be the poster child of how the Black folks in this community, how they needed to be given more opportunities to look at how well she’s doing.

(pp. 106,107)

Bianca’s success became her community’s success, highlighting the importance of kinship-like community connections that put its resources at her and her family’s disposal, activating familial capital on her behalf.

In Hodari and colleagues’ study, Hasina, a Black postdoctoral scholar in computer engineering [38] also exemplifies this broader sense of kinship. She explained how her childhood experience of poverty motivated her to focus her dissertation research on energy consumption in African American neighborhoods. Hasina explained,

I don’t know if it’s my race that influenced my research or knowledge of injustice because of social economic status. My dad was really rich when I was younger and I didn’t . . . really know the value of money. But real estate is one of those things that is cyclical. So when I was old enough to understand the value of money, he wasn’t rich anymore. He was struggling. And I guess I realized how not having money could hold you back. And at that point, it wasn’t about race. It was about access and I believe a part of that experience led me to looking at low income [populations]. I didn’t say, “Well, [I’ll study] energy consumption in African-American neighborhoods.” I said, “[I’ll study] energy consumption in low-income households.” So I think it was social economic status and people not having a level playing field when it really came down to it. It wasn’t about race

anymore. I mean, if you look at the numbers, yeah . . . many African-Americans are low income, but sometimes it's really about . . . money. . . . I think that drives my research in ways that I may not even be aware of.

(pp. 63–64)

This example illustrates how, instead of receiving familial support, Hasina “engages [in] a commitment to community well being” [15] (p. 79) by focusing her doctoral work in a topic that will benefit her community.

As we will see in the section titled *Overlapping Multiple Capitals*, HBCUs were successful at providing their WOC students in CS-related graduate studies with access to familial capital. Nikki and Mary, from Murray-Thomas’ [36] study, talked about professors who knew their names and support staff from academic services who provided them with additional learning opportunities as being “like a family” (p. 80) because they created a sense of community that was caring and provided for them.

#### 4.2.4. Social Capital

Despite often experiencing departmental cultures of exclusion and hostility, WOC were able to enact their social capital to find social and structural supports that helped them persist throughout their computing and tech graduate education. Denton et al. [21] identified in their systematic review the following as sources of social capital: groups and organizations (peer groups, cohort programs, affinity groups such as professional organizations, classroom communities, and academic group work), individuals within the education institution (individual peers, k-12 STEM teachers, faculty, advisors, mentors, coaches, alumni leaders), and individuals outside the education institution (CS professionals in the community, individual community members).

Instances of accessing social capital in our meta-synthesis arose in several of the categories identified by Denton and colleagues [21], including peer groups, faculty, computing and STEM diversity conferences, and professional organizations [30–32,34,36]. For example, in Herling’s [30] study of Hispanic women in computing, the majority of participants reported that they had actively participated in *Latinas in Computing*, a national organization that hosts annual conferences and virtual support groups that enable Latinas to interact with and support one another. Similarly, Jasmine, an African American CS student in Tran’s [32] study, participated in several student organizations for WOC in STEM. These provided her with counterspaces, opportunities to join efforts with others to improve WOC’s representation in STEM, and opportunities to connect with peers who, similar to her, experienced isolation in their programs. As Jasmine said, “I’m very active in [a group for women of color in engineering and science]. . . . [Through this organization] I’ve sort of been able to click with other people who may be the only one in their department. So we all come together. And that’s once a week where I’m like, ‘Ah, okay. They get me’” [32] (p. 183).

Thomas et al.’s [34] participant, Beverly, described how her mentor and her dissertation chair, recognized her intersecting identities as a Black woman and Ph.D. student and connected her with various opportunities and served as her advocate during her Ph.D. studies.

When I met her [the dissertation chair], it was an instant connection and synergy . . . She also recognized I am and was a black female . . . 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 [an] 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.

(pp. 6, 7)

We also found an instance in the literature where WOC had difficulties activating their social capital. This was the case of Serena, an Asian American educational researcher with

degrees in CS and educational technology in Hodari and colleagues' study [31], who found that being an immigrant and having immigrant parents limited the extent to which her social capital could be leveraged. She explained,

One component, out of many, of being an immigrant—in particular, an immigrant whose parents don't have access to a lot of resources—is that you don't come with a lot of social capital . . . You're really, from the ground up, building a set of networks and you don't have a lot of mentors . . . whether it's the time you go in high school taking SATs because your parents have no clue and have never even heard of it, don't know anything about what college applications should look like, don't really know friends or have other people that they know at their companies that are in positions where they could write you letters of recommendation . . . And so, I didn't have, kind of access to this whole set of social capital at that time that made it make a difference.

(p. 88)

The fact that her parents did not grow up in the U.S. limited their knowledge of the college application process with all it entails, from the necessary exams and application packets to the need for letters of recommendation, and the extent to which they could support her or find help from others to support her.

#### 4.2.5. Navigational Capital

WOC found resources and used strategies to access their own navigational capital and relied on others who could help them navigate social institutions not created with them in mind [30–32,34,36–38]. Resources included mentors, conferences, professional and student organizations, and peers.

In our literature synthesis, navigational capital appeared in the form of receiving mentoring by senior professionals [31,34,37]. Hodari and colleagues' participant, Georgette, a Latina professional in computing [37] recounted how during her Ph.D. program, she had lunch with a senior and well-respected professor who disclosed that he did not make tenure. She shared, "I thought, 'If he didn't make tenure and he's been as successful as he can, then if I don't make tenure, I'm going to be okay. And if I don't make tenure, maybe it's because that wasn't the right place for me' . . . I was like, 'It's okay to fail.' So that's really empowering" (p. 3). Despite sharing a story of failure, Georgette valued his honesty because it gave her courage to see that she could have an impact on lives even if her experiences were not always linked to success.

Participation in conferences where networking was encouraged also played a significant role in the lives of WOC graduate students as they navigated their computing and tech programs [31,37]. In Hodari and colleagues' study [31], Hailey described how participating in a conference helped her network within her field and encouraged her to continue in her computing and tech path:

I love the social aspect of [the conference]. I love how amazingly easy to talk to everybody is, and the ones who are high up understand that these students are in need to network and need to be pushed up and stuff. So they don't have a lot of expectations . . . It's more like, "I'm here to help you so just let me know how I can do that" sort of attitude.

(p. 87)

Student and professional organizations provided WOC with counterspaces or a support system where they could connect with peers going through similar experiences. Nine of the ten Hispanic women in Herling's [30] study were involved in the group Latinas in Computing, and four were involved in other related groups. Gracia, a Hispanic CS doctoral student in this study, was instrumental in forming a group for Hispanic Ph.D. students at her university. She explained, "That was my supportive group, which helped me get through the Ph.D. because we all shared and talked about it" [30] (p. 58). This

group provided a safe space, also called a counterspace, for her and other graduate students to share their experiences and challenges. Similarly, Corinda, an African graduate student in CS in Hodari and colleagues' study [31], was a leader in a group for women at all student and career levels in computing and tech "where they discussed computing content, professionalism and leadership skills, but they also could rely on each other as a community". This group helped Corinda "feel at home within the institution, and thereby promoted her ability to succeed in computing" (p. 86). We would like to highlight that, in both of these cases, organizations not only provided access to navigational capital, but also participants took the initiative to create and to lead these groups. Thus, their own actions and resilience contributed to the enactment of navigational capital.

Lexie, an African American and Asian American CS graduate student in the same study [31], benefited from having graduate student peers who were more advanced in their studies. They served as role models who helped her find new opportunities in the field and as resources to advance in her studies:

They sort of know the ropes as far as what you want, when you want to get things done in the building or good resources for whatever project I'm working on. And lots of times, they'll forward me things that sound relevant to me, if they see them on the web . . . They might mention a project that they worked on or someone else worked on that sounds like I might be interested in it for my work. So, they'll tell me what paper to read or what project to find.

(p. 88)

Lexie appreciated being able to rely on others who had experience that she lacked and that could help her navigate CS graduate school, a social institution not created with WOC in mind.

#### 4.2.6. Resistant Capital

WOC used their resistant capital in various ways, such as by "maintaining and passing on the multiple dimensions of community cultural wealth" [15] (p. 80), by volunteering to encourage interest in STEM, and by persisting in computing. Gracia, a participant in Herling's [30] (2011) study introduced above, is an illustrative example of this dimension of resistant capital. In Gracia's case, she passed on navigational and social capitals to others by forming her own student group for Hispanic students pursuing Ph.Ds. Her own prior experience of having a supportive group where all members "shared and talked about it" [30] (p. 58) helped her get through the Ph.D. and motivated her to create a similar experience for others having similar experiences.

The three articles by Hodari and colleagues [31,37,38] in this synthesis report instances of resistant capital among their participants through participation in volunteering opportunities to encourage interest in STEM among younger students of color. For example, Serena [31] explained that she was very interested in issues of computer literacy and in the use of technology to empower people, particularly high school youth in marginalized situations. She brought those two interests together in her outreach by empowering young people by helping them produce their own media environments where they can be creative and expressive and where they were "in the position of power to make choices that will constrain and guide how other people use their technology" (p. 88). In another example, Jade, a Black doctoral student in CS [37] focused both the topic of her dissertation and her work in CS and tech in general in topics that would support urban Black communities and that would contribute to bringing more Black young women into computing. She was confident that her experiences as a Black woman provided her with insights that others outside her community would not have, which allowed her to find ways that technology could help solve problems in her community. Some of the problems she wanted to tackle with technology included "issues of esteem for girls of color, which she suggests inhibit their participation in computing education and careers" (p. 4), and the use of effective technology to support the development of reading skills among urban Black children. Jade stated,

I think being a Black woman opens my mind to problems that technology can help solve. Somebody else who hasn't experienced that kind of thing a lot won't see that problem, and they'll go off and solve another problem, leaving this huge issue that is reading that affects everybody. They might not see it the way I see it. . . . Being a Black woman . . . Those are problems that I can specifically solve because I have those experiences.

(p. 4)

In both Serena's and Jade's cases, they use their CS skills to leverage their resistant capital to empower their communities and encourage younger members to participate in STEM.

Overall, one could argue that *all* the studies included in this meta-synthesis are examples of resistant capital. This is due to the fact that the WOC in these studies persisted and were successful in their computing and tech graduate education, a field and an education level not set up to include WOC.

#### 4.2.7. Overlapping of Multiple Capitals

As mentioned earlier, Yosso [15] pointed out that these six forms of capital are not mutually exclusive and that they overlap and build on one another. In their systematic review, Denton and colleagues [21] identified several different overlaps, such as aspirational and familial capitals, aspirational and navigational, navigational and social, familial and navigational, and social and familial. They noted that, in the studies they reviewed, resistant and linguistic capitals overlapped the least with other types of capital. If we consider persistence in CS and tech to be a manifestation of resistant capital, we argue that all the literature pieces in this synthesis include examples of resistant capital overlapping with other capitals. Additionally, some of the most compelling examples of overlapping capitals in our synthesis include the activation of resistant capital in conjunction with others, particularly aspirational and familial capital. We also found one case where linguistic capital overlapped with navigational capital, described below.

Resistant capital overlaps with aspirational capital in two examples we have seen earlier: Bianca's [28] determination to pursue a doctoral degree in spite of being told that she was not Ph.D. material and Jasmine's [32] motivation to pursue a doctorate to have a front-row seat in company decision making. Both women used their aspirational capital of being determined to pursue further education, thereby leveraging their resistant capital to challenge the inequities thrust upon them by their professor and supervisor.

Two examples of resistant capital overlapping with familial capital come from Hodari et al.'s research [37,38]. One of these examples is that of Jade [37] who desired to focus on topics that would support urban Black communities such as the development of technology to support learning reading skills, which would, in turn, contribute to bringing more Black young women into computing. In a similar way, Hasina's doctoral research on energy consumption in low-income neighborhoods worked toward improving the lives of people in African American communities [38]. In these examples, familial capital refers to their leveraging of cultural knowledges connected to their kin, broadly defined, that has modeled for them "lessons of caring, coping and providing" [15] (p. 79).

As mentioned earlier, we also identified an example where linguistic and navigational capitals overlap. Hailey [37] leveraged her linguistic capital by using her communication skills and her extroverted personality to activate her navigational capital by looking for people who would mentor her both in the corporate world and in academia. Hailey's ability to enact overlapping capitals resulted in an expanded professional and academic network for her future career.

We identified very little literature in our synthesis set addressing the activation of various capitals through structural supports in the form of departmental or institutional actions to support WOC graduate students, except for one study on HBCUs [36]. Murray-Thomas [36] found that HBCUs provided caring and supportive environments that did not inflict social pain, but instead invested in supporting the development of students' capitals.

The following examples show how HBCUs provided access to overlapping capitals to two graduate students in CS-related fields, Mary and Nikki.

Mary attended the same HBCU for her undergraduate and graduate programs. She had multiple women STEM professors who served as role models to her and who held her up as the “star person”. She stated, “actually, all of my math teachers were women. That was really cool to me to see them being women teaching math and at the time they would really encourage me just because I was the smart student at the school” [36] (p. 82). Mary’s school provided her with access to a “warm, caring, and supportive” graduate environment, where “professors saw her potential and provided the encouragement and support that she did not receive at home. They pushed her to finish” (p. 87). Through their actions and their example that provided her with women role models who were successful in academia, and by providing her with encouragement to continue her education, professors provided Mary with access to overlapping social, familial, and aspirational capital.

Nikki, a student in the same study [36], attended an HBCU as an undergraduate and a PWI as a graduate student. Nevertheless, her undergraduate experience prepared her to succeed in graduate school since her HBCU’s primary mission was “to prepare the students for their life after graduation” (p. 80). She explained, “They gave us our life skills. Even if we didn’t want to hear it, she gave it to us, our dorm mother. Even various professors, they advised you but as far as what classes to take . . . Academic services, career services were on point” (p. 80). In addition to giving practical advice, faculty and others created a family-like environment for her, with care and commitment to her well-being, and they always welcomed her back after she left. She explained,

I will not trade having gone to another HBCU for anything. I just feel every time I go back for homecoming; it’s like a family. I could feel . . . I kind of was the prodigal student . . . It’s just that it felt very warm and welcoming. They value their students; like my teachers knew my name. I had personal relationships with all of the teachers in our department. And I could go and talk to them anytime about anything.

(p. 80)

These professors and other services provided access to overlapping social, navigational, and familial capitals, as they expanded the concept of family from kin to Nikki and others in the HBCU’s community. Altogether, these examples show how HBCUs, especially in contrast to research on WOC in PWIs, were successful in supporting the development of and providing access to at least four different types of capital—social, navigational, familial, and aspirational—for Nikki and presumably other WOC CS and tech graduate students.

## 5. Discussion, Recommendations, and Conclusions

In this meta-synthesis, we outlined the pervasive and frequent instances of social pain experienced by WOC in computing and related fields at predominantly white institutions—including verbal and physical assaults from faculty and classmates [28,29,31,32]; low expectations and ascribing STEM successes not to competence but to affirmative action or racial guilt [28,29]; negative racial stereotyping [29]; and exclusion [30]. Given the abundance of such findings throughout our synthesis, we align ourselves with McGee’s [4] work, which underscores that the severe underrepresentation of WOC in STEM, and especially in computing and tech, is due to the field being designed specifically for “white men who are heterosexual, able-bodied, Christian, or atheist, [and] middle-class and above” (p. 634). In other words, the old, established practices of STEM academia have informed and created computing departmental cultures that are often hostile to those who diverge from this precedent. Furthermore, we view the low representation of WOC graduate students in CS and related fields as an important equity issue, where students of color (and particularly WOC) are not offered the same opportunities as their white and male counterparts. As McGee [4] noted, “research has shown that there is more bias in STEM professions than their non-STEM counterparts” (p. 635), even more so as it relates to diversity at the graduate level than the undergraduate level.

In this meta-synthesis, we also see that the activation of the different capitals in CCW contribute to lessen the impact of the social pain inflicted on WOC. In some cases, WOC were able to leverage these capitals through their personal efforts and by finding resources and people who could support them. Such was the case of the African American woman in Middleton's [35] study, who accessed her aspirational capital through her motivation to pursue her master's degree; or the case of Hailey [37], who enacted her linguistic capital by using her communication skills and extroverted personality to find mentors. In other cases, other individuals (professors and mentors) provided WOC with access to these capitals. Such was the case of Beverly [34], whose dissertation chair connected her with various opportunities and served as her advocate. This was also the case of HBCUs, where services and the entire educational experience were organized to provide access to these capitals.

Expecting WOC to leverage the different capitals during their computing graduate education, places the onus of resisting and changing oppressive systems on those who are oppressed by them, allowing these systems to stay intact and in place. We argue that it is the institutions' responsibility to change these oppressive systems and to provide WOC with educational experiences that support the development of their potential through supportive environments that do not inflict social pain and that connect with their community cultural wealth. More research is needed to identify the mechanisms involved in the activation of the different types of capitals to support the persistence of WOC graduate students in computing and tech at HBCUs so that other institutions, and particularly PWIs, can learn from their example to change their oppressive systems.

The following recommendations for institutions of higher education (IHEs) and for future research stem from the findings from this meta-synthesis. As noted above, IHEs have the responsibility to create environments where they provide access to different capitals and WOC have the opportunity to succeed. Thus, IHEs should first focus on prioritizing bringing WOC into their computing programs by conducting targeted recruitment efforts [39]. WOC already in IHEs can have a key role in attracting others similar to them by leveraging their social and familial capital; thus, they need to be supported in their efforts to diversify CS and related programs [37,38]. Additionally, helping attract others similar to WOC would provide them with opportunities to enact their resistant capital. IHEs should aim to leverage aspirational capital by hiring more faculty from underrepresented backgrounds, and particularly WOC, so that WOC students can see themselves represented [29,30]. IHEs should also aim to support the leveraging of social capital by providing both WOC students and faculty with formal mentoring [31], specifically mentors and role models from similar backgrounds [30] that will validate their experiences and avoid the internalization of responsibility for outcomes caused by external factors and, thus, minimize their experiences of social pain. Finally, all IHEs could emulate HBCUs in supporting the enactment of the different types of capital by creating warm, welcoming learning environments and investing in the potential of WOC [36].

IHEs should provide WOC with social and structural supports that access navigational capital to help them maneuver and succeed in computing and tech graduate studies. Faculty and staff should receive training to learn how to support the development of and leverage different capitals, connected to their performance evaluations, and address racism, sexism, and other -isms that contribute to the hostile culture of CS-related environments [28,29] and, thus, minimize WOC's experiences of social pain. CS and tech departments should implement policies that support accessing social and familial capital to ensure full inclusion [38]. These departments should encourage the use of culturally relevant pedagogy in computing courses [28] and the use of real-world examples and experiential learning opportunities [30]. These forms of pedagogy and examples could access linguistic capital by integrating cultural knowledges and language relevant to WOC. CS and tech departments also need to create environments through formal and informal means where social and familial capitals are leveraged, such as creating opportunities for mentoring, so that WOC are acknowledged and integrated as part of the social fabric [31]. Additionally, CS and tech departments must invest in professional development

that teaches faculty and staff how to support and serve as a mentor for WOC. Finally, WOC need structural and financial support to participate in counterspaces where they can support each other by engaging their own various capitals [28,29,36].

More research on WOC graduate students in computing and tech is needed in the following areas: the role of resistant capital though altruism and giving back in persistence [39]; other factors related to persistence [28,29]; and experiences during educational transition points, such as undergraduate to graduate school and master's programs to doctoral programs [28]. Given the key role of HBCUs in the training of computing and tech professionals of color, it is worth exploring topics such as the differences in persistence factors for WOC between PWIs and HBCUs and how they differentially provide access to the different types of capital [36]; the role of women and Black faculty in WOC's persistence [28]; and the strategies HBCUs use for the development and support of their students through the support of the different types of capital [36]. Furthermore, more research must be conducted on how IHEs, specifically members of faculty and staff, can support WOC graduate students' persistence in CS and tech, such as through mentorship, which as we have seen, supports access to several capitals. Currently, there is little research on how IHEs, particularly those that are PWIs, can or do, specifically support WOC's persistence in graduate computing education. Although more research is needed on WOC graduate students overall, studies on Asian American, Latinx, and Native women in CS-related graduate education students are especially needed.

According to Hiscock and Harris Perin [40], most students "attend graduate programs with hopes of emerging as leaders in their academic or professional fields"; however, few WOC pursue graduate school in CS and related fields, and even fewer will reach leadership positions (p. 2). Therefore, a small number of WOC in graduate school later translates to a dearth of WOC faculty, potentially leading to snowballing effects of younger generations of students of color in these fields being exposed to fewer positive role models [41,42]. Although efforts to broaden participation in computing and other STEM disciplines have been supported by the National Science Foundation and other national-level organizations, their impact has been exceedingly slow [7,8]. Thus, IHEs must take responsibility to dismantle the structural racism and sexism that exists within their computing, and other STEM, departments and move towards environments that support, value, and celebrate the contributions of underrepresented people, particularly WOC in CS-related graduate education.

## 6. Limitations

This meta-synthesis' limitations are linked to the methodological choices made by our team and the limitations of the studies included. Our methodological choices, such as the criteria to select which studies fulfilled our critical appraisal criteria, may have excluded studies that could have contributed valuable findings to the synthesis. Additionally, the participants in the studies included in this meta-synthesis are not necessarily representative of the racial/ethnic breakdown of the U.S. population as a whole. This is due to the fact that research authors' decisions about their research is not guided by representation, but by other factors, such as interest, consistency with their own research agenda, or funding received. Given that a meta-synthesis can only include what is available to the public, representation considerations cannot be enforced. Another limitation is the fact that the newest literature included in this synthesis is from 2018. This is due to the length of time that the meta-synthesis process takes, both in terms of search and selection and of analysis. For the benefit of the reader, we conducted a non-exhaustive search of works on WOC in graduate computing education released in 2019–2021. The result was the six works listed in the Appendix A.

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## Appendix A. Notable Works on Women of Color in Computing Graduate Education Published 2019–2021

The search phase of this project closed in late 2018, and studies on the experiences of women of color in computing graduate education continued to emerge. A selection of more recent studies for readers' further exploration is listed here:

1. Bahnson, M.; Satterfield, D.J.; Kirn, A. Students' experiences of unfairness in graduate engineering education. Paper presented at 2021 CoNECD, Virtual, 24 January 2021. Available online: <https://peer.asee.org/36123> (accessed on 30 October 2021)
2. Perkins, H.; Bahnson, M.; Tsugawa, M.A.; Satterfield, D.J.; Kirn, A. & Cass, C. Board 121: Exploring hypotheses regarding engineering graduate students' identities, motivations, and experiences: The GRADs Project. Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida, USA, 15 June 2019; pp. 1–9.
3. Rankin, Y.A.; & Thomas, J.O. The intersectional experiences of Black women in computing. In SIGCSE '20: Proceedings of the 51st ACM Technical Symposium on Computer Science Education, Portland, OR, USA, 11–14 March 2020; pp. 199–205.
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