LOYOLA UNIVERSITY CHICAGO

VOICES OF AFRICAN AMERICAN WOMEN IN COMPUTER SCIENCE: IMPLICATIONS FOR K-12 STEM EDUCATION AND BEYOND

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DEDICATION

To Zori,

So that your journey will be easier.

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ABSTRACT

Voices of African American Women in Computer Science is a qualitative dissertation about African American women who have successfully completed a computer science degree. This research explored how computer science education departments in predominantly White institutions (PWIs) contribute to the oppression of African American females. Critical race feminism (CRF) provides the platform that places the voices of women of color who have successfully obtained a computer science degree despite difficulties that have been imposed by the reality of racial biases that are present throughout the American education system and American culture at large.

This research was guided by the following primary question: What are the unique experiences that have influenced the success of African American females who have obtained degrees in computer science from PWIs? In order to establish fulfilling narratives of the participants' experiences the following secondary questions are also relevant: What factors have influenced participants' decision to major in computer science? What were the experiences of the participants during their time in their computer science program? How do these women make meaning of their experiences?

Both narrative analysis and analysis of narrative were used to interpret data gathered using detailed interviews. Findings were presented using both methods in an attempt to show a detailed use of data, as well as to also push the boundaries of CRF with the creation of guidelines for CRF methodology. The results show that African American

women in computer science have unique but powerful stories. This study highlights both positive, and negative factors that influenced these women during and after their academic experiences and fills gaps left by previous research in this area. Overall, this study holds implications for K-12 and higher education institutions as well as policy makers, and those who would simply pick up the torch of mentorship.

CHAPTER I

INTRODUCTION TO THE STUDY

A Reflective Preface: I Am Not A Computer Science Success

Thank You Ms. Cook

To a certain extent, I feel deeply that this dissertation is unexpected. It is perhaps surprising for me, as I initially set out to focus my doctoral efforts on curing the world of its ailments, distastes, and shortcomings for teaching mathematics, or science. I couldn't decide between the two. As an educator and even as a child, I have had a joyful love of science as well as a deep, respectful reverence for mathematics. At the time I began this dissertation, I focused on my belief that mathematics is a gateway to more opportunities and possibilities. However, having been an extremely successful science teacher I thought I might write a dissertation that would persuade more teaching candidates to enjoy science as much as I have and continue to enjoy it. In my experience, a great science teacher is a rare find. I am blessed to have won awards and accolades for teaching science. Ultimately, I did my best to ensure that after a year with me my students would forever know that they are powerful, capable, thinkers of science.

For my love of science, I owe a debt of gratitude to Ms. Cook, my seventh and eighth grade science teacher, who was the first teacher to awaken my love for science. I say awaken because prior to Ms. Cook's science class I remember school being a foggy haze. In this school haze, I went, I read, I completed worksheets. I remember the feeling

of pencils pressing against my pointer finger and even leaving marks or dents, probably because I never really learned to properly hold a pencil. However, in Ms. Cook's room, we almost always had to work with a partner or in small groups. That was awesome! In addition, we had to do things. We had to do research, experiments, test our hypotheses, and present findings. We had to do science! From that point on I did not like, but loved science. In high school I was president of the honor society and of the drama team. By the time I was a senior, I had to be reminded that there was a limit on the number of "executive" positions that one student could hold. I graduated number four in my class. When I think about being number four, I realize I could have done better. In some ways, high school seemed so easy. I often didn't study for exams, put in minimal effort, and still got A's and an occasional B.

From Big Fish to Meandering Minnow

I went to college with the aspiration of majoring in computer science and engineering. I thought it would be a breeze. After all, I always felt I was capable of anything, thanks to my father who always had words of encouragement. However, when I went away to college, I found it to be extremely difficult. I realized I didn't know how to study. Not only did I have poor study skills, but I had a poor grasp of time management as well. As a first-generation college student, I had no concept of how college was going to be. College was difficult. Due to a lack of study skills, lack of time management skills and less-than-challenging content in high school, I just wasn't prepared. Not only did I lack these needed skills, I didn't understand how to properly seek help. I felt like I had gone from being a big fish in a small pond to a meandering minnow just trying not to

give up completely. I quickly gave up on the idea of majoring in computer science, and finally found success in a communications and theater degree. I do believe if I had pursued a career in theater, I would have been successful. However, by the time I finished my undergraduate degree I was the single parent of a baby girl, and from that moment on, the most important thing was for me to be a provider and role model. So, I chose the career path that would allow me to provide for my daughter and spend time with her while inspiring others.

Inspired to Inspire

I went to graduate school to become a teacher. I wanted to inspire my students to love learning and, of course, to love science. I have worked not only as a science and mathematics teacher, but in part as a facilitator of computer science education in elementary schools. I later moved to other administrative positions. However, with all of my personal success, I have witnessed some concerning practices. On visits to classrooms, I remembered the work of Annette Henry (1998) who suggested that Black girls are seen as invisible to teachers and not thought of as serious learners. Similar to Henry's conclusions, in some of the science and mathematics classes I visited across various districts, girls were often called on fewer times and received less encouragement in comparison to boys. Girls were raising their hands over and over again, but not being called, until finally, some girls stopped raising their hands. I saw this as an effort by the instructor to ensure the engagement of the boys. Yet, this occurrence across multiple classrooms left me wondering if one of the salient factors that deny women access to computer science fields was the lack of powerful mathematical and science identities that

were being developed by girls in elementary schools. As a means to explore this wondering, I decided to begin with those, unlike myself, who have successfully completed a degree in computer science.

Although computer science is one of the fastest-growing, and highest-paying industries, when it comes to the study of computer science education for students of color, it is still one of the least researched areas. I clearly acknowledge that it is my assumption that students of color in computer science education programs, due to varying levels of consciousness, are aware that their pursuit of research regarding support for computer science students may be deemed as an irrelevant research issue. From my review of computer science journals, students of computer science tend to focus on the aspects of computer science breakthroughs related to algorithms.

Now, as a doctoral student and mother of a graduate college student who decided to keep her distance from science, technology, engineering and mathematics (STEM), I have often reflected on my experiences wondering what I could have done differently. More so, what should P-12 educators do differently? What should institutions of higher learning do differently? Clearly, this research touches on a number of my multiplicative identities. However, a visceral provocation of this research is to center the voices of and make visible those who by my observations are overlooked, i.e., African American females. As of now, it is my unwavering belief that if we as a community of educators at every level work together we can make monumental changes that will truly benefit all students. I am not a computer science success, by traditional means; however, I am a success every time a young girl in my charge finds her identity, authority, agency and

power in science, technology/computer science, engineering or mathematics. This dissertation is written with the undaunted ambition that it will be a catalyst to support the success of other African American women in computer science.

Overview of Study

Over the past decade, there has been a growing focus on the trajectory of STEM education to career pipelines. “Leaks in the pipeline” is a term that has been used to metaphorically represent women (Alper, 1993), and minorities (Allen-Ramdial & Campbell, 2014; Ball et al., 2017) leaving STEM-related fields. Women continue to be outnumbered by men in STEM fields. However, women of color are significantly more of an underrepresented population. The American Association of University Women, a non-profit organization that uses advocacy, education and research to improve equity for women and girls, asked in their 2010 report, why so few? Nearly ten years later the same question is now more relevant than ever.

Recently, research has highlighted the growing need to focus on the aspect of technology in STEM education, a focus of which is education in computer science. Computer science education has been seen as a gateway to improving problem-solving skills (Norris & Jackson, 1992). In addition to developing potential advanced problem-solving skills, computer science graduates have the potential to earn higher wages than most other graduates. According to the National Association of Colleges and Employers (2018), computer science-related graduates have higher starting salaries than other graduates with bachelors, masters and doctoral degrees. The beneficial financial possibilities for computer science graduates are further supported by other reports.

Various labor projection reports indicate two things about computer science-related occupations: they tend to have some of the highest-paying salaries, and the fastest-projected growth (Bureau of Labor Statistics, U.S. Department of Labor, 2018; Hogan & Roberts, 2015; Lockard & Wolf, 2012). For computer science graduates, their potential for financial advancement is just one of several reasons why the lack of diversity in this field must be further explored. Because computer science careers have some of the highest-paying salaries, perhaps an increase in female computer scientists will help to eliminate or reduce gender wage gaps.

Diversifying the field of computer science will also address some of the current issues with technology development. The lack of diversity in computing has been seen as an issue of talent deficit (Business-Higher Education Forum, 2017; Buzzetto-More et al., 2010). That is, a more diversified workforce in computing can lead to more innovative ways of addressing problems and solutions in the technology industry. Currently, White males are the prevalent developers of computer software products. As a result, products such as facial recognition software are often unconsciously developed with racial and/or gender biases. In her 2016 Ted Talk, MIT graduate student Joy Buolamwini discussed her experiences working with facial analysis software. She explained that the software did not detect her face because the people who coded the algorithm did not teach the software to identify various skin tones and facial structures. Although the software was 99% accurate in identifying White males, the accuracy was far less for women and people of color. In another example, Tay (a social bot created by Microsoft to research conversational understanding) initially made comments about humans being cool. Tay

then made distasteful and unethical comments because it was easily manipulated by malicious human interactions (De Lima Salge & Berente, 2017). Perhaps the software developers did not anticipate the possibility of Tay's interaction with spiteful race-related conversations. These examples are compelling indications that undiversified software development teams often lack consideration for people of color in general, but especially women of color.

The lack of diversity in the computer science workforce results from a lack of diversity in the population of students who are earning computer science degrees. Almost half of all bachelor degrees in computer science are awarded to White men. According to information from the National Science Foundation (NSF; 2019), White women in 2016 acquired only eight percent of computer science degrees. Even more disparagingly, the report indicated that Black women were awarded only two percent of the degrees.Hispanic or Latina women also each received only two percent of the degrees. American Indian or Alaska Native women received less than one percent of all computer science bachelor degrees. In addition, this NSF report (2019) shows that the percentage of Black women earning a degree in computer science decreased over the years.

African American Female Students within the Context of Higher Education

It seems relevant to provide some context regarding the experiences of African American females in the general setting of predominantly White institutions (PWIs) of higher education. Throughout various academic departments, Black women face issues of racism and sexism. They frequently encounter isolation, marginalization, eroticization and microaggressions (Commodore, et al. 2018; Green, et al., 2018; Walkington, 2017).

These conditions then affect their social, emotional and mental well-being. In addition, there have been indications of the distinctions between various types of opportunities for financial assistance. Walkington (2017) suggests that access to assistantships versus fellowships varies, stating that Black women were more likely to get fellowships which are financially beneficial. However, White females are more likely to receive assistantships, which not only provide financial support but also provide added access to faculty and research activities.

However, there is something about computer science that makes this particular degree increasingly becoming less desirable and/or less accessible to Black women. According to the 2017 NSF report, out of all the bachelor degrees awarded in computer science in 1995, African American women earned only 5.10 percent of them. Even more discouraging, since 1995, numbers have been on a downward trend. By 2014, Black women earned only 2.61 percent of bachelor degrees awarded in computer science (National Science Foundation, 2017). By 2016, the degrees awarded to Black women dropped to two percent (National Science Foundation, 2019). Also, only a small percentage of African American women are represented in computer science graduate programs. Only two percent of the computer science master degrees, and one percent of the doctoral degrees go to African American women (National Science Foundation, 2019). Reports such as this raise concerns about these points, but there is limited research that centers the voice and experiences of these women.

Critical Race Feminism

The theoretical framework that guides this research is critical race feminism

(CRF). Delgado and Stefancic (2001) use a simplified definition indicating that critical race feminism is the "application of critical race theory to issues of concern to women" (p. 171). Having origins in critical legal services (CLS), authors have and continue to use CRF to focus on legal issues in terms of the rights of women of color. Legal scholars of CRF focus on issues of the legal system's discriminatory practices which often criminalize women of color, but fail to support them when they experience domestic violence in the home, sexual harassment in the workplace, and a number of other concerns Wing, 2003). Similar to critical race theory, CRF addresses themes of power and oppression, but specifically for women of color. Critical race feminism is significant because critical race theory tends to focus on men of color, and feminism tends to focus on issues of White women (Delgado, 2003). Although CRF uses practices that are common to feminism such as reflexivity, it differs from the general feminist belief of an essential voice. Both feminism and CRT insufficiently address the intersecting, multidimensional experiences of women of color.

Theodorea Berry has authored or co-authored numerous works related to critical race feminism and its connection to research in education (e.g., Berry, 2009; Berry, 2010; Berry, 2015; Berry & Candis, 2013). She has identified six tenets of CRF, most of which are shared with CRT; the six tenets are race and racism, whiteness as property, interest convergence, anti-essentialism/intersectionality, counterstory, and multidimensionality. Delgado and Stefancic (2001, p. 7; 2000 p., xvi) explain that *race and racism* are a normal and permanent component of our society. It is an ordinary feature and looks natural. Although laws and rules may address blatant racism, they do little to remove the

everyday acts that are not obvious. The principle of *whiteness as property* acknowledges that the law allows holders of whiteness the same privileges and benefits allowed holders of other types of property (Harris, 1993). One privilege is the right to exclude students of color from various access points and routes to knowledge (Dixson & Rousseau, 2005). Issues of property negatively impacts African American students by denying them access to knowledge related to technology education which has the ability to position them as producers instead of consumers (Donnor, 2005). *Interest convergence* is Derrick Bell's concept that racial advances for Black people are only encouraged when they promote White self-interest (Delgado & Stefancic, 2000, p. xvii). Because racism supports the interests of White elites and the working class, there is little motivation to extinguish it (Delgado & Stefancic, 2001, p. 7).

Anti-essentialism/intersectionality indicates that no person has a single unitary identity that is easily defined (Delgado & Stefancic, 2001, p. 9). In critique of the essential voice of feminism, Crenshaw (1989, p. 140) explains that the intersectional experiences of Black women are greater than the sum of racism and sexism. Intersectionality of identity occurs when individuals possess two or more social markers simultaneously such as race, gender, ethnicity or class (Berry & Stovall, 2013). Women of color have multiplicative identities; therefore, they are not White women plus color or men of color plus gender (Wing, 2003, p. 7). *Uniqueness of voice/counterstory*, which goes against master narratives, is a method used by critical writers to challenge, displace or mock these destructive master narratives and beliefs (Delgado & Stefancic, 2001). Unlike other CRF tenets, *multidimensionality* is not a tenet of CRT. Multidimensionality

of identity exists when individuals possess two or more individualities that function at the same time, informing one another in practice, such as teacher as parent, teacher as parent and community member, and historian as traveler (Berry & Stovall, 2013). According to Wing (1990), women of color have layered multiplicative experiences. Multiply each part together, "one X one X one X one X one, and you have one indivisible being" (p. 194). Matsuda (1989) speaks of women of color having multiple consciousness. It is a multifaceted way of thinking that allows them to shift back and forth between various awarenesses of the experiences of people of color, as well as the White consciousness required for survival in elite educational institutions. Matsuda (1989) further explains that certain layers of consciousness are revealed or concealed, depending on the setting and who is present.

Advocates of critical race feminism also embrace two positions. The first position is that of praxis. CRF proponents operate with the need to exemplify the collaboration of theory and practice (Berry, 2010; Berry, 2015; Berry & Candis, 2013). Wing (1990) uses the term multiplicative praxis and suggests that we must not only talk about the complexities of our layered existence but act on it by means that may not translate into entries on our resumes by mentoring, inspiring and nurturing Black children, and young people. Matsuda (1989) indicates that multiple consciousness is not only about seeing the world from the view of the oppressed, but the search for justice and a path to a just world. CRF's second position is that it is multidisciplinary as it involves writings from authors of various disciplines (Berry, 2009; Berry, 2010; Berry, 2015; Wing, 2003). This allows it to be accessible to other subjects of research.

Critical race feminism is a relatively new theory, which may explain why it lacks a broad presence in academic research. Although significantly underutilized, CRF is a framework that easily lends itself to studying, analyzing, critiquing and celebrating the educational experiences of African American female students (Childers-McKee & Hytten, 2015). Although not frequently used, CRF has great potential for the exploration of transformative social justice change in education (Childers-McKee & Hytten, 2015). Some scholars such as Pratt-Clarke (2010) have used CRF in academic research to focus on African American females, as opposed to research that historically emphasizes African American males in education. She emphasized the importance of understanding that social justice advocacy hinges on understanding the role of race and gender in education.

This dissertation uses critical race feminism as a theoretical framework not only because of its attribute of centering the experiences of women of color but also due to its lineage from CRT's base in legal studies, social sciences and history (Wing, 2003; 1999). Using CRF as a framework questions the unyielding continuation of racism and sexism in higher education. Critical race feminism deals with the experiences of women of color who face numerous forms of discrimination, as a result of the intersections that cut across race, class and gender within a system of White male patriarchy and racist oppression (Evans-Winters & Esposito, 2010). These features make the decision to use this theory as a lens for this study to be a critical one.

Under the guise of diversity and inclusion, universities may boast about their missions to accept and educate all students, yet fail to concretely support them

adequately. Dismantling systems of oppression can only occur with a critical transformative agenda. Therefore, an underlying exploration of this research centers around diversity policies in higher education, as well as how computer science education serves as a construction of oppression for African American women. The multifaceted attributes of CRF make for a reasonable starting point to: (a) explore the multidimensional, intersectional experiences of African American women in computer science education; and (b) begin a process of transforming current practices and policies.

Purpose of this Research

The focus of this qualitative study is African American female students and their success as computer science graduates. This research seeks to explore how computer science education departments in PWIs contribute to the oppression of African American females. Considering the enormous impact that race has on one's trajectory from STEM education to STEM careers makes the application of a critical theory a must of this study. The perspective of CRF will provide the platform that indicates a need to highlight the voices of women of color who have succeeded despite difficulties that have been imposed by the reality of racial biases that are present throughout the American education system and American culture at large. By using CRF, the experiences of those whose voices are least heard will be centered.

Research Questions

This research is guided by the following primary question: What are the unique experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI)? In

order to establish fulfilling narratives of the participants' experiences, the following secondary questions are also relevant:

1. What factors have influenced participants' decision to major in computer science?
2. What were the experiences of the participants during their time in their computer science program?
3. How do these women make meaning of their experiences?

Definitions

The term *computer science education* refers to instruction that involves any aspect of the study of computers and processes of algorithms, including computer hardware and software engineering and design. Computer science education can occur in elementary schools, secondary schools and institutions of higher education. This study focuses on computer science education that occurs in departments of computer science at institutions of higher education that leads to a computer science-related degree such as bachelors, masters, or doctoral.

The Encyclopedia of African American Education best defines the term *predominantly White institution* (PWI) as "the term used to describe institutions of higher learning in which Whites account for 50% or greater of the student enrollment" (Brown & Dancy, 2009, p. 523).

STEM is an acronym for science, technology, engineering and mathematics. The T can be thought of as an all-inclusive topic of technology, and the E can be thought of as an all-inclusive topic of engineering. However, within the context of this study, it is essential to keep in mind that computer science is a critical aspect of both topics.

The *success* of African American women in computer science refers to the completion of a degree (bachelors, masters, or doctoral) in the discipline of computer science.

CHAPTER II

REVIEW OF LITERATURE

Over the past decade, there has been a growing body of literature that acknowledges the need for more women in computer science (CS). Researchers have indicated the benefits of increasing the presence of women in the field of computer science as a means to improve diversity. Studies have focused on differences between males and females as possible answers to rectifying gender disparity in CS. Unfortunately, women of color typically have little or no representation in those studies. More specifically, limited research has focused on the experiences of African American women in computer science and has typically focused on what can be seen as obstacles and challenges that they have faced. This review of literature summarizes studies that have researched factors related to reasons why so few women major in computer science in the United States. Specifically it was completed in order to investigate literature that may indicate reasons why some African American women have, or have not chosen computer science as a field of study. The intent was also to highlight their experiences as computer science students, and identify possible counternarratives that center the unique experiences of these ladies.

This review calls out gaps and limitations of the current body of literature which this dissertation will seek to fill. It shows the necessity of further research that includes the voices of participants from diversified groups like African American women, unlike the preponderance of current research which predominantly focuses on White women. In

addition, this review also highlights the need for the experiences of women in computer science to be studied from a more positive perspective shedding light on the unique skills and characteristics of the talented women who are successful in the computer science industry despite the challenges they have faced.

This review of literature focuses on factors related to characteristics of undergraduate, and graduate students who do or do not pursue computer science degrees. To select studies for inclusion, the search began by using the ERIC database. In order to ensure that a more thorough search was completed Education Research Complete, JSTOR, ACM Digital Library, and IEEE Xplore databases were also utilized for locating peer reviewed articles published within the last decade (2009 to 2019) in order to highlight current perspectives of this phenomenon. Due to the limited body of work articles from 2008 were also considered for inclusion. A combination of the following keywords were used in searches: computer science and computer science education, women, females, factors for success, Black, African American, minorities, and computing or information technology.

From the studies identified through this initial search, works that focused on populations in higher education settings were included, and others excluded. Although there were a number of studies that focused on university faculty in computer science departments, this review focuses on factors that are relevant from the perspective of university students. There is a growing body of research that highlights women of color in STEM, or in engineering. However, upon closer inspection it was evident that a number of STEM articles include participant samples, and/or discussions primarily

regarding mathematics, and science majors (e.g., Leath & Chavous, 2018; McPherson, 2014, 2017; Joseph, 2012; Russell & Russell, 2015). Even in articles that provided some diversity in participant disciplines, did not necessarily include computer science. Overall, not all articles that were labeled in title with the acronym STEM, or the word engineering clearly indicated the inclusion of computer science, or computer engineering participants (e.g., Dortch & Patel, 2017; Jackson, 2013; Kulturel-Konak et al., 2011). Due to ambiguity regarding distinctions between participants' experiences in computer science and other STEM fields, the initial goal of the review was to exclude them. However, because of the extremely limited body of research that illuminates the experiences of African American women research related to the general topic of STEM was included as long as the study clearly specified inclusion of at least one participant who majored in computer science or computer engineering.

Overall, a total of nineteen articles that focused on college-level computer science education experiences, or factors that may be used as predictors to majoring in computer science were found. All studies that were specifically about students' experiences or perceptions of computer science, as well as studies that clearly indicated the number of participants who were computer science majors were included. Studies were then organized into the following categories: comparing factors and choice across race and gender (n=10), programmatic factors that influence experiences (n=2), highlighting experiences of female samples (n=4), and African American Women in STEM Education (n=3).

Comparing Factors and Choices Across Race and Gender

The majority of research related to the disparity of women in computer science has examined the differences between female and male students. The articles reviewed in this section are listed in Table 1. These studies typically used quantitative methods, and focus on various internal and external factors of students. Some included sample populations of students who were not actually computer science majors in order to understand female versus male perceptions of computer science coursework. Overall the researchers in this section have made conclusions based on comparisons between genders based on factors and choices made across race and gender. These choices may have been based on interests, beliefs, mindset, or other characteristics of the participants within the studies.

Table 1

Articles Comparing Factors and Choices Across Race and Genders

Study	Sample	Focus
Bennedsen and Caspersen (2008)	N=100 students	Correlation between a student's well being, emotional health, and the student's success in introductory computer science courses.
Beyer (2014)	N = 1319; 872 females and 447 males; 83% White; 7% Hispanic; 5% African American, 4% Asian, and less than 1% Native American	Gender differences in first-year students' stereotypes about CS, interests, self-efficacy, values, and classroom experiences.

Cheryan and Plaut (2010	Study 1 N = 62; Study 2 N = 614 Study 1: 33 females and 29 males; 30 White, 11 Asian American, 7 African American, 7 Hispanic/ Latino, and 7 who identified as more than one race or other. Study 2: 334 females and 280 males; 269 White, 211 Asian American, 13 African American, 13 Hispanic/ Latino, 39 who identified as more than one race, 23 who identified as other, and 46 who did not identify their race.	Examine whether processes that explain why women were underrepresented in science, math, and engineering also explains the lack of male representation in humanities.
Cheryan et al. (2013)	Study 1 N = 293; Study 2 N = 54	Stereotypes of people in computer science affect females' and males' decisions to major in computer science.
Denner et al. (2014)	N = 741; 74% male; 5% African American, 32% Asian/Pacific Islander, 20% Hispanic/Latino, and 48% White.	Strategies that would lead to an increase in the number of community college students pursuing computer information systems degree.
Jung et al. (2017)	Group 1:N = 107; 34 females and 73 males; 11.21% Black or African American, 74.77% White or Caucasian, 1.87% Hispanic or Latino, .93% Native American or American Indian, 5.61% Asian or Pacific Islander, 5.61% other. Group 2: N = 116; 47 females and 69 males; 4.31% Black or African American, 84.48% White or Caucasian, 5.17% Hispanic or Latino, 1.72% Native American or American Indian, 1.72% Asian or Pacific Islander, 2.59% other.	Understand students' decision to major in technology.

Lehman et al. (2017)	n = 6,038 computer science students (within a larger population of STEM students) 1636 female, and 4402 male computer science students	Comparisons between genders that highlighted race/ethnicity, academic achievement, career aspirations, and other self-ratings.
Sax et al. (2017)	N = 8 million students	Document aspirations of majoring in computer science by undergraduate men and women.
Stout and Blaney (2017)	N = 1,631; 27% women and 73% men; 5% African American, 1% Arab/ Middle Eastern/Persian, 29% Asian or Asian American, 46% Caucasian, 9% Hispanic/ Latinx, 8% more than one race/ethnicity, .5% either Native American or Native Hawaiian//Other Pacific Islander, 1% Other, and .5% missing data.	Benefits of growth mindset on women's sense of intellectual belonging in computing.
Varma (2010)	N=150 undergraduate students divided into groups of 30 (15 females and 15 males) 30 White students; 30 Afro-American students; 30 Hispanic students; 30 Asian American students; 30 Native American students	To ask students why they thought there were so few women pursuing a degree in CS/CE at their institution.

Bennedsen and Caspersen (2008) researched emotional and social factors on learning computer science. Their hypothesis was that there is a positive correlation between a student's well being, emotional health, and *the student's success in introductory computer science courses.* They determined success in courses by the students' course grades. They used the variables of perfectionism, self-esteem, coping tactics, affective states, and optimism to measure students' emotional and social well-being. However, they found no linear correlation between students' exam scores, and

social well-being and emotional health. They determined that most students who passed appeared to have higher levels of self-esteem than those who did not pass. None of the variables showed a strong Pearson correlation. However, the correlation between the regularity and automata course and the variable of optimism was the highest at r=0.342, and the authors indicated that the preferred threshold is r=0.5. Bennedsen and Caspersen suggest that it would be relevant to repeat their study in different cultural settings with a multi-institutional study.

Beyer (2014) studied *gender differences in 1,319 first-year students' stereotypes about CS, interests, self-efficacy, values, and classroom experiences.* Using those variables Beyer sought to explore why women were less likely to take CS courses, and thus even less likely to major in computer science. Within this quantitative study there were 447 female, and 872 male participants enrolled in public liberal arts universities. Although Beyer discussed the racial break down of the participants (83% White, 7% Hispanic, 5% African American, 4% Asian, and less than 1% Native American) the results for racial, or ethnic groups were not disaggregated in any way that clarified how responses differed across racial/ethnic groups. According to Beyer women do not see computer science itself as being more negative. Women found CS as being a promising career and showed great respect for students majoring in the field. Despite respect for the subject Beyer's results indicate that women's values and interests were not as high. They had less interest in taking computer science courses. Women were more interested in career aspirations that allowed them to be *helpful to others, and society in general*. Women rated their feelings of self-efficacy of computer science lower than men.

However, women showed a higher belief than men that women have the same level of *ability to be successful* in computer science. Beyer also indicated that pragmatically women also were more likely to consider the percentage of job availability as a main factor in career aspirations. In regards to personality females showed higher ratings on conscientiousness, but otherwise no major difference was found in relation to personality types. According to Beyer the more conscientious a student was the less likely she or he were to take computer science courses. Students who were seen as having the personality trait of openness to experiences were thought to be deep thinkers, more artistic, and like to investigate. However, these students were less likely to take computer science classes. Overall Beyer suggested that *gender alone was not a sufficient predictor of identifying* successful computer science majors. Students who were interested in computer science tended to be low in conscientiousness and low in openness to experiences. Beyer suggested additional research utilizing the variable of personality.

A longitudinal quantitative study was completed by Denner, Werner, O'Connor, and Glassman (2014). The authors' focus was on finding *strategies that would lead to an increase in the number of community college students pursuing computer information systems degree* at four year universities. Participants completed a survey during the first, or second day of an introductory programming class across 15 community colleges across the state of California. Ages of the participants ranged from 15 to 66 years and 74% were male. Students self-identified as African American (5%), Asian/Pacific Islander (32%), Hispanic/Latino (20%), and White (48%). Almost half (45%) were employed, 13% were married, and 23% had school-age children who lived with them. Overall when

considering the pathway from community college to majoring in computer or information sciences at a four year university the study indicated varying factors for female and male students. Denner et al. reported that the variables that were more significantly predictors for women included taking higher levels of math, taking computer courses due to the interests in solving challenging problems, increase in expectations of success, as well as video game play. In fact, they found that *peer encouragement* and computer gaming were two of the most significant predictors in the intention to major in computer or information sciences. The problem which Denner et al. exposed is that females reported receiving peer encouragement less than males, and they also report less time spent playing video games. As a result the authors suggested supporting early opportunities for computer classes, as well as encouraging students to take higher levels of math classes. For female students specifically, Denner et al. suggested more opportunities *for peer support,* and gaming that appeals to women during class as well as encouraging it outside of class.

In a more recent study Stout and Blaney (2017) focused on the *benefits of growth mindset on women's sense of intellectual belonging in computing* when considering the amount of efforts spent on academics. The authors defined intellectual belonging as the sense that one is believed to be a competent member of the community. Their quantitative design utilized data sets that produced a sample size of N= 5, 922 students, 27% women and 73% men. The racial and ethnic makeup of the population was reported as 46% Caucasian, 29% Asian or Asian American, 9% Hispanic/ Latinx, 8% more than one race/ ethnicity, 5% African American, 1%Arab/ Middle Eastern/ Persian, 1% Other,

0.5% Native American or Native Hawaiian/ Other Pacific Islander, and 0.5% missing data. Their findings suggested that the growth mindset of women were nullified as they time needed to study increased. When women found that they had to spend a great amount of effort studying they were more likely to question whether they belonged in computing and therefore were more likely to change majors. Stout and Blaney indicated that their findings on growth mindsets challenged previous assumptions that growth mindset is consistently beneficial for students. They determined that instructors should be aware that growth mindset should accompany the encouragement and reminders that all students belong in computing, even those who have to work hard to succeed. They also suggested that unintended consequences such as assigning heavy homework loads to students should also be considered. This was not to say that there should be no homework, but that instructors should keep in that women's sense of belonging could be threatened by the amount of time spent on it.

A large data set of over eight million college and university students from 1971 to 2011, and selected year multivariate analyses of 18,830 computer science majors was used in a study by Sax, Lehman, Jacobs, Kanny, Lim, Monje-Paulson, and Zimmerman (2017). Their goal was to *document aspirations of majoring in computer science by undergraduate men and women.* They wanted to explore characteristics of those who chose to major in the field, while analyzing changes to this group over time, and identify the key determinants of the gender gap. They found that across all decades of the study women had less of an interest in computer science than men. However, over the years the overall interest in CS has fluctuated for both groups. The 1990s was a considerably high

interest time for men. Women's interest was highest for a short time in the 1980s as this was indicated as a time when CS work was gaining traction. Since the 1980s there has been somewhat of a constant decline in women's interest in majoring in CS. Some student characteristics emerged as predictors for both genders. For example, one predictor that was found to remain stable over time was that students' whose father had a STEM career and those who placed greater value on status or wealth were more likely to plan to major in computer science. The inclination of women rating themselves lower than men on their mathematical skills was found to be the primary reasonable for the gender gap in computer science, but its importance has weakened over time from 78.6% in 1976 to only 13.1% in 2011. Women's lack of commitment to making "a theoretical contribution to science" is also seen as accounting for the gender gap in the intention to major in computer science. The value of social activism was another leading factor. Women placed greater value on *social activism* such as helping others in difficulty and influencing social values. This characteristic accounted for 6.6% to 9.5% of the gender gap in computer science. Overall women or men who valued helping others and effecting social change were less likely to pursue a degree in computer science. Asian Americans and African Americans had the highest likelihoods of intending to major in CS. However, this information was not disaggregated by gender within those ethnic groups. Scientific orientation was another predictor of interest in computer science. Since women rated scientific goals as less of an interest this was seen as another reason for gender disparity. The authors also concluded that although women tend to have a lower math self-concept, the salience of math self-concept was weakening over time. They also suggested that

administrators and policymakers should focus on making sure women see connections between being artistic and creative with computing. They also indicated that it is essential to draw connections to computer science as being a field that *positively impacts society,* locally and globally. Sax et al. suggested that their study shows the nuanced distinctions of computer science from other STEM related fields and therefore future studies should separate computer science from other STEM related research.

Lehman, Sax, and Zimmerman (2017) focused on students who had decided to major in computer science. Their sample included 1,636 females and over 4,402 males who had identified as computer science majors and over 26,642 women planning to major in other STEM fields such as biological sciences, mathematics, physical sciences, and engineering. Lehman et al. focused on *comparisons between genders that highlighted race/ethnicity, academic achievement, career aspirations, and other self ratings*. Their findings suggested that there is more racial/ethnic diversity among women in CS than men in CS and women in other STEM fields. Within their study 8.40% of the women were African American/Black, 0.10% American Indian, 29.50% Asian American/Asian, 6.80% Hispanic/Latino/Chicano, 42.40% White/Caucasian, and 12.80% other. The study also suggested that women in computer science earned comparatively lower high school grades than women in other STEM fields, but higher grades than the men in CS. Lehman et al. indicated that women earned higher SAT verbal scores, but men earn higher math scores. However, the women in CS earned higher SAT verbal scores than women in other STEM fields. When it came to self-ratings of measures of ability and self confidence skills women in CS tended to often rate themselves lower than men in CS as well as

women in other STEM related fields. Although women in CS rated their computing skills higher than women in other STEM fields, they rated themselves lower than CS men. Women in CS self-rated their artistic ability higher than women in other STEM fields as well as the men in CS. Surprisingly, whereas men who majored in CS planned to go into computer programming fields women in CS rated themselves as undecided for career choices. Lehman et al. pointed out that future studies should disaggregate racial/ethnic data within CS by institution type in order to investigate how diversity may vary between institutions.

Jung, Clark, Patterson, and Pence (2017), focused on the population of men and women who were registered in undergraduate Management Information Systems, Computer Information Technology and Computer Science courses to *understand students' decision to major in technology*. They found that 62% of the males majoring in technology stated that they were *confident* in their programming ability while only 41% of the females responded as being confident in their abilities. They suggested that this may be one of the leading factors as to why there is a higher concentration of men in the field. Surprisingly Jung et al. determined that more *exposure to computer courses in grades K-12* did not positively improve women's decision to major in technology. They reported that women could not easily identify *positive role models* of other young women who major in technology, whereas they can easily identify male role models. Jung et al. determined that this can be seen as an assumption as to why more men major in CS than women. They also found that both men and women had a belief that technology majors had to be smart/intelligent and nerdy. Jung et al. indicated that this perception could be

another reason why women do not choose to major in technology. Jung et al. suggested that it is not only important to encourage women to major in CS, but it is also important to keep women in the major. Therefore the authors proposed that future research should focus on women's satisfaction with the computer science, or information systems courses they take.

Varma (2010) conducted face to face interviews with 150 undergraduate students from seven schools that were designated as Minority Serving Institutions in America to ask one question: *Why do you think there are so few women pursuing a degree in CS/CE at your institution?* Colleges and universities that were considered Historically Black Colleges and Universities, Hispanic-Serving Institutions, and Tribal Colleges and Universities were targeted. The interviews were divided into groups of 30 with 15 females and 15 males in each group and belonging to one of the major ethnic groups: White, "Afro-American" (term used by Varma), Hispanic, Asian American, and Native American. The students were in their second and third year of computer science (CS), or computer engineering (CE) studies. *Gendered socialization*, *technical anxiety*, and other reasons were the three coded categories for the participants' responses. Varma found that gender affects students' beliefs about why there are so few women majoring in CS/CE. Findings suggested that gendered socialization and technical anxiety were the main reasons for underrepresentation of women in CS/CE. However, when ethnicity and gender were considered there were different findings. For example, when considering ethnic differences Varma found that 53.3% of the White students believed in gendered socialization as the reason for under-representation of women. However, only 40% of

Afro-Americans, and 43.3% Hispanics, 33.3% Asian American, and 26.7% Native American perceived gendered socialization as the reason for under-representation. Although 50% of Asian students saw technical anxiety as the main reason for under-representation, 46.7% of Native American participants perceived other factors as the primary reason for under-representation. However, when gender and ethnicity were considered Varma found that 60% of White women, but only 53.3% of Hispanic, and Afro-American women focused on gendered socialization. Varma indicated that teachers in elementary, middle, and high schools should focus on fostering the mindset of girls so that they are motivated to see that CS/CE is consistent with their views. The author also suggested that it is important for higher education CS/CE courses to be taught by *instructors who are experienced in female studies*. As it was found that it is significant for females to have positive interactions with faculty and establish a *sense of belonging*. Overall Varma, concluded that there are important differences in the perceptions of students who belong to different ethnic groups and thus more studies should focus on how gender and ethnicity intersect in females' decisionsions to major in computer science, or computer engineering.

Cheryan and Plaut's (2010) quantitative study was designed to *explore whether processes that explain why women were underrepresented in science, math, and engineering also explains the lack of male representation in humanities*. They used two survey studies across two universities on the U.S. West Coast and focused on computer science, as the male dominated field, and English as the female dominated field. In study 1 (N =62) the participants included 33 females; 30 Whites, eleven Asian Americans,

seven African Americans, seven Hispanics/Latinos, and who indicated more than one race or other. Participants completed a questionnaire about English and computer science. The findings of Study 1 suggested that women were less interested in pursuing computer science than men. The reason was suggested that women felt a perception of being less similar to computer science majors, and thus had less of an interest in the field. Within this group men who felt similar to English majors were more likely to consider majoring in English. Therefore, the major finding from Study 1 was the significance of the perceived *feeling of similarity*. Study 2 (N = 614) included 334 females; 229 Whites, 211 Asian/Asian Americans, 13 African Americans, 13 Latinos, 39 more than one race, 23 who indicated Other, and 46 who did not identify their race. Participants received the same questions as Study 1 with additional questions about social identity threats and expectations of success. In Study 2 perceived similarity to people in the fields was still the greatest factor in predicting preferred fields even when controlling for other social factors such as identity threats and expectations of success. Thus, Cheryan and Plaut suggested that women's perceptions of how they relate to people in computer science is fundamental to changing the dynamics of gender disparity in CS. That is in order to get more women interested in the field it is necessary to change the perceptions, or images of the field in order to make it similar to how women see themselves. Social identity threats such as *stereotype threat* predict who is more interested. That is stereotype threats were stated as serving as belongingness cues that assisted in the formation of one's perception of similarity. The authors concluded that unless the issue of women feeling similar is addressed females will continue to have less representation in CS.

Cheryan, Plaut, Handron, and Hudson (2013) examined how *stereotypes of people in computer science affect females' and males' decisions to major in computer science*. Their research included two studies. In study one a total of 293 college students from two U.S. West Coast universities provided descriptions of computer science majors. The coded descriptions revealed that participants' perceptions of computer scientists were incompatible with female gender role. Students thought of computer scientists as being focused solely on computers and lacking interpersonal skills. This distinct image of a computer scientist being technology oriented, intelligent, but lacking social skills was shared by both men and women. However, women who had taken computer science classes were less likely to generate stereotypical images. Cheryan et al, suggested that this showed that the origin of stereotypical beliefs about computer scientists is largely created outside of computer science classes. As a result in study two they explored whether the media could change stereotypes and thus encourage more women to take computer science classes. For study two 54 participants were randomly assigned to read one of two fabricated news articles. Both articles, *Study finds computer science continues to be dominated by "geeks"* (stereotypical), and *Study finds computer science no longer dominated by "geeks"*(non-stereotypical), were created for the study. Women's interest were significantly affected by the article that depicted computer science as being non-stereotypical. Men were unaffected by the representation of computer science majors. Overall Cheryan et al. argued that a significant reason why women do not select computer science as a major is due to the stereotype of computer scientist being geeks, or nerds. However, they suggested that this perception can be minimized using print media.

They also concluded that the media has the power to increase females' interest in computer science by portraying computer science in a non-stereotypical manner.

Programmatic Factors That Influence Experiences

There are instances in which researchers, or program evaluators have begun to report programs that according to their findings have shown to provide more supportive environments for students in computer science, or STEM education. These articles (Table 2) have settings of specific university locations that have established environments that, according to the authors have provided various levels of support or interventions that have ensured the success of more women of color in STEM. It stands noting that Perna et al. (2009) focused on the supportive STEM environment that is provided at HBCU's such as Spelman college. However, the article did not clearly indicate the number of participants in computer science disciplines and was excluded from this review.

Table 2

Articles Highlighting Programmatic Factors that Influence Students' Experiences

Study	Sample	Focus
Frieze et al. (2012)	N = 259; 58 females and 201 males	School culture as a prominent indicator of factors that led to women's choices regarding participation in CS.
Kim et al. (2011)	N = 117 program directors; N = 96 program student interns Program student interns: 54 females, 42 males; 37 of the students were from underrepresented communities.	Computing programs that get undergraduates involved in research experiences could possibly be used as a catalyst to promote social change and increase women's interest in CS.

Frieze, Quesenberry, Kemp, and Velázquez (2012), utilized case studies from Carnegie Mellon University (CMU) to illuminate their belief that *school culture was the most prominent indicator of factors that led to women's choices regarding participation in CS.* They surveyed 58 women and 201 men who were CS majors in the fall of 2009 at CMU. In terms of social fit 23% of the men and 30% of the women strongly agreed with the statement that "overall, I feel like I fit in socially". As women moved through the program their sense of social fit became increasingly stronger. Fewer women than men felt that they fit in academically. Overall, the study indicated students' feelings about the environment at CMU. Eighty-seven percent of the women and 89% of men found that the environment provided them with everything they needed to succeed. Sixty-four percent of the women and 69% of the men felt that professors were approachable. Frieze et al. also indicated that there was an increase in the perceptions of leadership ability for both men and women as they moved through the program. According to the authors both males and females reported having good experiences with teamwork. Frieze et al. also indicated that their findings challenge stereotypes of CS. According to the researchers the students at CMU had some general beliefs about CS being geeky and nerdy, but overall describe themselves in a wide variety of ways including being "hardworking normal students," diverse," and "well rounded" among other things. Frieze et al. concluded that attitudes towards CS depend largely on c*ulture and environment* of the CS department. Thus, Frieze et al. determined that in order to increase women in CS there should be a focus on *cultural and environmental* change and not gender and gender differences.

Mixed methods research by Kim, Faann, and Misa-Escalante (2011) suggested *computing programs that get undergraduates involved in research experiences could possibly be used as a catalyst to promote social change and increase women's interest in CS.* The authors used a mixed methods approach, following a concurrent triangulation strategy, in order to explore their research questions. The study was comprised of two components: a national study of research experiences for undergraduates (REUs) in computer science education (CSE) and a formative and summative evaluation of one REU program focused on implementing practices that promote gender equity. They obtained surveys from program directors of 117 National Science Funded CSE programs that offered REUs nationwide with program goals, practices, participant demographics, and overall specific efforts designed to address gender inequity in these fields. They found that women benefited from participating in research experiences that have a critical mass of female students when *supportive role models* are involved. The authors suggested that with research experiences for undergraduate programs (REU programs) students can focus on the real world experiences that are significant to them. Kim et al. also indicated that REU programs have *strong faculty mentorship* that support students. In addition, both males and females benefited from experiences that connected students to *real world research communities*. Above all the REU experiences allowed students to see themselves as successful in computer science education. However, Kim et al. conclude that research experiences that are more beneficial to women include hands-on projects especially those that are based on real world applications and/or *social good.*

However, they indicated that further research is needed to indicate the efficacy of exploring internal and external gender issues within REUs.

Conclusions

The studies in this section have highlighted ideas of gender and racial differences as an influence of computer science majors. The suggested angle of highlighting computer science as being related advocating for social change has been indicated as a potential factor that could spark women's interest (Sax et al., 2017). Peer encouragement was highlighted as a significant predictor of females' interest as indicated by Denner et al. (2014). Still, salient indicators of whether or not women decide to major in computer science has been illuminated as being connected to beliefs about computer science stereotypes (Cheryan & Plaut, 2010; Cheryan et al., 2013). Although only two studies overtly pointed out the effects that stereotype threat has on the decision to select computer science as a major other studies showed underlying effects of stereotype threats. For example, studies by Beyer (2014), Lehman et al. (2017), and Sax et al. (2017) all indicate that if computer science majors are seen as being more artistic that could possibly increase interest in female students. Both studies that highlighted successful programs (Frieze et al. 2012; Kim et al. 2011) focused on the desire of female students to use computer science to promote social change. In both programs the needs of female students were in some way addressed by the structure of the program. Overall the programs appeared to have purposefully established overt beliefs in the significance of female students and their role in computer science. However, some of the studies have clearly illustrated that a comparison of gender alone is not a sufficient predictor of

success as a computer science major (Varma 2010; Frieze et al. 2012; Beyer 2014). Yet, a comparison of gendered experiences has continued to be a focus of numerous studies that seek to explore why so few women study computer science.

Comparing Female Experiences

This section focuses on articles (Table 3) that specifically focus on experiences and beliefs of females in relation to computer science, and STEM education. Although there are only three studies in this section they all highlight female participants and are all unique in terms of their approach. One of the studies, Ong et al. (2018) includes Women of Color from various STEM disciplines. Unlike other STEM-related articles, the majority of the participants in the study by Ong et al. are computer science majors.

Table 3

Articles Comparing Female Experiences in Computer Science, and STEM

Study	Sample	Focus
Cheryan et al., (2012)	N=100 female undergraduate students	Female, or male role models who embodied computer science stereotypes.
Laosethakul, and Leingpibul (2010)	N=282 137 American female students; 145 Chinese female students	Computer science perceptions Chinese and American women.
Ong, et al. (2018)	N=39 Women of Color; Participants' ethnicities include: 7 Asian-American, 8 Latina, 20 Black, 2 Native American, and 2 Mixed race/ethnicity; Participants' majors include: 24 computer science, 8 Physics,	Expand the knowledge of the ways counterscapes operate as conceptual and ideological as well as

	and 7 Engineering majors; Of the **20 Black women** (**11 in the discipline of computer science;** 7 undergraduates, 2 graduates, and 2 professionals).	physical settings.
Villa, Wandermurem, Hampton, & Esquinca (2016)	26 female engineering undergraduate students; each self-identified as Latina; Disciplines included Computer Science and Engineering (N=5), Mechanical (N=8), Industrial (N=2), Electrical and Computer (N=3), Civil (N=3), and Metallurgical and Materials Engineering (N=5).	Examined Latinas' identity development toward and in undergraduate engineering and computer science studies using a sociocultural theory of learning.

Cheryan, Drury, and Vichayapai (2012) experimented the effects that 100 female undergraduate students had when encountered by *female, or male role models who embodied computer science stereotypes* in interest and appearance, and the same with those who did not embody the stereotypes. Participants and role models interacted for approximately two minutes, then the participants' interests in majoring in computer science were assessed immediately after, and again two weeks later. Their findings showed that females who encountered role models who embodied computer science stereotypes were less interested in pursuing a CS major. They found that the *role model's gender did not matter as much as whether or not the person portrayed stereotypes of CS*. That is male role models who did not focus on stereotype beliefs were more effective in interesting females to pursue CS than female role models who displayed stereotype beliefs. The most salient positive factor was eliciting a *sense of belonging*. Cheryan et al. suggested that future studies should examine other likely causes for the effect of the stereotypical role models and whether additional factors were involved. They also

suggested that details of the components of CS stereotypes may also need to be further explored.

Findings by Laosethakul, and Leingpibul (2010) compared *computer science perceptions Chinese and American women.* Their study involved surveying 137 American female students and 145 Chinese female students focusing on factors such as computer anxiety, values, and foundational knowledge. They concluded that Chinese females perceive more equal opportunity for females and males in computer science. They suggested that American women have a higher level of computing anxiety and higher beliefs that they are not competent in computing. According to Laosethakul, and Leingpibul Chinese female students' gender perception towards computing is strong enough not to be influenced by computer anxiety. They found that Chinese women view the association of CS majors as being geeky and nerdy as a complement whereas American women do not. They also concluded that Chinese females are driven to be recognized as capable as men and thus view computing in a more positive light. Overall, they suggest that more research is needed to explore how gender perception of American females toward computer science is influenced by computer anxiety, and computer science efficacy.

The *conceptual ideological, and physical settings of counterspaces* was the focus of research by Ong, Smith, and Ko (2018). Their research questions focused on internal and external factors that influenced the participants to struggle or consider leaving STEM higher education, as well as the specific *intersecting identities* that may have been added factors in those struggles. They also explored ways that *counterspaces contributed to*

their persistence in their disciplines. They quantified the frequencies of central themes in order to determine which represented more robust occurrences. Out of their 39 participants (24 computer science majors, of which 11 were Black), *"76.9% mentioned isolation, 69.2% described at least one instance of a microaggression, and 97.4% declared having at least one form of a counterspace in STEM during their time in higher education"* (p. 215). Their findings suggested that women of color in STEM often found counterspaces outside their STEM departments. These spaces outside STEM departments included: *peer-to-peer relationships, mentoring relationships, STEM and non-STEM campus groups, and conferences* that were specifically created to broaden participation of women, people of color, or women of color in STEM education. Some participants did report inclusive counterspaces within their STEM department. However, it is important to note acknowledgements made by the the researchers in terms of limitations. They indicated that some participants attended historically Black colleges and universities and/or women's colleges. According to Ong et al. (2018) this is important to note because there was some indication that these types of institutions served as institution-wide STEM counterspaces. They conclude that it is significant for STEM departments to not only *create, and foster counterspaces*, but that STEM departments should also publicize efforts, encourage faculty participation through training and rewards, get students involved, keep engagement and levels of investments high not only at the onset of these initiatives, but throughout.

Villa et al. (2016) completed a qualitative study that included 26 Latina women who were engineering majors. The participants were students of a minority majority

Hispanic university on the U.S./Mexico border in a region of Texas. Villa et al. used naturalistic approaches to *explore identity development* that allowed them to understand the *multiple realities* of individuals in a particular context. They used semi-structured interviews that lasted approximately 90 minutes over the course of three weeks. Their themes emerged from their data collection. The theme of *engineering support clusters* as affinity spaces contributing to development of and persistence in engineering identities was a common theme among participants. The participants had support structures that allowed them to persist and develop agency to overcome any obstacles they faced. A second theme was that of Mexican or Mexican-American *family contributing to development of and persistence* in engineering identity. Family played a major role in the women's system of support. The significance of family and the associated physical and emotional closeness along with exposure to engineering artifacts at a young age were important in establishing strong engineering identities. The authors suggested that the families provided banks of social capital. *Equity in access* to engineering education was the theme that showed more diversity in responses. Although women in the study did discuss the lack of diversity in the engineering department, ten of them looked at the chilly department climate as a way to *prove and push themselves.* Others had mixed experiences which included some reporting that the faculty was supportive, and others indicating they received criticism from men in their program. The researchers also acknowledged that their participants appeared to have more social, and perhaps, financial capital than most Latina women who attend border universities. They concluded that

more research is needed to explore the theme of equity, but suggested the idea of *engineering being taught from a feminist theory lens*.

Conclusions

Once again computer science stereotypes were proved to be a powerful factor in females' decisions to major in computer science. Studies by both Laosethakul, and Leingpibul (2010), and Cheryan et al. (2012) show that traditional computer science stereotypes are deterrents to for American women. Similar to Denner et al. (2014), Ong et al. (2018) indicated the significance of factors such as peer to peer relationships. However, Ong et al. expanded this idea with their discussion of counterspaces. Villa et al. 2016 included themes of cultural capital, and family as support. In terms of equity in their engineering departments, some participants had issues, but did not elaborate on them, and others stated that they had no negative issues. It may be needed to keep in mind the study by Villa et al. was set in the context of a majority Hispanic university and not a PWI. However, the authors do shed some light on the significance of family in supporting and shaping engineering identities.

Experiences of African American Women in Computer Science and STEM Education

There are growing studies that have highlighted the experiences of Black women in STEM. While using the term STEM they do not always equally represent participants from various disciplines of STEM. A number of them often focus on one discipline such as science, or mathematics. As of now there is ambiguity as to whether or not researchers are implicating that the experiences of Black women in all STEM disciplines should be

considered generalizable. However, with the consideration of an anti-essential voice, a primary attribute of critical race feminism, articles that were labeled general STEM education were only included in this section if, all women identified as Black, and the researchers clearly identified the disciplines of each participant so that the number of computer science, or computer engineering students were indicated. As a result, the participant samples for the studies in this section (Table 4) are all Black, but may not all be computer science majors.

Table 4

Articles Regarding Experiences of African American Women in STEM Education

Study	Sample	Focus
Alexander, & Hermann (2016)	**8 African American Women** Master's Students: 1 Engineering; 1 Chemistry; 1 Statistics Ph.D. Students: 1 Biology; 1 Agriculture; 1 Biomedical science; **1 Computer Engineer;** 1 Engineering	Problems of racism for African American female graduate students at PWI.
Charleston et al. (2014)	**N=15 African American females All computer science majors**	African American women enrolled in computer science higher education programs.
McGee, & Bentley (2017)	**3 Black women; 1 Undergraduate junior Computer Science**, Math; 1 Ph.D. graduate, Mechanical Engineering; **1Ph.D. student, Computer Engineering**	Analyses of Black women's experiences in STEM majors/fields to examine how racism and sexism affect their experiences, to highlight psychological consequences, and coping to highlight implications for K-12 STEM classes.

Alexander, & Hermann (2016) completed a qualitative phenomenological investigation to *examine the experiences of eight African American women* in science, technology, engineering, and mathematics (STEM) graduate programs at one predominantly White university (PWU) in the South. All participants were full-time Master's students between the ages of 22 and 30. However, only *one participant was a computer engineer major.* They used semi-structured interviews that lasted approximately 90-120 minutes. The participants experiences were found to include issues of self-efficacy (i.e., diminished academic efficacy, and low research efficacy), racial microaggressions (i.e., racial stereotyping, invisibility syndrome, and ascription of intelligence) experienced in STEM classrooms, and a *lack of institutional support* (i.e., lack of peer support, *lack of faculty support*, and lack of understanding by student services). They suggested that PWUs should focus on culturally sensitive training for faculty, and additional support structures that are specific to the needs of minority and underrepresented populations in STEM programs. For example, they suggested increasing student research and academic efficacy by engaging minority students with senior students in research. They also recommended that resources should focus on emotional needs of students, by addressing their mainstream psychological adjustment issues.

Charleston et al. (2014) used a combination of critical race feminism (CRF), and black feminist thought (BFT) in their qualitative study of *African American women and their experiences in computer science higher education programs.* The authors suggested that CRF and BFT allow the voice of Black women to take precedence over the

normative conventions and iterations of Western thought. They utilized a phenomenological design to understand the common experiences of the participants. Their 15 participants, between the ages of 18 and 35, all identified as African American or Black women. Two participants had completed a Ph.D. in computer science, and 12 others were currently in doctoral programs. The majority of ladies attended a predominantly White institution (PWI) where they were currently, or recently enrolled in a computer science program. The study sought to determine factors that may be related to the lack of representation of African American women in the field. Their findings indicated several common challenges that were faced by the participants: (a) the *challenges of being a Black woman* in the computing sciences, (b) commonality of *isolation and subordination*, and (c) *sacrifices* related to computing science pursuance. The participants indicated that their experience in the computer science department was not welcoming since they were women, but even less welcoming to them as Black women. They also found that due to misperceptions and stereotypes the ladies were often *expected to do a poor job* in terms of their course work because they were female, and Black. There was an absence of both institutional and faculty support indicating that at times their *professors provoked causes of isolation*. Even if Black men were in their department frequently they would interact more with White men, than with Black women. The ladies in the study indicated that there was an additional sacrifice of having less of a social life when studying computer science. The authors suggested that faculty should examine their own biases towards racial ethnicities, and women. Charleston et al. suggested that *hiring diverse faculty* would help as it may lead to the *availability of*

mentors. They also recommended the implementation of *student support groups*, specifically for safe space for women of color.

Using a phenomenological qualitative research McGee and Bentley (2017) examined the experiences of *three African American wome*n in STEM. Two of the three women were computer related majors (one undergraduate, computer science; one PhD, computer engineering).Their analysis focused on the *psychological consequences* that may have developed due to the participants' racial and sexist experiences. They also considered *expressions of resilience* in response to the experiences. They conclude that there is a need for institutional change to make space for Black women (and other students of color). They suggest that there be more support such as *race- and gender-conscious mentoring* for Black STEM students.

Conclusions

Issues of racism and sexism are highlighted as prevalent factors in the experiences of African American women in computer science departments. African American women, often deal with stereotype threats within CS departments. As indicated by Charleston et al. (2014) the experiences of African American women are a result of varying combinations of intersectional identities. These negative experiences can lead to psychological consequences (McGee & Bentley, 2017). All authors highlighted in this section suggest the need to focus on support systems for African American women.

Overall Findings

This literature review focused on research that sought to determine why students select, or do not select, computer science as a major. The initial goal was to highlight

studies that focus on the experiences of African American females. Due to minimal articles found on this specific topic, the study was extended to include all research related to higher education students' perceptions of computer science across race and gender.

Overall, there were a number of themes that were discovered as being negative factors that were contributing to the lack of women in computer science. Factors related to *racism, stereotypes, and biases* were found to play a major role in limiting female's desires to major in computer science (Charleston et al., 2014; Cheryan et al., 2012; Cheryan et al., 2013; Cheryan & Plaut, 2010). Although issues of stereotypes and biases affected women of all ethnicities, racism was a common theme for Black women. Another closely related element was a *sense of belonging*. Research that related to a sense of belonging explored factors of students' personalities, mindset, self-perceptions, and self-efficacy (e.g., Beyer, 2014; Lehman et al., 2017; Jung, 2017; Stout & Blaney 2017). If women felt they did not have a sense of belonging they were less interested in computer science.

Since, issues of racism, belonging are aspects of the *environmental conditions* of computer science departments, the environment of computer science departments could be deemed an integral part of the problem, or solution. Some of the researchers concluded that the faculty's position of being approachable, supportive, mentoring, and overall providing positive interactions are most beneficial (e.g., Frieze, 2012; Kim, 2011; Varma, 2010), and a lack of faculty, or overall institutional support provides a negative experience (Alexander & Herman, 2016). Researchers have suggested that improving the environments of computer science departments can begin with having more professors

who are knowledgeable of female studies (Varma, 2010), or even having STEM related classes taught from a feminist approach (Villa, 2016). Providing women with safe spaces within the department was another focus of research. The establishment, and use of *counterspaces* such as safe spaces for peer to peer interactions (Denner 2014; Ong, 2018) was another suggestion for an environmental change.

Another way to pique women's interest in computer science may be to relate computer science education and careers to issues of *social relevance*. Researchers suggested that in general women have found careers in social change, and instruction that has real world relevance appealing (Sax et al., 2017; Kim, 2011). Although some solutions were pointed out, there is an overwhelming imbalance in what appears to be negative factors. What is more, these negative experiences have the potential to create harmful psychological consequences (McGee & Bentley, 2017). Literature has provided some overview of why so few women, especially women of color major in computer science. The current question is what factors exist in the experiences of Black women who are successful?

Suggestions for Future Studies

Further research should consider the intersections of race and gender with studies of computer science. The incorporation of other intersectional identities may also be beneficial. Research has found that gender alone is inept to explain the disparities in computer science. To that end, it may be remissive to determine that other intersecting identities, such as those who are a part of LGBTQ community, or have disabilities, are irrelevant. In considering the vast differences of individuals and the numerous

intersectional identities any future research should begin to highlight intersectional experiences thus reducing intersectional invisibility.

Safe spaces, or counter spaces, have been seen as beneficial in supporting African American female students. Whereas HBCUs have been found to provide nourishing environments, this is not the typical case for PWIs. Additional research is needed to determine if schools, specifically PWIs are prioritizing cultural awareness training and have plans in place to change the dynamics of CS departments so that all students welcomed and continually supported.

There is not enough research that centers the voices of African American women, and Women of Color in general who have persisted against the challenges in order to complete their degree in computer science. Their narratives about their experiences and the internal and external factors that have propelled their success can serve as empowering counterstories. Overall, research that focuses on the experiences of women of color is limited, and thus need to be expanded.

Finally, another angle for future research that has not been clearly determined by authors are comparisons of the distinctions between STEM groups. That is, research should highlight comparisons of perceptions, motivations, and factors related to women in various STEM areas. Currently there is a tendency to group all STEM majors together, frequently with the exclusion of computer science.

Purpose

The purpose of this study is to continue the investigation of underrepresentation in computer science. However, whereas the majority of other studies have focused on

obstacles that often deter women from computer science this study will investigate the characteristics that can be seen as beneficial factors that have lead to the completion of a degree. The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI). In order to get a complete overview of the unique experiences of participants the following secondary questions are also relevant:

1. What factors have influenced participants' decision to major in computer science?
2. What were the experiences of the participants during their time in their computer science program?
3. How do these women make meaning of their experiences?

CHAPTER III

METHODOLOGY

The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI). In order to get a complete overview of the unique experiences of participants the following secondary questions are also relevant:

1. What factors have influenced participants' decision to major in computer science?
2. What were the experiences of the participants during their time in their computer science program?
3. How do these women make meaning of their experiences?

This chapter discusses the rationale for the use of the research design and methods, including information about the research sample, an overview of relevant contextual information, detailed descriptions of data collection, plans for analysis and synthesis, ethical considerations, trustworthiness, and limitations. At the end of the chapter is a brief summary.

Critical Race Feminism Methodology

Critical race feminism (CRF) is still considered a relatively new theory, but continues to gain traction. Various authors who have used a CRF framework with qualitative approaches such as traditional narrative (Griffin, 2013), phenomenology (e.g.,

Charleston et al., 2014; Berry, 2014), discourse (e.g. Pratt-Clarke, 2010), and autoethnography (e.g. Linder, 2011; Berry, 2005). Later authors began using CRF with research narrative writing that was biographical or fit in the category of memoir (e.g. Berry 2010; Berry and Candis 2013; Berry and Cook, 2018). Authors of those examples use traditional methods of analysis and do not specify the use of critical race feminism methodology. In naming critical race feminism as methodology I proceed with caution while honoring, and acknowledging the work of the foremothers, and forefathers of both CRF, and CRT. I realize that although I have attempted to exhaustively search for the use of critical race feminism specified as methodology there may indeed be a glorious work that has yet to come to the forefront. As such I contacted two of the most prominent elders of CRF scholarship, Adrienne Wing and Theodorea Berry. Professor Wing (A. Wing, personal communication, February 7, 2019), explained that since her use of CRF has been from the discipline of law she, understandably so, has not utilized research methodology, but referred me to Dr. Pratt-Clarke. Using CRF as a theoretical framework, Dr. Pratt-Clarke (M. Pratt-Clarke, personal communication, February 7, 2019) stated that she used discourse analysis as methodology. I have not found any researcher who states the use of critical race feminism as methodology. This was also confirmed by one of the responses I received from Dr. Berry (T. R. Berry, personal communication, March 17, 2019) as I explained my dissertation proposal to use CRF as methodology. As such I have paused in reflection of whether this is due to a lack of need, or due to CRF's underutilization in what may be considered a relatively embryonic state. As a result, in the following sections I will detail my proposed use of critical race feminism methodology.

Through various articles Berry (Berry, 2015; Berry, 2010; Berry, 2009; Berry, 2005; Berry & Cook, 2018) has authored works that have indicated the applicable uses and elements of critical race feminism in education. Five of the six CRF tenets are derived from CRT: *Race and racism, Whiteness as property, interest convergence, anti-essentialism/intersectionality, and uniqueness of voice/counterstory.* However, CRF also includes the tenet of *multidimensionality*. Researchers using critical race feminism must also work towards the collaboration of theory and practice (Berry 2015; Berry 2010; Berry & Candis 2013), which Wing (1999) considers multiplicative praxis. Finally, critical race feminism utilizes multidisciplinary perspectives as authors of various disciplines contribute to CRF writings (Berry 2015; Berry 2010; Wing 2003; Berry 2009).

Qualitative Methods

Due to critical research's connection to qualitative study I used this overview of qualitative methods as a starting point. This study utilizes qualitative research design because qualitative research is conducive to critical research which calls for rich storytelling. There are five features of qualitative research as defined by Bogdan and Biklen (1998). Qualitative research is *naturalistic* in that it takes place in natural settings with the main instrument for data collection being the researcher. Qualitative research is *descriptive,* as data is in the form of words, or pictures from interview transcripts, field notes, photographs, videos, memos, and other documents and records. The researcher must scrutinize all details then uses quotations from the data to present findings. Having *concern with process*, rather than just the outcome, is another characteristic of qualitative

research. The utilization of various processes allows for enhanced understanding of the activities and meanings that are a part of the situation being studied. Data analysis from an *inductive* approach is another qualitative trait. Data is not used to prove, or disprove hypotheses but can allow the researcher to construct understandings, or theories. The final trait according to Bogdan and Biklen (1998) is that qualitative researchers are interested in how different people make *meaning* of their lives. Qualitative research focuses on meaning and understanding, utilizes rich descriptive data, and lends itself to a critical research perspective (Merriam & Tisdell, 2016). A qualitative study allows the researcher to truly explore the essence of the topic while taking into consideration specific meanings established by participants. Overall the intent of qualitative research is to understand those meanings of human action (Schwandt, 2015).

Storytelling

CRF methodology uses counternarrative as an analytic tool to centralize the experiences of women of color in order to raise critical consciousness about racial and social injustices. Counterstories or counternarratives, terms used interchangeably, counteract stories of hegemonic society (Delgado, 1989). Authors indicate that there are three types of counterstories: autobiographical, biographical, and composite (Solórzano & Yosso, 2002; Yosso, 2006). I choose to think of counterstories as having two broad categories as described by Dixson and Anderson (2017) first hand account, and composite stories. However, under the category of first hand account are two types: autobiographical, and biographical. All counterstories serve to provide voice to those who have been marginalized, build community so that others who are oppressed know

they are not alone, disrupts taken for granted beliefs of the world that have been created by master narrative, and provide a platform to facilitate transformation (DeCuir & Dixson, 2004; Delgado, 1989; Dixson & Anderson, 2017; McKinley, Brayboy, & Chin, 2019; Yosso, 2006*). It is not enough to say* counterstories *highlight, or include people of color*, and it *is not enough to* simply *write one's story to share or vent* about personal struggles. Counterstorytelling is purposeful in its *intentional centering of People of Color's perspectives* as well as a *critical historical reflection of their experiences* (Yosso, personal communication, February 22, 2019). Thus, multiple layers of data collection and positioning in social context is an essential aspect of each type of counterstory.

Counternarratives as a first hand account is thus autological as they are first hand accounts of people of color. The author presents the counternarrative to expose or critique the normative thinking and dialogue that extends racial stereotypes, thereby providing agency and centering the voice of those who are socially and politically marginalized (Berry 2010; Berry & Candis 2013; Dixson, Anderson, & Donnor, 2017). These counterstories often focus on the experiences of students countering master narratives associated with deficit mindsets, and lack of motivation.

Writers of *counterstories as first hand accounts that are autobiographical* may use various terms. In using critical race feminism, Berry has used the terms autoethnography (e.g., Berry 2014, Berry 2005), as well as the term memoir (e.g., Berry 2010; Berry and Candis 2013; Berry and Cook, 2018). The specific name may have meaning to the writer. Berry and Candis (2013) used the term memoir because of the aspects of recall and revealment in one's storytelling. The counterstory is about what, and how well the writer recalls, as well as the intentional and unintentional selection of things

that are revealed. Although the story is autobiographical in nature there is still a need to layer sources of data. Berry and Candis (2013) have spoken of the importance of field notes as sources of data in counterstories. The collection of other observational data such as student's work, or other artifacts from one's classroom is appropriate and typically deemed as an exempt process of the Institutional Review Board (Berry & Candis, 2013). Reflexive journal entries from the storied individuals as well as field notes are examples of primary sources of data. With reflective journaling the writer acknowledges their multidimensionality (Berry and Candis, 2013). Field notes can serve as data and analytic tool. For example, field notes are important sources to create reflective writing prompts (Berry and Candis, 2013). Berry and Candis (2013) have identified suggested steps for this process of presenting collected data as a counternarrative. Each story may begin with an individual free writing, or journaling of experiences, then it is useful to exchange narratives with others (if possible those who are participating in the same activity) so that questions may be posed to aid in critical reflection, and to assist in revealing other details that are not mentioned. Finally, the stories are then condensed for the intended purpose (Berry and Candis, 2013).

Writers of *counterstories as first hand accounts that are biographical* in nature must take additional steps to ensure the story is being told as intended by the individual. Everyone's story is unique, and even though one story provides insights into the circumstances and complexities of the individual there are many more stories that could be told. As CRF researcher, I feel we should not force the story that we want to hear. This does not mean that we cannot establish context. However, if we are unrelenting in our probe to get a particular response, whose story are we telling? It is important to allow the

interviewee to cover all that she wants to cover without interruption (Kim 2016). During the interview process the researcher should collect field notes that will enhance the written transcripts. With CRF it is important that the stories acknowledge aspects of multidimensional identities as these are salient aspects of the individual. Since these identities are sometimes manifested in various means providing the storied individual with an opportunity to share their stories by using other methods such as poetry, photography, or other creative means should be encouraged. Another aspect of counter narrative in biographical format is ensuring that the story is rendered in the way the individual intended. For first hand accounts the narratives of the storied individuals, which may be written by the individual, or collected through interviews, are primary sources of data. Although, I will outline procedures as a researcher who is engaging in the collection of biographical first hand accounts. I choose this method because the creation of CRF counterstories should not be limited to those who work in the field of education. Therefore, CRF conscious researchers must carefully construct and report the stories of those who do not have the inclination to write their own stories, but wish to share them. However, with this method comes the responsibility to ensure that the voices of the storied individuals are represented from the perspective they intended.

Composite stories are created with data from at least four sources. Composite stories must be created with empirical research data (e.g., findings from surveys, focus group interviews, etc.), existing social science, humanities, legal, or other literature on the topic(s) evidenced in the research, judicial records (court filings, rulings, oral arguments, etc), and authors' professional and personal experiences (Solórzano & Yosso, 2002; Yosso, 2006). Considerable time must be taken for the analysis of data. The

researcher then uses the analyzed data to create composite characters who symbolize the themes manifested from the research (Dixson, Anderson, & Donnor, 2017; Yosso, 2006). In other words, the author constructs a story involving composite fictionalized characters.

The characters are positioned in social, historical, and political settings that allow the dialogue to speak to the research findings and creatively challenge racism and other forms of subordination (Yosso, 2006). In composite counterstories the characters engage in critical dialogue that challenges the status quo.

By means of first hand account, or composite stories, CRF counterstories centralize, not simply highlights the voices of women of color. The application of a critical theory to research methodology promotes empowerment, decolonizing, and humanizing the experiences of the participants (Winkle-Wagner, Gaskew, & Lee-Johnson, 2019). I will clearly present details of the methods used in this study as one model for the utilization of critical race feminism methodology. I must underscore and subscribe to the reality that there is no one way to use critical methodologies, and find that among critical scholars creativity is commended. Finally, I must affirm that the utilization of critical methodology is not to be taken lightly, or used frivolously to vent or rant about one's own racial struggles, but to advance the understanding of how law and policy are operating (Ladson-Billings, 2013). Although a person of color may use storytelling methods to relate to personal experiences, the appropriate use of a critical method must focus on broader social justice meaning.

Research Sample

Recruitment efforts began with the use of the pilot study which commenced with the approval of the Institutional Review Board (IRB) in March 2019 as a project of practicum coursework. This was an earlier phase of the research, which was originally intended to test the interview protocol. During this phase participants were to have graduated between the years of 2014-2019. Recruitment efforts were completed by contacting professional organizations, and local companies that would likely have Black female computer scientists as members. Individuals who were publicly recognized as computer scientists were also contacted. No participants were acquired during the pilot study, and thus no data was collected during that phase. In April 2019, after the proposal of this dissertation amendments to IRB were made to expand the recruitment process, allowing me to post recruitment information using various social media platforms such as Twitter and Linkedin, as well as through university alumni lists, alumni newspapers, email, word of mouth, etc. The inclusion years of participants' graduation was extended to the range of 2000-2019. Research participants shared the following basic demographics. They self-identified as African American female. It was important for participants to self-identify as African American and female because race and gender and are not characteristics that can necessarily be ascertained by an observer. Participants completed a higher education degree (B.A., M.A., M.S., Ph.D. etc.) in computer science/engineering from a predominantly White institution. This was essential as experiences at Historically Black Colleges and Universities (HBCUs) have been found to differ from those at PWIs (Hurtado et al., 2011; Perna et al., 2009). Literature has found that STEM related departments at PWI have been cold, whereas

those of HBCUs have been warmer and nurturing (Hurtado et al., 2011; Perna et al., 2009). This is a phenomenon that warrants more research. All participants have graduated within the years 2000-2019. The graduation year is another inclusion criteria because it was important to ensure experiences were current, and relevant to the atmosphere and practices of departments during recent years. The fact that a number of Black computer scientists, male and females, have been found to have better support and success at Historically Black Institutions, as well as the limited number of females who do major in computer science compounds my concerns for finding participants. A participant demographics matrix, Table 5 highlights the participants' chosen pseudonyms and other interesting information that the participants shared.

Table 5

Participant Demographics

Pseudonym	**Age**	**Year of CS Degree Conferral**	**Degree Type(s)**
Ashley	35	2004, 2006, and 2010	Bachelor's, Master's, and PhD.
Jasmine	36	2005	Bachelor's
Nancy	26	2019	Master's

Since CRF accepts and acknowledges the intersecting and multidimensional identities of African American women (Berry 2015; Berry 2014; Wing 2003) it is important that salient identities are acknowledged in research. Wing (1999) explains that identities are multiplicative and while some aspects of identities of women of color, such as race leads to discrimination, other identities such as being heterosexual, or a lighter skinned African American can relatively privilege them. CRF acknowledges and accepts

the significance of all aspects of an individual's multidimensional/multiplicative identities. Therefore, in addition to basic demographics such as age, and the year of their degree etc., each participant was asked if there were other salient identities that they wished to share, but no additional salient identities were mentioned by participants.

Data Collection Overview

Data was collected through multiple detailed interviews, participants' optional artifact submission, member checks, and field notes. As a CRF researcher, it was essential that the voices of the storied individuals ring through without the interference of personal biases. My only guidance was to situate the narrative within the participants' experiences as a computer science major. Literature has been published that focuses on issues of racism and sexism that African American women experience in computer science departments but I did not direct their narratives into that space. As a CRF researcher, my role was to share the unique experiences of these ladies, and I did not drive their responses to support my personal agenda. It was very important that the voices of the participants are highlighted above my own. However, because CRF is about empowerment and transformative research it was essential for oppressions to be uncovered, and social justice is promoted.

Interviews

Data collection began in May 2019, and continued through August, 2019. A general research protocol shown in Table 6 was used for the first interview to invite the participants to share their stories. Although the intent was to hold each interview in person due to travel issues and general conveniences for participants each of the first two in-depth interviews were completed via video conferencing using Zoom (2019).

Details regarding dates, times, and durations of the initial two interviews are found in Table 8.

Detailed interviews not only allowed for richly detailed narratives but also helped to build rapport. According to Kim (2016) often during the first interview meeting, the participant would typically focus on public knowledge, or information that they expected that the researcher wanted to hear. During the second and subsequent interviews the participant offers private accounts. For that reason, this research used two in-depth interviews, to gather the majority of data. As seen in Table 6, at the end of interview one there was an added option for creative and open-ended reflection that had the potential to illuminate other thoughts and identities of the participants. After basic introductions, and questions to gather demographic information questions remained open-ended as shown in Table 6 allowing the participants to narrate their experiences related to being an African American female student in a computer science department at a PWI.

The questions were sectioned into categories that were meant to build upon each other. Since the most important aspect of an interview is building rapport and trust (Kim 2006) the opening questions not only functioned to begin the interview process but were used to build rapport and trust as the participants were reminded of confidentiality. I moved to demographic information which was needed to acknowledge the participants' intersecting and multidimensional identities. Perceptive data gathering began with background information. This was labeled perceptive data because it was based on the participants' perceptions of their experiences. Narratives are not records of fact, but are created through meaning-making, from one's memories, experiences and perceptions (Kim 2016, p. 346; Wertz et al., 2011, p. 317). The things that people perceive as actual

events are the main components of their story. In order to get a complete understanding of the situation it was important to develop the contextual background information. These sections were also meant to purposefully uncover meaning making related to the multifaceted individuals whose stories are being centered. For example, one of the sections was labeled *perceptual details: factors of resilience and empowerment* to allow for the acknowledgment that Black women are characterized by more than stories of pain, oppression, and discrimination, but also stories that show their ability to flourish despite adversity (Wing, 1990). Overall, from the demographic information throughout every aspect of the interviews were purposeful moves to discover and acknowledge various aspects of the multiplicative identities that equate to the uniqueness of each participant. In order to ensure research questions were being addressed each research question was aligned with an interview question.

Table 6

Interview One Protocol

Interview Script (notes in italics)	Rationale/ Category	Corresponding Research Question
Thanking the participant, introductions, review of informed consent, and the research purpose. Ask if the participant has any questions. Answer as needed. One way that I am ensuring confidentiality is by allowing you to select a pseudonym. So what would you like for it to be? *Allow participants to select a pseudonym before recording begins.*	Rapport building and establishing pseudonym	
Audio Recording Begins		

Of course, you are asked to be a part of this study because you are an African American woman with a computer science degree. However, I also want to ask if there are any other important identity that you would like acknowledged? *(Examples are but will only be given if the participant needs clarification such as sexual being a feminist, an activist, religious identities, LGBTQ?)* Do you mind telling me your age? What year did you receive the degree? Great, thank you.	Demographic information Contextual	
Tell me your story. I really just want to know your story. How did you get to this point? So feel free to go back into your childhood.	Perceptual/ Background	Q1: What factors have influenced participants' decision to major in computer science?
So once you were accepted into the program… How were things? *Used to continue elaboration, if needed.* Tell me about some of your most memorable experiences in the computer science program? *Stop here depending on time, or continue to the next question, if at least 30 minutes are left.*	Perceptual/ Background	Q2: What were the experiences of the participants during their time in the computer science program?

Only if a discussion of challenges emerges…. So, what would you say is the story of how you made it through this program? *If no discussion of challenges emerges…* It seems like you had a really great experience as a student in the computer science program. Tell me more.	Perceptual detail: factors of resilience and empowerment	Q3: What factors have influenced the success of the participants?
Audio Recording Ends		
Share Optional Prompt The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional reflections about your computer science education experience as prose, poetry, or some other form. You may write your response on this sheet, and/or use a different sheet of paper as needed. You may also share a copy of an artifact that you already have such as a journal entry, notes, an illustration, a poem, song or anything else you would like to share that will enhance the narrative regarding your experience as a computer science major at a predominately White institution.	Perceptual and/or Creative Artifact	Q2: What were the experiences of the participants during their time in the computer science program? Q3: What factors have influenced the success of the participants?
Please keep in mind sharing this artifact is optional, but if available, please bring it to the next interview.		

The utilization of critical race feminism goes beyond highlighting the experiences of women of color. Critical race feminism involves the significance of unique voice, the salience of intersecting identities, and the multidimensionality of consciousnesses.

However, one of the most prominent features of critical race feminism is that the narratives of women of color are centralized through counterstorytelling. As data was collected, transcripts from interviews were reviewed to establish follow-up questions. All questions for interview two were built off data collected from interview one. Unfortunately, no participant provided optional artifacts.

During interview two participants were asked to elaborate more and/or to clarify information from interview one. Since stories are based on perceptions and memory in the initial telling certain critical details may not be revealed. It was important for the individuals whose stories are centered to be posed with questions to address absences in their revealment (Berry & Candis, 2013). Table 7 shows an example of questions for interview two. I felt that it was important for my approach to be semi-structured and begin with a broad view of the participants' experiences. For example, I understand that mentorship, or the relationships that participants have with teachers, or other role models may be a potential factor in their success. Instead of asking, "what people were beneficial to your success?" I frame the question as –"what experiences have influenced your success?." Utilizing non-judgmental questions will be essential.

Table 7

Interview Two Protocol

Interview Script (notes in italics)	Rationale/ Category	Corresponding Research Question
Thanking the participant, review of informed consent, reminding participants of confidentiality. Ask if participants have any questions. Answer as needed.	Rapport building	
Audio Recording Begins		
During the first interview, you mentioned that while in class you felt that even faculty treated you as if you didn't belong there. Can you help me to paint a picture in my mind? Tell me about an average day from the moment you enter the building, and go to classes. You mentioned that {position, idea, person, philosophy, etc.} played a big role in you completing the degree. Tell me more about that.	Perceptual details	Q2: What were the experiences of the participants during their time in the computer science program? Q3: What factors have influenced the success of the participants? Q4: How do these women make meaning of their experiences?
During our last meeting, I asked about an optional artifact. Do you happen to have it? *If yes…* Great. So tell me about this. If no... Well, it was optional. *Depending on*	Perceptual details	Q2: What were the experiences of the participants during their time in the computer science program? Q3: What factors have influenced the success of the participants?

whether they imply they wanted to, but did not have a chance to do so… Feel free to send it to me later if you like.		Q4: How do these women make meaning of their experiences?
Audio Recording Ends		
Thank the participant again.		

Initially, interviews were to be held in person. However, due to the participants' various locations video conferencing by Zoom (2019) was used, for the two initial interviews. Some conversation transpired with participants before and after the actual interview session. However, details of the dates, and times of interviews one and two are outlined in Table 8. Although approximately five to ten minutes were used at the beginning and end of each interview for additional information, the time shown in the table represents the actual time of the recorded interviews that were then transcribed. There was a total of two semi-structured interviews with the option for a third mini interview which was extended via email. I wanted the women in this study to feel empowered to share their narratives, and as such I left the option to have a follow-up for more information. The third interview served as a stage of member check to ensure that interpretations were in agreement with the storied individuals' meaning.

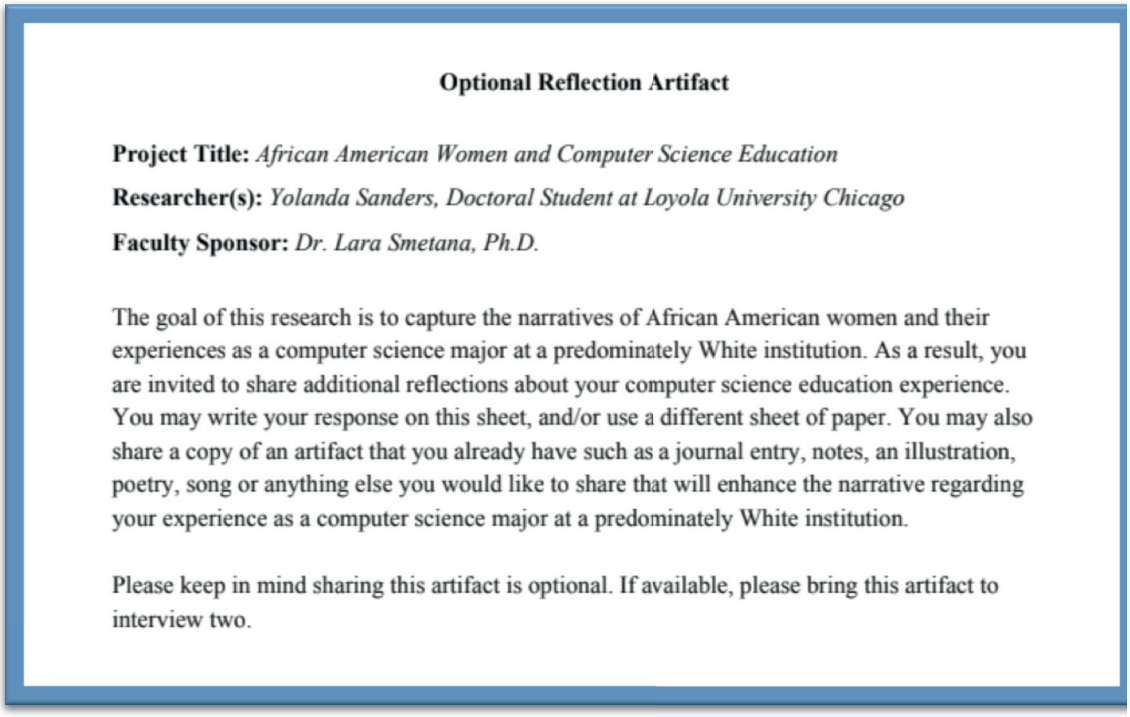
Table 8

Interviews One and Two Details

Pseudonym	Interview One Date	Interview One Duration	Interview Two Date	Interview Two Duration
Nancy	05/21/2019	53 min.	05/23/2019	35 min.
Jasmine	06/26/2019	40 min.	07/01/2019	30 min.
Ashley	08/12/2019	45 min.	08/19/2019	33 min.

Optional Artifact

An optional component allowed for additional data collection from the individuals whose stories were centered in this dissertation. At the end of interview one, I invited participants to optionally share copies of written reflections, notes, journaling, etc. and to bring it to the next interview. The prompt used is shown in Figure 1.



Optional Reflection Artifact

Project Title: *African American Women and Computer Science Education*

Researcher(s): *Yolanda Sanders, Doctoral Student at Loyola University Chicago*

Faculty Sponsor: *Dr. Lara Smetana, Ph.D.*

The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional reflections about your computer science education experience. You may write your response on this sheet, and/or use a different sheet of paper. You may also share a copy of an artifact that you already have such as a journal entry, notes, an illustration, poetry, song or anything else you would like to share that will enhance the narrative regarding your experience as a computer science major at a predominately White institution.

Please keep in mind sharing this artifact is optional. If available, please bring this artifact to interview two.

Figure 1. Optional Artifact Prompt

Since this study is not autobiographical the use of optional artifacts would allow the storied individuals an opportunity to share more of their multidimensional identities that they felt were relevant. This would have allowed participants to tell their stories and allows for other multiplicative identities to be discovered by the researcher. Unfortunately, none of the participants provided artifacts.

Member Check

Member checks were used to determine if the researcher accurately rendered the story according to the participants' intentions (Sandelowski, 2008). I used member check to ensure the centralization of accurate first hand accounts of the participants. After findings were analyzed and interpretations were made I shared this information with the

participants, January 2020, via email interview on a case by case basis to ensure that their intended narrative meaning remains centralized. This enhanced credibility and ensured that my own biases do not influence how the participants' perspectives are portrayed, as well as to determine the accuracy of the findings. During this final communication process, I also asked participants to submit thoughts of reflection.

Memos and Reflective Notes

Extensive notes and memos were kept throughout the study to capture fine points and details. Field observation notes captured nuanced elements that transcripts cannot, such as participants' demeanor, body language including gestures, facial expressions etc., as well as details of the setting, including furniture arrangements, atmosphere etc. (Brodsky, 2008). These details that cannot be quoted can be richly described in field notes. The utilization of purposeful field notes add a well-needed layer of richness to qualitative research. The use of field notes as operating within the realms of a data sources as well as analytic tools. In addition to the observable details which enhances data, field notes also served the purpose of capturing reflective thoughts, and analytical practice (Brodsky, 2008). General reflexive notes and memos were kept to continually bracket my biases, and reflect on my overall thoughts, impressions, assumptions, and feelings that I acquired during the interviews, as well as keep extensive memos regarding the analytic process used for data analysis. For example, during the interview time I met with each participant using Zoom (2019). During the interview I used audio recordings to capture audio data, but I also took notes of things such as how the participants sat. I noted whether or not they looked comfortable, whether or not they were seated upright, etc.

After each interview and throughout the process I kept reflective notes, some very private thoughts about the daunting process of completing this dissertation as a whole, and some about the daunting process of interviewing people who already have their Ph.D.

Data Analysis

To assist with the management of data, some memos, codes, etc. Dedoose (2019), a qualitative software, was used. A variety of data analysis approaches were considered which would emphasis the tenets of CRT such as a questioning approach outlined by Winkle-Wagner et al. (2019), utilizing CRF tenet questioning, and multiple consciousness coding, similar to double consciousness coding as suggested by Lee-Johnson, and Henderson (2019). Qualitative data analysis is predominantly an intrinsic interpretive process (Freeman, 2017). Thus, the interpretations of one researcher is not necessarily the same as another. There is no specific, and universal right way to complete qualitative data analysis, but data may prompt, and inspire the researcher to think in various ways (Freeman, 2017). Using a narrative approach to analyze data involves considerations on various dimensions such as *life story* versus *categorical*, and *what* is told versus *how* it is told (Josselon, 2011). It is a creative process as the researcher/analyzer must discern the voices within the narrative paying attention to the told, as well as what is unsaid (Josselon, 2011). Therefore, in an effort to utilize the rich data provided to its fullest potential analyses was completed using two approaches, narrative analysis, and analysis of narrative.

Narrative Analysis

Being a relatively new and underutilized theory, as previously mentioned, authors have used a CRF framework with traditional qualitative approaches such as traditional narrative (Griffin, 2013), phenomenology (e.g. Berry 2014; Charleston et al., 2014;), discourse (e.g. Pratt-Clarke, 2010), and autoethnography (e.g. Berry 2005; Linder, 2011). Later authors began using CRF with research narrative writing that was biographical or fit in the category of memoir (e.g. Berry 2010; Berry and Candis 2013; Berry and Cook, 2018). Yet, storytelling has the power to connect with a larger group of people beyond the scope of traditional modes of research. CRF research that is written as autoethnography, or as memoir requires the researcher to author their own stories.

Methods of research which involve autobiographical writing have tremendous value. However, I contend that researchers have a duty to those who have powerful stories to tell, but do not have a desire to author them. For this reason, narrative analysis should be utilized. Since uniqueness of voice/countersory is a central tenet of CRF and since the unique stories of these ladies and other African American computer scientist have not been expressed using this method I felt compelled to expand the boundaries of CRF methodology and utilize narrative analysis to tell these unique stories which I refer to as biographical narratives of first hand accounts. Since these stories counteract majority stories and are intended to reach a broad audience of readers (Delgado, 1989), I also refer to them as counterstories, or counternarratives.

Narrative analysis was used to create biographical narratives of first hand accounts. According Polkinghorne (1995) researchers using narrative analysis organize

data into coherent developmental accounts. Emotionally intense events of each participant's interview data were synthesized into what Polkinghorne (1995) calls an "emplotted narrative." I wrote each narrative using data collected during the interviews for each participant. This method embraces the truest sense of critical race feminism (CRF) by centering the uniqueness of the voices of African American participants using storytelling. Storytelling is, after all, a tradition in Black culture (Delgado, 2000). Therefore, instead of plunging into excerpts of quotes related to greater themes, relying on the tenets of critical race feminism(CRF) a counterstory which highlights each participant's unique voice is presented at the beginning of chapter IV.

After each interview, I began transcribing later the same day or the following day. It was not unthinkable to complete my own transcriptions since I had only three participants and at the time was not working, in an effort to focus more time on my dissertation. However, as a result of my inefficient typing skills, and lack of professional transcription tools the task was extremely daunting. For at least some of my transcripts it took me a full day and a half to complete the first transcription draft. After the first draft I reviewed each two more times for accuracy. In the end, the process of listening to the voices of these women over and over again provided me with a feeling of thorough knowledge of my data.

I began my narrative analysis process primarily by reviewing transcripts by hand making notes of anecdotes that I felt were spread throughout the transcripts. I also referred back to my personal notes, reflections and perceptions, of the participants' demeanor and setting that I kept in a journal, my field notes. I then used Dedoose to code

excerpts of data using narrative coding explained by Saldaña (2016) coding from a literary perspective. I coded for literary elements which would later yield various components of a story. For example, I coded for the protagonist details the participants shared about who they are as individuals throughout the span of their shared life. The antagonist code represented those who were oppressive or showed opposition to the protagonist. Rising action code represented the emotional turning points and incidents that lead to conflict. Climax code were used for incidents that were related to high levels of conflict for the participants. I coded for falling action places where participants indicate their support, or intrinsic strengths to persevere. Coding for the resolution included the participants' ending thoughts, and messages to future computer science aspirants. My first attempt at crafting a story was unsuccessful as I attempted to incorporate as much data as possible, thinking that I was keeping the voices of the women as holistic or complete as possible. I felt that everything they had to say was so extraordinarily valuable I tried to include it all. This resulted in an extremely long and overall unappealing story. So I reviewed data for each story element category again using pieces of data that I felt first and foremost were emotionally powerful, and secondly those that addressed my research questions. In order to consider excerpts I used a story map organizer to outline the story and compare various excerpts to determine a meaningful beginning/background information, point of conflict, and resolution. In order to structure the data into a cohesive narrative I reviewed autobiographical narratives from a book that used CRF (Berry and Mizelle, 2006) as an exemplar examples. Similar to those examples, in order to keep the narratives succinct, I chunked anecdotes into memorable

themes. As a way of fine tuning the stories a technique known as narrative smoothing (Kim, 2016; Polkinghorne 1995; Spence 1986) was used. With narrative smoothing the researcher infuses details for context in order to fill gaps that remain. To assist with identifying gaps I asked graduate student peers, and graduate writing tutors, from the university writing center, to read and provide feedback on the stories. Each part of the story is taken from the data, but was arranged and smoothed into a coherent narrative. I reviewed the themes and arranged them to begin with a recollection of the participants' childhood memories and expand throughout their experiences in their college computer science programs. This provided smoothing chronologically across the lifespan of youth into young adulthood, where conflict arose. Each story's resolution is comprised of factors that helped the individuals not only persevere but also have hope for future African American women in computer science. The introduction to the participant was created using demographic information and notes that I jotted down in my journal during the interview. These narratives provide a hint into the psyche of these multidimensional women and the factors that helped them to persist even during times of difficulty. Although each of these stories span across various times in the participants' lives I consider them "storied episodes" (Polkinghorne, 1995) of their lived experiences since each narrative focuses solely on events that are related to their identities as computer science majors. Their stories are powerful.

Analysis of Narrative

The second method of analysis utilized was analysis of narratives (Polkinghorne, 1995). This process was used to compare and contrast participants' experiences through thematic categories. I consider this a more traditional use of narrative analysis. In order to accomplish this, I made notes during the interview in my journal capturing words or instances when they laughed a great deal about certain topics, appeared annoyed, or even hurt. After interviewing each participant, then transcribing audio into data it was easy for me to remember the words of these ladies as the sounds, tones, and energy of their voices hung in my memory then, and still lingers now. I reviewed the transcripts several times. Relying heavily on the information that was told during the interviews I completed several rounds of inductive coding using an open ended approach to see what themes would emerge across the three participants. After several rounds I determined which themes to include in this analysis. Narrative analysis is about deciding what is and is not significant (Josselson, 2011). I have presented those themes in chapter IV after the participants' individual stories. Finally, through a deductive process similar to the four step critical race theory analysis technique (Winkle-Wagner et al., 2019). I reviewed my initial findings and aligned them to CRF tenets. Using each portion of data and general interpretations I formed questions or wonderings that were connected to relevant CRF tenet. I then used the questions to frame my analysis through an interpretive process explaining connections to the tenet. In my findings I have incorporated the CRF interpretive analysis into the thematic section. In this way, the findings clearly lend themselves to the connections between race and social injustice within computer science

departments at PWIs.

Findings are presented in Chapter IV. The chapter begins with the narrative analysis presentation of biographical counterstories. The next section of the chapter is the analysis of narratives which includes the thematic categories and aligned interpretations of CRF tenets. The alignment between themes and CRF tenet questions are listed in Table 10, located at the end of Chapter IV.

Ethical Considerations

Although there are minimal inherent risks with this study certain measures were taken to ensure the protection of each participant. Informed consent will be a priority. Once interested potential participants contacted me, I discussed the study, and answered any questions they had. I will also complete the initial screening to ensure inclusion at that time. Once inclusion was verified I shared a copy of and explained informed consent. Consent forms were distributed via email, mail, or in person. Once signed, participants scanned and returned via email, or in person prior to the beginning of interview one.

Interview one was to be face to face. If for participant convenience interview one is via video, or phone, signed consent will be received via email prior to the beginning of video conferencing, or phone call. Due to the location of participants and their convenience interviews were completed predominantly via via conference. I reviewed and explained consent at the beginning of each interview as it was not only important to remind participants of confidentiality, but that they did not have to answer any questions they did not want to answer.

The self-selection of pseudonyms was another way to ensure confidentiality. To protect participant identity throughout the study, identifying information was removed from all data and their pseudonyms were used to identify them in all data gathered and in data summaries. Although I am able to identify participants by name only pseudonyms were recorded in field notes. Interviews were audio recorded and transcribed using pseudonyms. All identifying information such as company names and names of institutions were removed from data. Additional data such as optional reflection notes from participants were labeled with pseudonyms. Some contextual information was changed, or some details in findings are not shared in order to protect the identity of the participants.

Trustworthiness

Considerations of trustworthiness are essential elements in qualitative research (Bloomberg & Volpe, 2019; Cresswell & Poth, 2018; Merriam & Tisdell, 2016), and important to consider when completing research to center the perspectives of others. Trustworthiness in qualitative research is different from quantitative research. In qualitative research, trustworthiness relies on the standpoint of both researcher, and participants, instead of numerical analysis (Cresswell, 2009). As a result, the researcher aims to be trustworthy by using procedures that involve varying levels of engagement from participants.

Even within the realm of qualitative research there are differences in the idea of the value of validation. Cresswell and Poth (2018) acknowledge that there are varying views of the significance of validation. Critical research is a movement of change, and

defies mainstream norms of research because of its biased nature, and therefore contradicts traditional ideas of what constitutes valid research. Overall critical research is *opposed to mainstream ideas about* knowledge, facts, truth, objectivity, validity, and how *to articulate findings* (Carspecken, 2019, p. 16). I have integrated the following procedures into my study to add levels of trustworthiness.

CRF Core Techniques for Trustworthiness

Since this work represents the first known use of CRF methodology there are no specific references to define CRF methodology trustworthiness. However, CRF scholars value uniqueness of voice/ counterstory, multidimensionality, for both participant(s) and researcher, and multiplicative praxis. To further identify procedures that would align with CRF techniques of trustworthiness I reviewed the work of authors who have used a CRF framework in their research. Common elements include keeping memos, field notes, reflexive journaling (Berry and Candis, 2013), incorporating one's positionality (Berry, 2009), and telling one's own story (Berry, 2005; Berry and Cook, 2018). My use of these CRF techniques for trustworthiness is explained below.

I told my story verbally to participants because they asked, and I was willing to share as I knew this would build trust with my participants. However, I began this dissertation by s*haring my story* because my experiences add to the credibility of this study. Notes from detailed *memo* writing highlight my thought processes and epiphanous moments of learning from the data, as well as rationales regarding coding and other analytic decisions. Memos have the ability to enhance data analysis by increasing complexity, density, clarity, and accuracy (Charmaz, 2011; Groenewald,

2008).

Reflexivity through *reflective journaling* allowed me to bracket my biases, position my experiences and acknowledge my own multidimensional identities within the significance of this research. My journal entries are emotional entries filled with any number of affective moments of my journey. In addition, it allowed for my own empowerment through writing. In addition, narrative researchers use reflexivity to consider the interpretive context (Josselen, 2011). I have acknowledged that this research is very near and dear to me. As such I have had to continually investigate my own biases and position as an African American female. As a qualitative researcher, my personal experiences, perspectives, and beliefs have been a factor in the composition of my research, and my interpretation of data (Cresswell, 2009; Cresswell & Poth, 2018). What is more CRF acknowledges and accepts *multidimensionality*. As such reflexivity allows me to acknowledge my own multidimensionality.

Overall, my *positionality* is shared throughout this work. My perceptions of African American females' encounters in higher education at PWIs, and in other STEM related contexts have been framed by my own experiences. As a result of my background and keeping my biases confined I did not impose expectations onto the participants. I kept reflexivity notes throughout the research process. Reflexivity adds to my study's trustworthiness and reflections of my multidimensionality. Another important aspect of CRF which I highlight in later chapters is the collaboration of theory and practice. With the awareness of our multiple consciousness (Matsuda,1989), or multiplicative identities Wing (1999) a CRF advocate must work to partner theory with practice in order to

improve the conditions of the world in which we interact. Wing (1999) calls this multiplicative praxis. Although extensive reflexive notes were created throughout this process, I highlight some reflections including my plans for multiplicative praxis in the final chapter of my dissertation.

Member Check

Lincoln and Guba (1985) suggest that one way to ensure findings will be found credible is with the use of triangulation. The use of data triangulation was intended at the onset by using my reflective notes, interview data, as well as artifact samples from the participants. These three points were intended to be used in order to get a more detailed view of the stories of the participants. This was also meant to strengthen the research as a means of verification of evidence that I obtained from interviews. Since none of the participants shared additional artifacts, *member check* during the third interview was an essential source to support triangulation. Participants were given the opportunity to provide feedback on my findings essentially allowing them to clarify my interpretations. Lincoln and Guba (1985) identify member check as the most crucial means of establishing credibility. In order to allow participants time to read and reflect on the findings member check was completed via email. To receive meaningful feedback I looked for examples of member checks used by other authors. I found a protocol called Synthesized Member Checking (SMS) created by Birt et al. (2016) and used a modified version of their design. After sharing my findings with participants I asked them to please review the excerpt and provide the following feedback:

- Does my use and interpretation of your quotes match your experience?

- Do you want to change anything?
- Do you want to add anything?
- What are your reflective thoughts in terms of being a participant in this study?

Peer Debriefing

Peer debriefing was used as another technique to ensure a rigorous and credible study. Lincoln and Guba (1985) indicate that peer debriefing involves the researcher engaging in a scrutinizing process of feedback from a peer. During this scrutinizing process the researcher's biases are exposed as searching questions are revealed. This allows for potentially inadequate reasoning and rationale that seems complete in the mind of the researcher to be exposed. I utilized peer tutors at the university writing center to assist with this technique for establishing credibility.

Rich, Thick Description

Throughout this study I kept extensive memos, and other notes. With these extensive notes I was able to incorporate more details into various processes of this dissertation that provided layering of data. With these descriptions the goal was to transport the reader into the conversations I had with participants providing them with a shared experience (Cresswell, 2009). As a means of eliciting a feeling of "shared experience" I presented interview data of the participants as biographical narratives in chapter four of this dissertation.

Limitations and Delimitations

Limitations

Limitations of this research are inherent in its limited focus. This research was restricted to the specific topic of the participants' experiences related to computer science education. As a result, it does not capture numerous experiences throughout the lives of these individuals.

Researcher bias is another potential limitation to attend to. To lessen the impact of this limitation I incorporated reflexive practices throughout this study and have continued to bracket my potential biases. In order to build rapport with the participants and ensure their genuine stories were shared, each featured individual participated in detailed interviews. I openly answered any questions, assured confidentiality, and expressed multiple times that my goal was to center their stories and experiences as accurately as they remembered them. As seen in my interview protocol I did not attempt to access memories of experiences that were specifically negative but allowed the participants' narratives to develop in the way they presented them.

Delimitations

The utilization of critical race feminism allows for the replacement of traditional modes of analysis, with methods such as biographical counterstorytelling. With counterstorytelling, the researcher creates a narrative that intentionally centers the perspective of women of color, with a critical reflection of their experience. The use of this method demonstrates a rejection of stock narratives and the idealization of what real research is and can be. In considering the empowerment of the women in the study, and

their unique voices, their stories are clearly distinguished, and identifiable to them.

As an African American female, I am well aware of the multiple levels of racism and sexism that one can experience. Those issues must continue to be addressed, and not ignored in our society. However, this study sought out to highlight the voices of the participants in order to explore possibilities to improve the experiences of women who will pursue computer science degrees. If we are to move towards transformation, we must be aware that the problem exists. Where various articles (e.g., Alexander, & Herman, 2016; Charleston et al., 2014) have been written focusing on the obstacles that African-American women in computer science face, few if any, focus on the unique characteristics that centralize the strength and resilience of these ladies. It is valuable to find out what unique experiences have contributed to their success in the completion of their computer science program. Another option would have been to illuminate the experiences of those who, like me, began with the intent to major in computer science, but decided to change their majors. There is also a growing number of African American women who are going into the tech industry who were not computer science majors. This phenomenon does not seem to be explored by academic research articles thus far, but are evident in online videos that highlight women in tech such as Kimberly Bryant (an electrical engineer by degree), founder of Black Girls Code ("Black Girls Code," 2018). Thus a major delimitation is the scope of the study and participant sample. However, critical race feminism as an anti-essential methodology does not attempt to make the experiences transferable. Black women are more than the multiplicity of oppression, and discrimination but are also characterized by multiplicity of strength and joy (Wing,

1990). CRF allows us to centralize the stories of women who have been marginalized by society as a whole, as well as to celebrate their victory despite those things.

Finally, there are numerous other counterstories that should be examined in further research related to computer science education. One specific topic remains a primary catalyst for this study. Additional research should explore support for current computer science students, as well as the potential exposure to computer science among secondary and elementary school African American girls.

> There is a need for a coalition of educational researchers who seek to understand Black girls' multiple realities. Along these same lines, there is a need for scholarly endeavors that not only serve to empirically validate the experiences of girls of African descent, but also make use of such findings to strengthen coalitions across academic genres and communities, transform pedagogical practices in classrooms; and, actively promote social and educational policies at the micro- and macro-level, with those in mind who exist at the intersections of race, class, and gender (Evans-Winters & Esposito, 2010, p. 15).

The experiences of African American girls are valuable and need to be explored in relation to the phenomenon of computer science education. I have chosen to begin with the end in mind, so to speak, by understanding the experience of those who have succeeded in this field. If we identify those factors that have contributed to African American female computer science graduates perhaps we can create supports that will better assist with future success of young girls, and college students who have an interest in computer science. However, there is still much more work that is needed to build a

strong pipeline for African American females in computer science education.

Summary

In summary, this chapter provides a detailed description of the research methodology of this study. Critical race feminism's method of counterstorytelling was used to center, instead of marginalize, the voices of African American women. The total participant sample included three women who self identified as being African American and have received a degree in computer science from a predominantly White university from 2005 to 2019. Various techniques were collected to ensure trustworthiness including member check, peer debriefing, and techniques common to CRF such as using reflexive journaling, field notes, memos, positionality, and telling my own story. In addition, thick descriptions were also incorporated to support trustworthiness. This chapter concludes with the acknowledgment of potential limitations.

CHAPTER IV

FINDINGS

Herstory of Computer Science

The goal of this research has been to "center the experiences" of African American women who have successfully completed a degree in computer science. This study adds to the existing literature that has been reviewed in Chapter II by filling the gap of specifically centering their experiences by emphasizing the voices of African American women through storytelling. These counternarrative have been completed through qualitative research with the use of extensive interviews, and narrative analysis. The interviews of this dissertation have been guided by the following primary question: What are the unique experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI)? In order to establish fulfilling narratives of the participants' experiences the following secondary questions are also relevant:

1. What factors have influenced participants' decision to major in computer science?
2. What were the experiences of the participants during their time in their computer science program?
3. How do these women make meaning of their experiences?

Narrative Analysis

This chapter begins with a presentation of the biographical counternarratives created in response to the previously mentioned research questions. At the very least, the data are presented in biographical story format to reach and provoke reflection in a larger audience of readers. Storytelling's oppositional nature has the power to challenge and rebuff stories that reflect majority mindset causing exploratory thinking for the readers (Delgado, 2000). The best outcome is to move from a discussion of the current reality to explore possibilities that provide insight to a better reality for African American girls and women in computer science. These stories do involve examples of racism, feelings of isolation and being ostracized. Yet throughout these difficulties, each of these women's stories is a resounding anthem of resilience and persistence. Each narrative lends itself to words of encouragement for African American girls who will grow up with a desire to receive degrees in computer science. They provide possibilities for computer science department faculty who would have the courage to consider ways to make computer science education more inviting for African American women. I present to you the biographical counterstories of three successful African American women.

Ashley: A Computer Science Professor, Enlightening Future Engineers

Currently a professor, age 35 started her undergraduate experience in computer science at age 16. During our meetings Ashley is at home in what may be a home office. She is in a very relaxed position leaning forward over something large such as a large pillow. She has agreed to speak with me as it is August, and thus, nearing the end of her summer break. I can only see indistinct outlines of frames hanging on the walls. Ashley's

tone is free of stress, but her speaking pace is very upbeat and fast. The tone of her voice is clear, friendly, cheerful even, and filled with an undertone which invites a sense of levity and humor. A number of her comments are made in a joking tone and she laughs powerfully throughout her interviews. This is Ashley's story.

Math Was My First Love

My dad had all girls. I'm the third of four, and for an African man, that's a sad thing. An African man is supposed to have a son to take on his name. Instead, my father had four daughters who he would end up giving to other families. People had always told him not to invest in daughters because it would not be for his benefit. It would only benefit the in-laws. However, my dad had the attitude of, whatever, "God blessed me with these kids, and I love my daughters."

My family left America when I was five years old and moved to Nigeria. I remember when I was in third grade my teacher gave us homework packets at the end of the term so that when we come back to school in January we would have done all of this homework. However, at the time my family had just moved to that city and I was new to the school. I thought we were supposed to complete the packet of work and turn it in the next day. So I took six weeks or one month's worth of homework and did it in one day. I got to school the next day and turned it into the teacher. The work was done! My teacher looked at me with amazement and said you were supposed to turn that back in after the break, in January. I just said oh, I thought it was due today. That was fabulous because from third grade I knew I was good at math. In fact, I was so good that while I was in third grade, I was doing my sisters' math homework. I was working with math three or

four years ahead of me. I just took their textbook and just went through the problems. I just thought it was so cool. I even ended up skipping a grade. I went from fourth grade to sixth grade and that was mostly due to my love for math.

Why Not Be an Engineer?

My family moved back to the States when I was in high school. I went to high school in an area that was mostly White. If people in high school knew me it was mostly because of my sisters. I had a popular social sister, and I had another sister who was good at writing, but I was the smart one. So if people didn't know me through my sisters they knew that I was that girl Ashley who could help them with their math. By the time I finished high school I was 16 and had started looking for the degree that had the most math. Growing up in my home there was always the idea that you can be whatever you want to be. People were saying go into nursing. I told them, I do not like blood. I do not like spit. I don't like hospitals. I don't like sick people. I am good with numbers. Then some people suggested that I go into pharmacy. So I shadowed a pharmacist and I thought it was boring. It's just drugs. So I continued looking for the degree that had the most math because I was really good at math. I knew I was strong in math and I saw with a lot of the engineering programs the first two years were just math, physics, and chemistry. So, I decided I wanted to be an engineer. My sisters always used to laugh at me. They used to say, "oh you are going to be a mechanic. Oh, you're going to be on the side of the street fixing cars." They used to always say stuff like that but that's family, right? Nevertheless, I looked at electrical engineering. By the time I left high school, I had decided I was going to be an electrical engineer.

I Can't Believe We Are Talking About Body Odor

When I started I went to a community college that was close to my house. That's where I did the first two years. There was a group of us, six guys and myself who all started in the program. We all knew we were going to transfer, but for me, I really didn't have a school where I really wanted to go. I just knew I wanted to do engineering. Eventually, I got a scholarship and went away to college. It was a small school and it had electrical and computer engineering combined, and there were thirteen of us. Four of us were majoring in computers and the remaining nine were doing electrical. I was the only person of color, and I was the only female in my set. The whole cohort, and perhaps in the whole program I think there was one other. I believe there was one Black woman who was graduating who was two years ahead of me but I never spoke to her because it was like her last term. I spent four years there, but there was no other Black person in the computer engineering program. I think in the mechanical and chemical program; I know there was a Black guy in chemical. I don't remember his name. And I feel like there were some who are MEs (mechanical engineers) as well but in the electrical computer, I was the only Black person. I remembered from my second year meeting a Black female chemistry teacher. She always wanted me to do something with chemistry but I was the person who just went into the lab and broke stuff. I could never get the Bunsen burner to work. I mean I just sucked at that. In a classroom, I was the best student, but in the lab I sucked. I can laugh about it now!

However, when you are the only Black woman in your program, you tend to stand out. I mean people find comfort when they have someone else in a room that looks like

them. We think there is just a natural connection. So when you are the only one, well it is not always easy. I joke about the lab, but truthfully I spent a lot of lonely nights in the lab working alone on my assignments at two in the morning. Okay let me say this, I got through high school in the US because my math was so advanced, I was able to take university-level calculus my senior year of high school because I tested out of the algebra and geometry classes. So I think that's where it started. The thing about it is people said that the logical process of following steps to arrive at an answer is very similar to the way we write program languages. So there is the folklore that if you are good at math you are good at computer science. I didn't write a computer program until my third year at university. However, I had already convinced myself that I would be good at it because I was good at math and my mastery of math went back to the time I was eight, so ten years later I just happened to be really good at it. But the truth is when I started programming I did struggle. See the guys would come and they were working together in teams. They would get the work done faster because they were working as a group and I would often work by myself. I would end up with long nights in the lab. I would spend countless hours working on my assignments because I had no one to work with. So it was difficult I won't lie, but I knew I had to do it. I had started it, so I couldn't go home and say I want to switch majors. It was not an option in my family. So one thing that was difficult was not feeling like I was a part of the team when it came to things like assignments. I admit I don't think the guys in my assigned group really intended to leave me out. I think, since they were all in the same dorm (for men) it was just easier for them to spend more time together and really interact more. There were times in which they said things like, hey we

finished the assignment. I would say no we didn't because I didn't do anything. In a sense, I felt like they didn't want to exclude me it just worked out that way.

Still, there were other issues. Keep in mind, within the engineering program there were no Black people, but typically for a roommate, they would pair you with other people in your program. However, I think I was nineteen at the time I came back to my dorm one day and found out my roommate decided that she was moving out. She was a year behind me in electrical engineering and she decided to move in with a friend down the hall. She didn't even tell me she was moving out. I just came in and saw her packing her stuff. Then I got called into the office of student development by this lady named Margaret. She said basically that my roommate was moving out, and if I was going to have an individual room I was going to have to pay like $500 more. At the time I was just thinking where am I going to get $500. Then Margaret continued to explain that my roommate moved out because she said I had a body odor. I was shocked. She smokes and comes in at two a.m. all drunk but I'm the one with a body odor? It was so weird. I just remember feeling pissed. Not only was this like a fabricated personal attack but now I had to pay $500. I called my mom crying because I was like how are we going to afford this $500? My mom paid for it, but that was a difficult time. Now I can think back and laugh about it because oddly enough a year later the girl needed my help to get through electronics. Electronics is like this third-year course. So she had now come to me for help in electronics after all she did to me. So I helped her. But I thought -I never forgot that you moved out and you never said anything to my face about moving out. That was one of the things that have stayed with me. And I believe that it has stayed with me because I

was the only Black woman on campus but I had to go, and have a conversation about body odor with someone from the university. It was so belittling to have someone basically ask me if I have ever heard of deodorant. Seriously? Like seriously?

So there were things like that, but some of the things that kept me going were my professors. I could go to their offices and just cry. I mean there were those that you just never bothered, but there was one professor, in particular, he was the best! He would invite the group to his house and he would bake cookies. They were the biggest cookies. Eventually, he left to work for a non-profit organization that builds houses. I think he and his son started working with that organization together. As a professor, he was just the best! I sent him an email, and said, thank you, just for being you. He was beneficial in me making it through the program.

Another thing was just that I had to take some initiatives. Like I said I was the only female in the computer set of the program so I decided to reinstitute the Society of Women Engineers (SWE). It had been dead and wasn't really functional. At that time, I told all the other ladies who were in engineering, hey look we need to form a community. So we had our community of women engineers and we got together, once a month just to chat and to form a community. It was less about solving problems, you know. We were there, we were together just eating pizza and watching movies. That helped me to establish a posse on some level. The society and professors who showed they cared were important aspects of support throughout undergrad.

There Were No Hidden Figures, Only Beautiful Minds

By the time I was in graduate school it mattered less whether I had friends in the

program. I knew who I was. I was confident in myself and in my ability enough that it didn't matter as much. However, the funny thing is that by the time I finished undergrad I had decided that I just wanted to focus on math. So I went into graduate school thinking I would major in mathematics. Once I got into the program I had to take this third-year math course because my background was in engineering. I had to finish proofs and matrix algebra, stuff like that. I remember sitting in this class one day, and I was just looking at this White guy who was constantly writing on the board and I can see there was just this little patch left in the middle of the board. I thought about that movie, *A Beautiful Mind* and I was like hell no that will not be me! I also kept questioning, what is the application. I didn't see the application. All we would do was talk about problems all day that were on the board. I just thought I'm not going to end up as John Nash or end up like the guy from *Good Will Hunting*. When I was in school I only saw movies of White guys going coo coo. I laugh and joke about that primarily because those were the only stories that were told. Looking at my professor constantly writing on the board, not providing any practical application, and thinking about those common stories of math, I just knew being a math major was not for me. I went to the office that day, and changed my major. I went back to computer science. Back then we didn't really have any movies about engineering and mathematical Black women, like in *Hidden Figures.* It would have been nice to see some Black women or even seeing some White women doing math back in the day. But all we had seen were these White guys going cuckoo. I don't want to be crazy. I know I laugh and joke about it now, but you know I say it again I don't think I ever saw a Black engineer who was a woman. In terms of people of color, I knew they

had a Society of Black Engineers but my university was so small that there were like only four Black people in the whole program that had a thousand people. So I went to complete a master's in computer science and when you think about it, math was so abstract. I just decided it wasn't the right thing for me. But overall, grad school was just different. As I said, I already knew who I was. I wasn't looking for friends, I wasn't trying to fit in, I knew my abilities I knew what I wanted to do. I knew that I did not need people to study with me because I actually had shown by graduating at the top of my class that I could handle this kind of work. So with this kind of confidence came a lack of need to seek community. I think in my whole master's program I didn't talk to anyone form my school maybe one person I have their number because they were my sister's friend who went to high school with us like ten years ago. But I didn't try to build a community. I think I was the only Black person. If I wasn't it didn't matter. I think in undergrad it mattered to me that I was a person of color and that I was a woman of color. In grad school, I just focused on the work. I admit, in grad school, like in undergrad I am sure I was met with racism, but I cannot provide a specific example, because if there was a problem I just worked harder. Ultimately, not only did I complete my master's in computer science, but I also completed a Ph.D.

Find Your Posse

Now I am a professor of computer science. In the institution where I teach, I feel like I'm the only Black woman in science. In my department of about sixty faculty member, there is one other Black person and he's a guy. When I took out my braids he was just like oh did you cut your hair? I looked at him and I was just like, Negro please,

if anyone in this department should not be asking about the hair on my head it shouldn't be you. I remember I had a student last year who I was their first Black professor and it just blew their mind that there were Black professors. So they came up to me and talked to me because of the color of my skin and they were not even in computer science they were just doing a minor. Like I said, for a lot of people, you take comfort when you walk into a room and see other people who are like you. It is a very lonely existence to be in the lab at two a.m. on holiday weekend and knowing that there is no one else in your classes you have their number that you could call. Right? Especially when you're underage you need a sense of belonging. You're also trying to figure out who you are as an adult, and when you don't have that community it is hard. So you wonder why a lot of Black people go into sociology and things like that. Well, it is because that's where they see a lot of other people. Like if your brother had gone through a particular program you're more likely to go into that program because he can tell you to do this or don't take a course with that guy. So I think on that issue if there were more Black women or if there were more women of color and their profiles were raised we would continually have more women of color in computer science. I mean when you think about computer science you think of Steve Jobs, and Mark Zuckerberg, and Bill Gates you do not think Black women. And it's a weird thing how we've seen that Black women can actually get these degrees but they go to Silicon Valley and they leave. They leave because the culture is not inclusive. So it's not just about us having these Black people it's about creating a culture that is inclusive even after the university level and especially at the job level.

Now I think back to things and wonder if there were things that my professors should have done differently, or better, what I can do differently. One thing would be to consider gender-neutral assignments. For example, one of the projects that had to do was with this game called Breakout. It was just blocking with a paddle that basically moved up and down on the screen with this thing that bounced up and down. There were also these bricks that you had to destroy. Perhaps if I were a guy I would love to do that because perhaps at some point I grew up playing that game. I feel like a lot of my assignments were very gendered and that they emphasized things that the guys would be into more than most women. In addition to the incorporation of gender-neutral assignments also the incorporation of other voices in the classroom would be a good place to start. I'd never seen a female computer scientist by the time I had graduated from undergrad. I am very sure they existed but I didn't know about them. I couldn't tell you a Black computer scientist who had done something awesome. Like I can't tell you even now. I still can tell you I know they exist but I don't know what they've done. Not just Black, but also Indigenous, Hispanic, etc. Computer science is mainly White and Asian and so just by including other people who have done well would be a big step in the right direction. In that way, even if I'm still the only Black person in the class, it helps to have content with depictions of other Black people who have excelled in that field. So I think that is something that professors can do, think about assignments and content. In terms of the student body, I think a lot of people do not even realize that they're being exclusive that they are excluding people. Like the guys who would get together and work on their time in their dorm. They all lived in the same dorm so I don't think they were thinking,

oh it's two in the morning let's ask Ashley to come over and work on this project since we are all up and working on it. I think sometimes it's just educating people because they don't know they are being exclusive. Even if it's just excluding people who are like single parents, or excluding people who have to work. Saying let's meet at six p.m. when someone has a summer job or even a job in general that just doesn't help. When it comes to working in groups instructors should lay down ways in which people could be excluded in groups and ensure that groups consider those things. That way it's not the minority's responsibility to advocate for equal treatment but it's the majority realizing that the treatment is different and they should be more accommodating.

However, I will say it is important for Black female undergrads to build up their confidence early. You're not just going to get to a university and feel like you can do this job if you haven't already started feeling that way as a young person. Not being exposed to it is not in itself a disadvantage. You're not just at a disadvantage because you didn't study at the best school. You are disadvantaged because you do not think you are able.

The biggest stumbling block of people entering computer sciences is that they have the wrong mindset. I tell people this is not rocket science but if you go in there with the mindset of woe is me I cannot do this then you will fail and you will fail early. Then you will drop out because you did not have a support system. So I think building confidence is so important. And confidence comes from exposing yourself to other people who have traveled that road before and asking questions because information is power. Information is key.

So I think it's also important to have mentors very early. I don't know if this is

more advice to young Black women who are aspiring to be computer engineers or more to people like myself who have degrees to make sure we are mentoring people. However, they need to ask questions so that they go in knowing what they are supposed to be doing in high school math. It's important to know what math courses they are supposed to be taking. It's not the computer science courses that drive people insane first and second- year it's the math courses you have to take. By the time you are in your third year, you will have about six math courses because it is important to know all the algebra and differential equation courses. So if you don't have a strong math background you will be overwhelmed, and knowing that is important.

I can say there are a lot of scholarships for women of color. There are also lots of conventions for women of color. When women of color get together women in general just get together it is a beautiful thing. As an undergrad, I never went to those because we were so far and I could never afford them. Actually, I never really knew that those kinds of conventions were available until I finished undergrad. Something like Grace Hopper where people go every year and it's like is a big celebration. I've never been to Grace Hopper but I tell my students, you need to go to Grace Hopper. It's funny because they ask me how it is, and I tell them, I don't know but you need to go! So I fill out scholarship applications for them to go.

Another reason why conventions and things like that are so important is because of community. What makes computer science difficult for Black women is the lack of community, that's the hardest thing. Everybody needs a posse and as a Black female computer science major in a PWI, you've got to find your posse. So that's why during

undergrad our chapter of the Society of Women Engineers was so important for me, not only was it about socializing with others but for me, I was also in a leadership position. But everybody needs a posse everybody needs a crew. And finding your crew early is important if you don't have a crew then it is very, very difficult to get through. And that's why going to those conventions and having a mentor is very, very important. They help to extend your community.

Finally, let me discuss this idea of intersectionality. People underestimate what that is, for example, my department they are always talking about getting our female numbers up. When I go to this thing that science puts up and has all of these women across the faculties of science that come together and they all talk about their roles and whatever. I am the only Black woman in the group and I listen to them and try to feel sorry for them but I can't because at the end of the day they are White privileged people in my mind. So I think it is important to not trivialize that you are a person of color and not just any color. Hispanics and Black people are not in the same group as Asians and Indians. They are in fact all different groups. As a Black woman, you are part of two minority groups. One, you are a woman, and two you are Black. So it's a double burden. However, it’s not your job to represent all Black people. There so many times I felt like it was my job to represent all Black people and make all Black people look good. I guess it was to inspire other Black people to go into computer science, but that was exhausting. It’s not your job to represent all Black people or all Black women.

What I love about the field is that once you get in and get the basics you can do whatever speaks best to you. Computer science is very, very flexible. You can do

whatever you want on the globe with computer science. If you want to be a lawyer you can be a patent lawyer and focus just on that. You want to be a doctor you can be a doctor who specializes in making tools the other surgeons use to heal people. If you want a spare job, there are so many jobs for you to teach computer science in different ways K through 12, universities, and also at the boot camp level. For me being in a classroom is the best part of what I do. I love my job so much sometimes I will work 80-hour weeks and get home and still check my email. It's as if I have to ask myself, shit, are you cuckoo right now? I love what I do. I think that's what I love about computer science. It's a fact that it's just whatever you want to be after you get the basics. After you make it through undergrad you can use that degree to do whatever you want on the planet.

Jasmine: Appreciating the Beauty of Computer Science

Jasmine, a first-generation college graduate, now 36, got a BA in computer science in 2005. Each time we meet she wears her curly hair pulled back into a mid-length ponytail. She is seated in her university office as she is currently working as a professor. Her smile is warm and knowing. Stacks of papers nearly fill a section of her desk. Few decorations are on the white walls. Her office is quiet and professional. It is summer but Jasmine meets me between her scheduled classes and projects. Rays of sunlight surge through gaps in the blinds. She and I joke a little about technology, the irony that a computer science major is having trouble with her computer. There is a slight technical issue on her end but it is quickly resolved. The tone of her voice is clear, and calm with an air of contentment, and satisfaction. Her pace is not noticeably fast,

but not at all slow. The terms "com sci" and "CS" are frequently used by Jasmine as she refers to computer science.

Not a Super Go-Getter

Ever since kindergarten I just wasn't a super go-getter, or straight-A student. I grew up in a single parent, middle-class family. My mom didn't have a lot of money, but what she did have she funneled into Catholic schools. My educational experience was good. I just didn't have anyone who would say, "sit at the table and do your homework," and stuff like that. There were a couple of reasons I didn't have this structure. One, my granddad was very strict, so my mother decided to parent in a different way. Two, she was just extremely busy. Essentially what that meant was that I never had a structure in terms of disciplining myself to do homework.

My interest in computer science started in high school. It wasn't until my junior year when I took my first computer science class. I don't even remember why I took it, and I didn't really know anything about it. At the time I think I just needed an elective. It happened to be great exposure because for me that was a really low stakes class. In high school since I didn't know anything about things such as stereotype threat, I just thought of it as a fun elective, like taking a basketball class. There were no associated anxieties. There was only fun, excitement, and joy. Since it was so much fun, it was easy for me to pick it as a major. Besides, my family members, especially my grandfather and my uncle, who was an engineer, insisted that I do something that would make more money. They were very focused on topics such as gender inequality. They pretty much wanted to make sure I was not lowering the bar for myself. My grandfather would say things like, "Why

be a psychologist, why not be a psychiatrist?" My mom, on the other hand, was happy with whatever I decided.

Mathematical Disconnect, The Struggle is Real

I went to college as a com sci major. The CS classes were easy. Programming was like a puzzle, and puzzles have always been intriguing. I found it interesting that I could type words on a screen and they would transform into something interactive. It was neat. It was just something intrinsically appealing to me.

Math, however, was a different story. It was incredibly hard, and basically a story of struggle! I just felt unprepared and that had a lot of stereotype threat attached to it. I went to a professor in my department for help, or at least guidance because I really didn't know what to do. When he looked over my grades he was surprised I was doing well in my programming classes, because I was almost failing my math classes. He basically said "the two usually go together" as if it was not possible for me to do well in programming since I was struggling in math. Ultimately, they were not helpful. I left that conversation feeling worse, and it turned me off to the idea of seeking help. In retrospect, now that I know what I know about first-gen students, stereotypes and all the other stuff, I feel like my college experience was sort of a blueprint for universities on how to do everything wrong in terms of making minority students feel comfortable.

My sophomore was a little bit more manageable because my best friend who is also a Black woman joined me as a CS major. She had started off as an accounting major but found it really boring. I said, "Hey, come on over to computer science." At least with her, I was no longer "alone" so to speak. She liked com sci but she also struggled. Her

struggle was different from mine. I think we grew up differently, so I don't think she had any stereotype threat. She went to what was basically a predominantly Black high school. She was always at the top of her class. Although she did not struggle with grades or stereotype threat she struggled with her health. She frequently wasn't able to get a good night's sleep because of how she was feeling, health-wise. Also, there was likely no one who was at her house to tell her to sit down and do homework. Honestly, if she had a different best friend she probably would have been a lot better. She probably would have learned a more disciplined way of working. Since I was the person that she spent the most time with, she wasn't going to get that from me. So we both kind of struggled in that regard. It was better for me because I had someone I could ask questions, and do homework with. It all felt more manageable, and I stuck with it.

I still never really felt comfortable asking my professors for help. As a result, I started finding ways to focus on my programming strengths which led me to do a number of projects on the side. I basically used those independent studies to figure things out and gain the skills that I needed. My uncle didn't go to school for engineering, but he had to pick up coding to do his job. He would give me enterprise coding packages that he got from work, and I would use them for my independent study. He would often help me figure things out, otherwise I am not sure if I would have made it. So, I feel really lucky to have graduated.

Of course, the goal was then to get a job. The strangest thing was back during that time, the early 2000s, I would go on interviews and the person in charge at these companies were White guys who did not have degrees. They were completely

antagonistic towards people with 4-year degrees. They would say things such as, "Okay, prove to me that you are a thinker." It was a bit condescending, to say the least. Eventually, I got an entry-level help desk position working in the IT department of a law firm because my mother knew someone at the law firm.

Something So Beautiful Is So Rare

Working as a computer scientist at a law firm was a fantastic experience. I loved everything about it. Oddly, a lot of people didn't like their jobs, but I loved everything. It was so fun! At the same time, there were so many things going on in the news. There was ongoing talk about the catastrophic damage and aftermath of Hurricane Katrina. World news was still focused on Iraq, and ultimately there was just a lot going on during the time right before and after I graduated. I was a poli-sci minor in undergrad, but I really wasn't able to take too many classes that were sociological in nature. But I became more and more interested in understanding what was going on in the world in terms of racism and different inequalities. So, I started reading independently about this stuff and I still wanted to learn more. Essentially, I began the process of thinking about graduate school in political science. I continued working full time at the law firm in the IT department while working on my Master's. At the time, my ultimate goal was to come back to CS. However, I began to read that the job market was really difficult and that a Master's wasn't enough. So, I thought I would apply to this Ph.D. program and I would either get into my top choice or at least I would get a raise at work whichever happened first. As life would have it, both things happen at the same time, but I had already mentally committed to getting my Ph.D. I transitioned away from the IT Department at the law

firm and CS in general, and into teaching political science which is where I am now.

Basically, what I do is integrate com sci into what I do now. For part of my work, I do quantitative research methods. At this point, I might write coding that goes along with the survey. CS for me now is less about functionality and more about aesthetics. It's completely about building something pretty. Something beautiful is so rare in terms of what I'm doing. For example, I just ran a survey that has numerous open-ended responses. I used com sci to create a form to make that process a lot easier and just look quite beautiful. In that way, I still have that same joy I found in high school with CS.

My Message Is Simple, Have Fun!

To all the Black girls who want to grow up to be a com sci major, my message would be to have fun. Play with some code and think of something that you want to be able to make. If it interests you try to play around with it and try to figure it out. Coding is just like a logic puzzle. Creating things is just fun. If you want to create something this is a way to do it. Do not lose the playfulness and the joy of it. That way at least you have something to hold on to when other people are doubting your possibilities. It is also important to find other people who are supportive from beginning to end. Just always, always find joy, and have fun!

Nancy: Being Your Own Champion

Nancy at age 26 is a graduate with a master's in computer science, class of 2019. When Nancy's image comes into focus on my computer I see a young woman who is seated comfortably in what appears to be an apartment. She has a gentle smile, and

cups her hands in front of her, sometimes tucking them under the bottom of her shirt. She is by an open window. The curtains sway out slightly as a gust of wind makes its way inside the home. It is a sunny summer day. The buzz of cars moving, and the engines of loud trucks traveling up and down the streets of a busy urban city are easily heard. We exchange pleasantries in an effort to get to know each other a little before jumping into the interview. Nancy's tone has hints of angst as she details her experiences perhaps as a result of telling her story, still fresh in her mind. She is seated by the window. Her hands remain tucked, perhaps closed and on guard, throughout most of our interview sessions.

New Programmers for the New Tech Age

I have always been a science person, or at least a tech person. It was something that my parents definitely pushed. At a young age I remember one summer going to a technology camp. I was maybe five, and it was even on an evening show. It was Sixty-Minutes, or something like that. They were introducing the new programmers of the new tech age.

I definitely was one of those kids who excelled at math. I loved it! I ran out of math classes to take by the time I was in eighth grade. At that point my parents wanted me to try to go to a public school. Let me clarify that my parents aren't rich but when I was younger they found ways to make sure I had the best opportunities possible. So I ended up going away to a boarding school on the east coast. I think people should know that there are some super boarding schools out there which provide unbelievable opportunities, and you don't have to be extremely rich to become a student.

I loved my high school, because they had tons of CS classes. They had numerous science classes and high-level math classes like linear algebra, fractal geometry, and multivariable calculus. I knew those classes would be super useful because those are the basis of machine learning, which was a major interest of mine. I was able to head start on all of those things. The teachers were also extremely supportive. For example, they would fund me to do anything and they would let me do research projects. It was absolutely a school with a lot of support, but it was definitely like being in a bubble. It was not racially diverse; it was a college prep boarding school so it was predominantly White. I don't know how many Black kids there were. There weren't many Latinx kids either. In my class there may have been three. I can't remember any Asian kids. Looking back on it I think I should have felt weird because it was so wealthy and so not diverse. I still think I was fine; I was still really happy. I didn't have any problems because everyone was super supportive.

From Supportive Bubble to Being Ostracized

When I went to college I started having problems because I was a Black woman in a culturally insensitive environment. That was a huge wake up call for me. It was definitely the first time that I felt ostracized, and didn't really know where, or how to fit in. I came from a bubble of a boarding school where everyone dressed the same, played the same sport, and had the same general interests. It didn't matter that our skin color wasn't the same. In high school, even though people were different we were still kind of the same. My undergrad university was not like that at all. I was pretty unhappy my first year there. It was as if my professors doubted my ability before they even knew me. In

fact, I don't think they cared to know me. They took one look at me and saw that I was a Black woman and it was all over. I have always been the girl who was into science and math, and I can code. I was so good at it. But I started doubting whether or not I actually liked it.

CS was actually good at my undergraduate university. It was well noted not only for the quality of the program but also for things such as community outreach. Students from the program would go out into community elementary schools to sponsor coding clubs. However, there's no such thing as intro level CS. So many people are self-taught coders by the time they get to school. Even though I could code it was super intimidating. I really started doubting myself. I went into molecular biology as a major, but that didn't go well. I was overwhelmed with all of the work, but I did well in almost all classes. There was one that was the worst. When I talked to the professor, instead of providing me with hope, direction, information about resources, or just a supportive and empathetic ear, I was basically left with an ultimatum. He said something like, "You know, I see a lot of people enter my class, and um, so I know who is going to succeed, and I know who is not going to succeed. Someone like you can't succeed so you are either going to have to withdraw from the class or I'm going to fail you." I was shocked, and I didn't know what to do. He was a tenured professor. To me that meant he could really do whatever he wanted, and no one was going to stand up for me. Still, I reached out to my advisor and they said, "Oh, that's not cool." Really, that's it!

I ended up changing my major to ecology. It was as if I had wasted a semester. My parents ended up paying about $10,000 extra so that I could take some summer

courses to make up for the time lost. That in itself was unfortunate. In a way it all turned out to be a blessing. The ecology department was a lot more supportive. I got through and graduated, but I continued to think about CS and how the sciences in general were lacking diversity. I started wondering if I wanted to work in a field that type of environment. So I took a position in political science after I graduated. Let's face it, there were many more Black people so that was nice. At that point I figured I would just follow in my parents' footsteps and go to law school. I took the LSATs, but I was torn. There was something I began to miss about the sciences.

Finding My Way Back to Computer Science

I spent about a year in the political arena. During that time, I felt how miserable every lawyer was. They were underpaid, and overworked. I decided a profession in law just not my thing. I could still care about political causes and can do something else. I worked at a startup for two years. I did hybrid data science, and really enjoyed it. It was a typical startup culture, with two White men in charge, but I actually didn't feel alienated in it. I was able to thrive there because I had been in a world of White men my whole entire life. I felt no problem, and felt no alienation there. However, I know that some of my coworkers got fired for not being a "culture fit" which is always a red flag. In a temp position, you only get hired if you fit the culture. But if the culture is generally set by bro-ey White guys who started the company when they were twenty-five with their dad's money you know who the culture is going to be dominated by. So there were a lot of typical White male dominated issues with things like salaries, and layoffs. I felt like I wasn't being challenged enough. I felt like I wasn't learning enough about technology. I

didn't have the general software skills that I wanted so I decided to go back to school.

I Am Not Your Black Culture Connoisseur

I started my master's program in 2017, and day one was a nightmare. At first, I was excited because during orientation there seemed to be some diversity. Then I found out that all of the students of color, were all actually from a local art and design college. They were student designers, just doing a guest course and also had to come to the orientation so they weren't actually students of the university. There were a lot of technical programs, but out of all of them, I was the only Black woman. I just thought, oh God, here we go with this nightmare. It's going to be hell!

All of the programs were predominantly Asian. I don't mean Asian American I mean from China. There were definitely culture and language barriers. The magnitude of everyone in every CS program, in that auditorium made me realize I actually just missed White American people. I just had no one to talk to. I sat down by this guy who turned out to be from Dubai. He was one of those wealthy kids whose parents paid for him to get degrees so he could stay in whatever country he wanted. He introduced himself to me, and at first I thought it was cool, perhaps I will have some people to talk to after all. He started saying things like, "you know all the cool hip-hop contexts, right? I'm sure you do." I actually saw him text his friends. He didn't know that I saw him text his friends but I saw him writing something like, "Oh I met this cool Black girl who is definitely going to show me all the cool places around the city. I can't believe I've lucked out on this one." He assumed that those were my interests. They could be, but they might not be. Basically, he didn't want to know me. Besides, we were at a university, and a good one at

that, but he didn't see any type of academic breadth beyond my ability to be this culture connoisseur, this tool for him to better appropriate Black culture so that he could seem cool. I just moved away from him.

There was another kid from Taiwan who was actually in my program. He explained how he had never been to America before and have never left Taiwan. He kept saying he was afraid, and he figured he should stay away from certain parts of the city. Of course those were the Black areas. He started asking me about basketball, all these other very targeted questions. He was essentially saying, I'm afraid of Black people, where should I not go? Those were the conversations I had, and that was day one.

An Unbelievably Reckless Instructor

Within about two weeks into the program one of my professors, who was the program director started having one on one meetings with everyone in the program to check in and see how things were going. I told him that I really wanted to focus on machine learning. He said, "You know, um, I don't really think you could succeed and get a job in machine learning. So maybe you should try something easier." This was literally my first two weeks there. He didn't know anything about me. I didn't let that conversation deter me but it was annoying having the pressure of knowing your professor doesn't believe you are capable.

Within the class setting I stood out because I was pretty much the only African American, and I was female. I already knew that if I were absent from any of the smaller lectures I would be noticed. In classes such as the one about sociology anytime we had

class discussions about something relating to people of color I definitely felt like I was singled out because often I was the one person of color in the room. There had to have been a better way of having discussions without the entire class looking for me to chime in on every subject about Black people. At the same time, with some professors such as the one who told me I shouldn't focus on machine learning, it was extremely uncomfortable because it seemed as though they were racist, or at least they were using controversial articles that could be easily misconstrued.

For example, one day he gave us a sociology reading that he didn't put into context. It was an article that had quotes from Carol Stack's (1974) work. It was about cooperative living and it explained that Black people living in this building would support each other to survive. They would trade things such as cigarettes, food, and their children. Then the problem is you have all these kids from China who have never met a Black person before, and then you are giving them these reckless readings where you don't put them into context, saying, hey this is thirty years old. This is the twenty-first century, sociology is a lot different now, cooperative living is not like this. Well this made me feel like my classmates were going to become scared of me, or think I trade food stamps for children.

A Friend Is Good, but A Champion Is Great

Later in the program I met my friend Macy. She is Taiwanese American, and lives right down the street from me. I think we bonded because we were two of the few American females in the program. Literally for the past two years we did every single homework assignment and project together. We just clung to each other. Interestingly,

Macy's trajectory and treatment at the school was completely different from mine, even though we essentially had the same grades, same everything, except the same race. Come to think of it, I had slightly better grades than her. Even though often I was at the same level with her if not higher, I started realizing that the school would not offer me opportunities.

It seemed as if inherently opportunities were given to her, and not me. For example, the Grace Hopper Celebration of Women in Computing is one of the biggest CS conferences for women, if not the biggest CS conference in general. Macy was offered the opportunity to go to the conference to represent our university but I was never asked to do that, which was weird. I started realizing that I needed to create networks and opportunities for myself. I pursued everything independently. I reached out to one of my old TAs from undergrad who was now a data scientist. He ended up becoming one of my biggest champions. He got me a full scholarship to the Grace Hopper program by getting funding from a tech company. My relationship with my graduate university was basically my independent pursuit of success. They somehow found ways to get my image and name on their website as if they supported my success, and diversity in general, but I created my success. They never gave me any. I had to become my own champion.

A Different Type of Bubble

Now that I have graduated I want nothing more to do with that university. I didn't even go to my commencement because I just didn't want to be there anymore at all. My advice to those who decide to go to a PWI for computer science is to really do your research and know what you are getting into. Graduating from a prestigious university in

some ways does make a difference, and in some ways can provide opportunities when you graduate. But you need to know, it can be very isolating, because it is not going to be diverse. In some ways I think it's like a bubble. Instead of it being a bubble of warmth and support that you may have felt in high school, it can be a bubble of cold isolation. It can also be like this place where you are constantly in the spotlight. If you are the only Black woman you will be noticed. It's just that you never know how people will react to you. There is the question of whether or not people would get to know you for the individual that you are, or will they take one look at you an mentally place you in a box, with a label. So do your research and if at all possible make sure you have friends there. I mean if not in the program, just make sure you have support from someone. Black students, especially Black women will have a void without those supports. At the same time, know you will likely have to get out and seek opportunities for yourself.

I know things can change, but in order for change to occur it will take a lot of courageous people speaking out about things that they know are happening. For example, why would these universities not try to do more to ensure that there are no reckless instructors, like the ones I had? I know they can do more to make things more diverse, and inclusive. More can be done. However, when you think about all the racial issues of our country, not to mention our president it can seem hopeless. As for me, in the same way that I have had other people support me who were my champion, I want to be a champion to others some day. Perhaps, someday soon, Black women in computer science will no longer need champions, because every student should automatically get the support they need.

Analysis of Narrative

The findings within this study have forged a number of thematic representations related to the experiences of Black Women in Computer Science. As stated previously this research set out to center the unique experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White institutions (PWIs). This study focused on factors that influenced participants' decision to major in computer science as well as their experiences during their time in the CS program. These stories are not meant to be generalized across all the African American population. However, in terms of identifying some of the factors that have influenced participants' decision to major in computer science, and their experiences there are some common themes that are highlighted in this section. The themes explored in this chapter include those that provide a glimpse into the experiences of the participants and illuminate some of the factors that contributed to their decisions to major in computer science as well as some of the numerous factors that have contributed to their success.

The idea of i*ntersectionality (Crenshaw, 1989),* Black women existing as more than their race and gender, is an overlapping theme that spans across all aspects of this study. Whereas, the previous section used narrative analysis to highlight their unique stories, this chapter utilizes analysis of narratives to compare and contrast participants' experiences through thematic categories. The themes explored in this chapter include (a) exposure to STEM related courses in K-12 education, (b) positive and negative experiences with professors (d) systems of support, (e) struggles related to computer

science pursuance at PWIs, (f) desire to create social change, and (g) possibilities: a hopeful future for African American women. Each theme is analyzed in a general context of analysis of the narratives that the women provided during their interviews. Themes that are more central and appear to have supported broader meaning for the participants were analyzed using tenets of Critical race feminism. Table 9 shows the themes and analyzed tenets that are presented in this chapter. Table 10 shows the themes and aligned CRF questions that were utilized to create the CRF tenet interpretations.

Table 9

Themes Aligned to CRF Tenets and Ideologies

Themes	CRF Tents and Ideologies
Exposure to STEM related courses in K-12 education	Multidimensionality of identity; Whiteness as property
Positive and negative experiences with professors	Whiteness as property; Race and racism; Interest convergence
Systems of support	Interest convergence; Counterstory
Struggles related to computer science pursuance at PWIs	Multidimensioality; Multiple consciousness
Desire to create social change	Multidimensioality; Multiple consciousness
Possibilities: a hopeful future	Multiplicative praxis

Exposure to STEM Related Courses in K-12 Education

One of the factors common to the three participants was that each had at least one anecdote that went back to their STEM (science, technology, engineering, and mathematics) experiences during their K-12 education. Although each experience was different for each participant and the initial awakening to the possibility of engineering

occurred at different ages, each of their decisions to major in computer science can be traced directly to their K-12 STEM-related coursework.

Just as other identities of self begin to be formed at an early age, the mathematical identities of the three participants—salient factors in their persistence in computer science—began during their K-12 academic experiences. Mathematical identity has been defined as the ideas, tactics, and overall way one sees, talks about, and positions oneself in relation to the subject of mathematics (Bishop, 2012). Two of the participants developed strong mathematical identities at young ages and generally felt that they had a natural proclivity toward math prior to high school. One participant, Kati, realized in third grade that she could easily understand mathematical concepts that were two or more years above her grade level, explaining that she once completed a month's worth of math work in one day and that she would often work on her older sister's math assignments: "So from third grade I was good at math. When I was doing my third grade work, my sister who was in fifth grade at the time, I was doing her math homework." Nancy, another participant, explained her level of math knowledge in elementary school: "I have always loved math. I definitely was one of those kids who excelled at math . . . to the point where I ran out of math classes to take . . . by the time I was in eighth grade."

Although there is no obvious and overt evidence of Jasmine's K-8 math experience, the fact that she does not mention it is also significant. This can be viewed as an omission (Josselson, 2011) used to suggest that her math identity was not as strong or as positive as it had been for the other two participants. Computer science degrees require numerous courses in math, and Nancy's and Ashley's high level of mathematical

identity, established early in K-12 experiences, proved to be a tremendous advantage. These two participants, who spoke so often of their positive positional identities with math, went on to receive graduate degrees in computer science, a clear demonstration of their commitment to the field.

It is not surprising that a strong math identity was a significant factor in Nancy's and Ashley's decisions in choosing their major; indeed, the connection between computer science and mathematics is not a new concept in computer science studies. As Ashley said, "I started looking for the degree that had the most math because I was really good at math." And Nancy mentioned that even when she was in high school, she realized the importance of math for her college aspirations, alluding to the significant math offerings available to her in high school:

> They had like, high level math classes, like linear algebra and fractal geometry, and multivariable calculus. Which I knew would be super useful because, those are the basis of machine learning which was like my major interest.

Here, the two participants with positive identities toward their math capabilities confirm not only that they had developed their identities as capable doers of math during their K-8 experience, but also that their love for math was a significant factor in their choice of major.

In addition to a strong math identity being a critical factor in the decision to major in computer science, K-12 exposure to coding and other computer science classes were also important factors. Two of the participants indicated having had experience with computer science and coding classes during high school. Both felt more than a natural

ability to complete coding assignments, and each expressed some level of fun, joy, and excitement in the class. This provided an emotional connection to the subject and established an identity of being a capable computer scientist. Jasmine said about her high school computer science experience, "It was like a puzzle, and puzzles are interesting to me." Early immersion in coding provided the participants with an interest in the field. Exposure to computer science during a low-pressure environment developed a connection and an intrinsic interest. Jasmine explained further:

> My story as far as computer science goes started in high school during my junior year. I took a computer science class. I don't even remember why I took it. I didn't really know anything about it. I think I just needed an elective. And so that was a really good exposure. Because what that meant was it was really low stakes.

Nancy explained how her high school provided exposure to several types of math and science courses from which she was able to choose ("They had tons of CS classes," she recalled). She also remembered being exposed to computer science as early as age five at a tech camp that she attended; her exposure to computer science at an early age and again in high school were prominent memories. Computer science exposure prior to college was a major factor in both Nancy's and Jasmine's decisions to major in computer science, and as they entered college, they already saw themselves as capable computer scientists.

Wing (1990) suggested that women of color are more than the complexities of layered identities, that we have layered multiplicative identities. Such *multidimensionality of identity*, as related here to the participants' decisions to major in

computer science—which itself is such a fundamental part of the complex identities that define these women today—began during their K-12 STEM academic experiences.

The participants' experiences with K-12 STEM education also shows indications of *Whiteness as property.* Each had opportunities to engage in higher levels of STEM-related course work. Two of the three participants took higher levels of math coursework during their secondary-education experience; two took computer science coursework during high school. All participants stated that they attended predominantly White secondary schools, a significant factor in their having had the opportunity to take advanced STEM courses. It is therefore important to keep in mind Donnor's (2005) theory that there are issues in our educational system linked to the denial of access to technology education. This denial tends to position African American students merely as consumers of knowledge instead of producers of it. Donor is speaking of the critical race tenet of Whiteness as property, but identifies technology as property.

Positive and Negative Experiences with Professors

Mathematical identity and exposure to computer science and were key factors affecting the participants' decisions to major in computer science. Once enrolled at PWIs, the expectations and support of professors became key factors in determining their degree of success, with participants reporting both negative and positive experiences with professors.

Two participants provided anecdotes of negative experiences with professors related both to their interactions with them and to the types of materials used in class. One participant, the only Black woman in the classroom, described her emotional

discomfort when the class was exposed to a journal article that included excerpts from a 1970s-era sociology book on cooperative living that could have been read as being culturally insensitive. As Nancy explained, "Yeah, and so then the problem is you have all these kids from China who have never met a Black person before, and then you are giving them these reckless readings where you don't put them into context," adding that "then my classmates would become scared of me, or think I trade food stamps for children. Because no one would say anything about it." Nancy recalled another example:

> I remember [my professor] was doing one-on-ones with everyone in the program to check in to see how things were going. I told him that I really wanted to do machine learning, and he was just like, "Well, you know, I don't really think you could succeed and get a job in machine learning, so maybe you should try something easier." … Like this [was] literally my first two weeks [there], and [he didn't] know anything about me.

Nancy's professor had already decided—even before getting to know her as an individual—that she did not have the skills, talent, or capability to be successful in work that was challenging, clearly overlooking the fact that she was intelligent enough to have been accepted into this prestigious school and to take classes within the department. Her professor's insensitivity trivialized Nancy's rights as a student. Harsh interactions such as these have the potential to diminish one's agency and identity for computer science. Nancy explained further:

> I was pretty unhappy my first year there, and I really didn't know what to do and what I wanted to do. I really had this identity crisis sort of…. I had always been the girl who was into science and math and I can code…. Do I actually like it?

This struggle was brought about by her unhappiness with the university, which was related to the lack of support from her professors.

Jasmine described how she struggled with math class, even though she was very successful with the coding aspects of class, explaining that when she tried to seek help, she was met with an unhelpful response. Jasmine called her undergraduate experience "a blueprint for how to do everything wrong for making … minority students feel comfortable." As a result, she avoided seeking help from professors, which effectively limited her access to a knowledge resource—faculty interaction and mentorship—that is foundational in institutions of higher education. The negative experiences with professors that were reported by these participants contributed to creating stereotype threat, a sense of self-doubt, and doubt about their aspirations for being a computer science major. These examples speak to the tenet of CRF regarding whiteness as property and provoke the question of whether the professors at PWIs feel that Black women have a right to earn a degree in computer science. At PWIs, knowledge can be seen as property.

The good news is that such negative experiences are not necessarily the norm among Black woman in computer science. Indeed, there were some professors in computer science departments who stood out as being helpful—though it seemed to be up to the student to find them. Jasmine related the following:

> So, there were two people in particular who were always really encouraging and knew how to actually teach and break down the topics to the fundamental pieces, who I felt more comfortable going to see. And there were others who were pretty condescending and just the opposite.

Ashley had especially fond memories of some of her professors:

> But my profs. There was a prof. . . . I would not have made it through the program without him. Even though I never had that community among my peers, the profs were always people I could go to. And I could just go to their office and cry. And they would all listen to me.

Each participant shared instances of being championed by professors who assisted with needed resources and emotional support. But the overall experience differed among the participants; for Nancy and Jasmine, getting support was not the norm at their universities; for Ashley, supportive faculty were more prevalent.

The participants' examples indicate that computer science departments have not done enough to eliminate instances of racial microaggressions, stereotyping, and overall culturally insensitive teaching. Because interest convergence indicates that racial advances for Black people are only encouraged when they promote White self-interest, and because racism supports the interest of White elites, there is little motivation for the dominant society to extinguish it (Delgado & Stefancic, 2000, 2001). This would suggest that for some PWIs, or at least for some individuals within computer science departments, interest convergence does exist. This raises an important question: How

can interest convergence be created on a larger scale across all PWIs so that supportive computer science departments and faculty become the norm for all students, regardless of color or gender?

Systems of Support

Since the support of their professors and peers—and the university itself—was not always available to the participants, each had to establish her own system of support and to create her own set of opportunities. Although the participants forged ahead and created these opportunities for themselves, some were annoyed and frustrated at having to do so. One participant spoke of reinstating the Society of Women Engineers because of the lack of comradery: "I was the only female in my program so [I] reinstituted the Society of Women Engineers." She went on to explain that this allowed her to "chat and form a community" with other women. She also expressed this idea as the need to find one's "posse": "Everybody needs a posse. Everybody needs a crew. And finding your crew early is important. . . . If you don't have a crew, then it is very very difficult to get through." Another participant realized that she needed to create opportunities for herself because she felt that her university did not provide her with opportunities to participate in special projects or to attend conferences representing the university. She mentioned finding someone from her high school who helped her get a scholarship to the Grace Hopper Conference: "I created all this independent success because they [my university] never gave me any." Nancy, another participant, recalled:

> Once I realized I could create opportunities for myself, that's when I realized that I didn't need anybody…. I don't care that I had to do everything, I mean I'm

> annoyed [the university] never gave me not a single opportunity. Like not one. And they want to take credit for my success? Like that's very frustrating.

Nancy found empowerment in her ability to change her circumstances when no one else would.

Another participant indicated that because she was having a difficult time with her classes and since she felt that her professors were not very helpful, she had to try to complete course requirements by doing independent study. She mentioned that her uncle helped her with her coding and that her mother was instrumental in her getting a job. Jasmine stated: "So when I think about success, I guess the other part of success is having the networks of people. Those were not my professors." These women had to establish systems of support to fill huge gaps that were not attended to by their professors, or by the academic experience as a whole. Support for these women was needed because of the lack of female representation in their programs. For some, it was about a lack of support from professors and a lack of support in general from the university community. These incidents that lead to feelings of frustration and annoyance often go untold in the majority stories that depict Black women as angry. But these women create a counter story to the negative master narrative by transforming the frequent frustration and annoyance to create paths of opportunity.

Struggles Related to Computer Science Pursuance at PWIs

The struggles faced by Black women in computer science at PWIs take an emotional toll. It is an unfortunate reality that each participant had some level of conflict in the process of getting her degree. Although rigorous college courses require equally hard work, the toll these women paid went beyond academic effort alone and involved struggles associated with gender, race, stereotype threat, and feelings of isolation.

Jasmine explained her struggle with stereotype threat in this way:

> So the story of college is the story of struggle and a story mostly of threat. And I mean threat, just kind of always worrying. If I did think about going to office hours, I was always worried about, you know, what if I looked stupid with my professor. Well, what will they think [of me]?

Although Nancy attended a predominantly White college-preparatory boarding school, she experienced higher levels of race and gender when she went to college:

> I didn't have any problems [in high school], but when I went to [college], I started having problems. Like, that was a huge wake-up call for me. That was definitely the first time that I felt ostracized, and like didn't really know where, or how to fit.

Ashley acknowledged that there were issues of racism throughout her college experience, but she chose to think of them as indicating that she herself had to improve:

> I'm very sure in my undergrad and in my grad school experience, even when I was doing my PhD, that there were times when people were very racist. I just blocked it out, or I said this was because I wasn't working hard enough.

In another example, Ashley indicated additional struggles related to being the only Black woman in her computer science cohort. Since the men in her program lived in the same dorms, they would get together and work on assignments when it was convenient for them:

> When I started programming, I did struggle with it. Because the guys would come and they were working together in teams. And they would get the work done faster because they were working as a group. I was working by myself. . . . . So it was difficult. I won't lie.

Ashley's experience is an indication that even when the faculty at PWIs are supportive, there are other circumstances that create difficulties for African American women, such as the isolation from the group that Ashley experienced. With each participant, there were clear examples of struggle. Since the normalcy and permanence of racism is one of the tenets of CRF, the fact that these women reported race-related issues is not in itself surprising. Still, there were several factors—supportive family dynamics, for example—that helped each individual persevere despite those difficulties.

With analysis of narratives using CRF questioning, the tenet of multidimensionality emerged. As women of color, each of the participants had multiplicative identities. Each experienced multiple consciousnesses, shifts between

awareness of being a person of color—the core of self-identity—and the consciousness of being rooted to a White-dominated world, as is required for survival in educational institutions (Matsuda, 1989) like PWIs. Their ability to persevere was thus a product of both external and internal factors— supportive families or professors and their own intrinsic sense of self. This raises two important questions: Should Black girls who plan to attend PWIs have additional preparation before attending? Would adequate culturally relevant teaching and pedagogical strategies (Ladson-Billings, 1995a, 1995b) used throughout K–12 education sufficiently prepare African American girls to make the shifts between their Black experiences and those of the mainstream in order to successfully navigate the realms of computer science departments at PWIs?

Desire to Create Social Change

Each participant indicated a desire to create social change. Nancy recalled a time when she had considered leaving the computer science field to work in the political science sector:

> I started volunteering and . . . working in some poli-sci things. . . . I felt like, you know, I was really torn, because . . . a lot of the people here in . . . public interest law was like super supportive. And I felt those were the people who shared my personal interests. You know what I mean? Like, you know, concerned for the world, or had more world views. Obviously, those were like predominantly people of color.

Ultimately, Nancy's work in political science was overshadowed by her desire to return to computer science. Jasmine, however, transitioned into working full time in political science. She mentioned that she had a computer science job that she actually enjoyed as a help desk agent at a law firm: "Working at a law firm was a fantastic experience. I loved everything about that." Jasmine went on to mention that as an undergraduate, she had minored in political science but was unable to take many classes that were "sociological in nature." This was something she was especially interested in doing in order to "help [her] understand what was going on in the world . . . in terms of racism and different inequalities in the US." Jasmine gave no indication that something at the law firm had led her to pursue political science. It was more about her interests in social issues.

In her profession as a computer science professor, Ashley also does her part to eliminate inequalities. She reflects on her teaching in order to provide her students with instruction that transcends gender biases and White-male-dominated stereotypes of computer science. Here, Ashley speaks about addressing inclusion and recognizing biased thinking:

> I try to teach what I do, but I also try to empower students to do the same thing. But it's an uphill battle. It's an uphill battle. But it has to be fought. . . . I think every professor should address these issues of inclusion, because it affects us all. Computer science— every major has some marginalized groups or some groups that we just ignore.

Ashley's experiences as an African American computer science student at a PWI added a dimension of understanding to her position as a professor. Each participant's desire to create social change was related to her multidimensionality of identity. Women of color have layered, multiplicative experiences (Wing, 1990), and their experiences create a multifaceted way of thinking and seeing the world. Since multiple consciousnesses (Matsuda, 1989) are derived from these layered existences, women of color may tend to explore social justice as a way to right the injustices of the world. Matsuda (1989) explained that multiple consciousness is more than just making shifts between various forms of awareness. It entails the search for a path to a just world. Whether through computer science or via other avenues, these women have embraced the pursuit of social justice.

Possibilities: A Hopeful Future

The participants were clearly hopeful about African American female computer science candidates of the future, and they offered meaningful advice for the candidates and for those who would mentor and educate them.

Ashley expressed that mentorship and confidence are important for Black women who want to major in CS programs. As she explained, mentorship leads to confidence, and confidence leads to having the right mindset:

> I think it's important to have mentors very early. So I don't know if it's more advice to them and more to people like myself who have degrees to make sure we're mentoring people. . . . It's important for them to build up that confidence early. You're not just going to get to university and feel like I can do this job if

> you haven't already studied feeling that way as a young person, and being exposed to it. . . . You're not just disadvantaged because you didn't study at the best school. You're disadvantaged because you do not think you're able. The biggest stumbling block of people entering computer science is that they have the wrong mindset.

Ashley's words reminded me of Pamela Smith's (2003) writing about mentorship. Although Smith wrote about mentorship in relation to Black women who were entering the field of professorship at law schools, her words are applicable to computer science as well. Smith (2003) spoke of the lack of mentoring as being one of the biggest barriers to the professional advancement of Black women. She indicated that Black women are denied mentorship and thus are denied the opportunity to receive coaching, counseling, and other support that would assist them in moving into a senior position. Mentoring is an example of the CRF position of multiplicative praxis (Wing, 1990). In this way, Black women do not just talk about the complexities of our existence; we also work together to fight against oppressive forces.

Another participant's advice was to establish a network for support and to be a go-getter. Nancy explained that there would be a void and a sense of loneliness if networks were not established. In addition, she mentioned that these networks were also essential for getting a job: "Black students, especially Black women, are going to have a lot of voids if they don't already have a network here, and if they are not the go-getter type [who] makes opportunities for themselves." Jasmine reminded aspirants to simply

"not lose the playfulness and the joy of it." She and all the participants alluded to the beauty of computer science and the flexibility of the major.

Table 10

Themes Aligned, CRF Tenets and Ideologies, and CRF Tenet Questioning

Themes	CRF Tents and Ideologies	CRF Questioning
Exposure to STEM related courses in K-12 education	Whiteness as property; Multiplicative identities	Is quality STEM education property? Is it easily available to White students? Is there equality in access to high quality STEM education? Do schools that serve White students provide more access to various high quality STEM courses? Would African American students have an academic advantage if they attend predominantly White K-12 schools? How can academic leaders ensure equity in K-12 STEM education so that African American students develop strong math and computer science identities prior to college? Do students need to explore different layers of their identities? Do African American children at all schools have an opportunity to explore and develop various academic identities?
Positive and negative experiences with professors	Race and racism; Interest convergence	Do all professors of PWIs feel that Black women have a right to earn a degree in computer science? If race and racism will continue how will computer science departments at PWIs find interest in supporting African American women? How can interest convergence be created on a larger scale across all PWIs so that supportive computer science departments, and faculty becomes the norm for all students, regardless of color, or gender?
Systems of support	Interest convergence; Counterstory	Do CS departments at PWIs see any benefits in establishing relevant systems of

		support for African American women?Do PWIs acknowledge the frustrations they create for Black women? Do they realize their insensitivities?
Struggles related to computer science pursuance at PWIs	Multidimensioality; Multiple consciousness	Should Black girls who plan to attend PWIs have additional preparation before attending? Can the development of multiple consciouscsiouness be learned?
Desire to create social change	Multidimensioality; Multiple consciousness	How can schools support Black women's natural desire to work towards social change? Aren't there natural connections to computer science and social justice?
Possibilities: a hopeful future	Multiplicative praxis	How can African American women support each other? How can ideas and theories of support for African American women in CS at PWIs be put into practice? How can we establish a better outcome?

Summary

This chapter began with a narrative analysis of the data. Using this method of analysis, data were presented in the form of unique biographical counter stories for each participant. Each participant's story was unique, and using narrative analysis allowed their individual voices to be placed front and center. Although segments of their narratives were highlighted with themed titles relevant to their individual experiences, each story spanned their early K–12 experience, then weaved into their encounters at PWIs, and ended with words of hope for future computer science aspirants.

Analysis of narratives was used in the second section of this chapter to compare and contrast participants' experiences through thematic categories. Six themes were explored in detail: (a) exposure to STEM-related courses in K–12 education; (b) positive and negative experiences with professors; (c) systems of support; (d) struggles related to pursuing computer science at PWIs; (e) desire to create social change; and (f) possibilities—a hopeful future for African American women. Intersectionality (Crenshaw, 1989) was a peripheral theme that encompassed all aspects of this study. Themes that were more central and appear to have supported broader meaning for the participants were related to the tenets of critical race feminism. Table 10 shows an alignment of the themes discussed in this chapter, corresponding to CRF tenets and questioning used for CRF analysis presented in this chapter.

CHAPTER V

CONCLUSIONS

Over the past decade, there has been a growing focus on STEM education to careers pipelines. Leaks in the pipeline is a phrase that has coined to metaphorically represent women (Alper, 1993), and minorities (Ball, Huang, Cotten, & Rikard, 2017; Allen-Ramdial, & Campbell, 2014) leaving STEM related fields. Women continue to be outnumbered in STEM fields. However, women of color are significantly more of an underrepresented population. There is a significant lack of diversity specifically in the area of computer science because there is a lack of diversity in the student population aspiring for degrees in computer science.

The goal of this research has been to center the experiences of African American women who have successfully completed a degree in computer science. This study adds to the existing literature that has been reviewed in Chapter II, filling the gap by specifically centering the voices of African American women and providing a more complete narrative to be told through qualitative research with the use of extensive interviews, and narrative analysis. This analysis goes further by not only indicating struggles that Black women have in computer science departments of PWIs, but it also illuminates factors which have supported their success. It then moves to a place of hopeful possibilities for young computer science degree candidates as well as

considerations for CS departments in PWIs. The interviews of this dissertation have been guided by the following primary question: What are the unique experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI)? In order to establish fulfilling narratives of the participants' experiences the following secondary questions are also relevant:

1. What factors have influenced participants' decision to major in computer science?
2. What were the experiences of the participants during their time in their computer science program?
3. How do these women make meaning of their experiences?

There were three participants in this study. One, a graduate with a bachelors in computer science, another with a masters in computer science, and the other having bachelors, masters, and Ph.D. degrees in computer science. This qualitative study was completed by using multiple interviews with each participant during the summer of 2019. Extensive data was gathered from interviews. Each participant had the option to provide additional artifacts, but did not submit any. In order to highlight critical race feminism (CRF) methodology data was analyzed in two ways in Chapter IV. Narrative analysis as discussed by Polkinghorne (1995) was used to craft emotionally intense events into a biographical counterstory told from the point of the participant. This method centered the unique voice of each participant using storytelling. Chapter IV concluded with the use of analysis of narratives which compared and contrasted the

participants' experiences through thematic categories. The themes identified were then aligned to CRF tenets and ideologies.

The primary purpose of this study was to center the voices of African American women who received computer science degrees from predominantly White institutions. In doing so I was able to uncover some potential factors that have influenced participants' decisions to major in computer science. At a young age participants seem to indicate a natural proclivity towards mathematics. Two participants mentioned making high achievements in mathematics at the elementary level of school, and two mentioned the significance of being exposed to coding prior to college. Therefore indicating the *significance of STEM related coursework beginning in K-12 schools.* Once the participants were in the computer science program they all appear to have experienced some level of isolation, and racism. It is unfortunate that some professors were a source of ostracism. Difficulties of two participants were emphasized by the negative reactions they received from professors. Although one of the participants recalled having great interactions with her professor she still had struggles as she often had to work on assignments alone. Overall, these women *all had some level of struggle*, and those *struggles were either made easier, or intensified by support, or lack thereof from professors.* The importance of community was another topic that all participants shared. For some it was about having one good friend in the program, or networking while attending conferences such as Grace Hooper. Two of the participants stressed the salient need to *create one's own communities and opportunities*. There was an overt desire to promote social change among some of the participants. At least two of the

participants provided thoughts about mentoring. Mentoring is related to the *hope for the future* that these ladies clearly have for future computer science majors. Overall, in terms of hopes for the future of African American women in CS education it appears to be evident that the best possible future is one that truly embraces and purposefully supports Black women.

Two participants mentioned making high achievements in mathematics at the elementary level of school, and two mentioned the significance of being exposed to coding prior to college. Therefore indicating the *significance of STEM related coursework at an early age*. Once the participants were in the computer science program they all appear to have experienced some level of isolation, and racism. It is unfortunate that some professors were a source of ostracism. Difficulties of two participants were emphasized by the negative reactions they received from professors. Although one of the participants recalled having great interactions with her professor she still had struggles as she often had to work on assignments alone. Overall, these women *all had some level of struggle*, and those *struggles were either made easier, or intensified by support, or lack thereof from professors.* The importance of community was another topic that all participants shared. For some it was about having one good friend in the program, or networking while attending conferences such as Grace Hooper. Two of the participants stressed the salient need to *create one's own communities and opportunities*. On some level at least two of the participants provided thoughts about mentoring.

Similar to other studies the results of this study indicate that African American women in computer science programs at PWIs do undergo some level of struggle and it is not uncommonly related to their race and/or gender. Other studies have alluded to the harsh reality that professors or often the cause of Black women feeling ostracized. However, this study shows the salient value of supportive professors. Although some studies indicate that having a natural proclivity in math is important for computer science majors, this study indicates that early exposure to computer science classes are also salient factors. Whereas other studies indicate the significance of safe spaces, and mentorship, the findings of this study suggests that in order for Black women to be successful they often have to create spaces, communities, and opportunities for themselves.

This study was completed using a critical race feminism theoretical framework to further analysis data. In relation to the tenets of *multidimensionality of identity, and whiteness as property* it is concluded that early K-12 constructed identities and exposure to quality math and/or computer science courses are needed to spark an interest in African American female students. It is not difficult to imagine that without exposure to these courses and opportunities African American girls will be less likely to go into this field. Exposure alone may be a prominent factor in the trajectory of Black girls' decision to major in computer science. However, African American girls must be given the opportunity to explore these opportunities. Educational administrators must ensure that Black girls are not denied opportunities to be exposed to computer science education in K-12 environments. If we want more African American girls to pursue computer science

degrees we must instill strong math and computer science identities during K-12 education. This is best if strong math and computer science identities are developed in K-8 education, and are supported with opportunities for higher levels of math courses in secondary education. What is more it is important for these opportunities to exist across all schools regardless of the demographics. High levels of quality math and computer science education must be available to all students, and not just within schools that serve predominantly White students. Educational leaders must have the creativity, and courage to ensure policies, practices, and overall STEM related coursework that is implemented with fidelity to all students.

The support and expectations of the professors is monumental in the overall experience of the computer science majors. For Black women being singled out, and having to endure culturally insensitive texts, as well as condescending remarks from professors is enough to lead them to doubt themselves. Computer science education cannot continue to exist as *property* that African American women are not entitled to acquire. Professors can create a wonderful experience, or a traumatic one. Since race and *racism is a normalcy* of American culture it is up to courageous and self-reflective academic leaders and policy makers to create more *interest* for the support of African American women in computer science departments at PWIs. They must establish *interests* in supporting African American women in computer science.The examples shown indicate narratives that *counter* the majority narratives showing the insensitivities that Black women endure at PWIs and still persist to successfully complete the program.

The ability for African American women to persevere at PWIs is often a product of external factors such as a supportive family, or supportive professors, but also their intrinsic perceptions of who they are. The persistence of African American women in CS at PWIs are motivated by aspects of their *multiplicative identities*. Since multiple consciousnesses (Matsuda 1989) is seen as a valuable trait in maneuvering places of higher education, especially PWIs, educators should consider whether there should be more intentional development of this attribute in African American female students. The multiplicative experiences (Wing, 1990) of African American women creates a desire for social change. African American women in computer science are compelled via their *multiple consciousnesses* (Matsuda, 1989) to find a path to a just world. Therefore, it would be beneficial for computer science departments to provide access to those connections within their programs.

Through *multiplicative praxis* (Wing, 1990) CRF advocates go beyond theorizing, they also act and put into action meaningful practices such as mentoring. As exemplified by the women in this study, Black women do not just talk about the complexities of our existence, we work to work together to fight against oppressive forces. Mentoring can make a difference in the success of Black women in computer science at PWIs. There is hope for a better reality for African American women in computer science at PWIs. One way to begin to establish this reality is to bring African American women to the table for discussions and implementations of change. Overall, in terms of hopes for the future of African American women in CS education it appears to

be evident that the best possible future is one that truly embraces and purposefully supports Black women in computer science at PWIs.

Implications

K-12 Education

It is essential that every school has a rigorous computer science curriculum in the K-12 setting and that African American girls are purposefully provided with coding opportunities. Coding at an earlier age will help to ignite an interest in coding in college. In order for African American girls to be truly ready for college level mathematics they must have robust mathematics instruction throughout the K-12 level. A strong mathematical mindset at an early age helps to make computer science coursework more manageable in college. It is important that girls are not overlooked in K-12 math classes, but are empowered in math classes. K-12 educators and academic leaders must do what is necessary to ensure a robust curriculum that is accessible to all students, especially Black girls. There are many factors that go into the making of high quality education. These factors which include a acknowledgement of the students' gender and race must be considered. Educational administrators must ensure that Black girls are not denied opportunities to be exposed to quality mathematics and computer science education.

Predominantly White Institutions of Higher Education

Faculties and departments of computer science at PWIs must take the time to evaluate their programs, and their professors. They must have the courage to desire change and accept nothing less in order to develop safe spaces, and various support systems within the department for African American women. This should include

support and mentorship. It may mean hiring consultants, but more so bringing those who have been ostracized to the table in order to get their input for ways to make things better. Above all those who have been oppressed deserve a seat at the table to establish plans to change the culture of computer science departments at PWIs. This type of change not only takes courage but relentless commitment from those who are in power.

Recommendations for Further Research

There are many more counterstories that need to be told. Others like me who started as a computer science major and did not finish have stories to tell. Additional research is needed, particularly in K-12 computer science/technology classes. Some K-12 school systems utilize curriculums such as CS4All. More research is needed to determine how effective these programs are in preparing students to be CS majors. Additional research is needed to determine if an additional or supplemental curriculum is needed. The exploration of culturally relevant teaching strategies effectively used in higher education courses, especially in computer science departments has astronomical potential. In addition, although this study focused on computer science education, the reality is that struggles of African American females in computer science continues far past the day of graduation. These are factors that still need to be explored.

CHAPTER VI

REFLECTIONS OF A CRITICAL RACE FEMINIST SCHOLAR

When I presented my dissertation proposal I explained to my committee that I am not a computer science success. At the time I felt that because I did not graduate with a computer science (CS) degree I could not consider myself a CS success. I, like a number of other women, started out with the intent of majoring in computer science but changed my major. Needless to say, I felt like a failure. However, I was shocked when my participant Jasmine said that she did not consider herself a computer science success. Jasmine and I talked about how she still incorporates her computer science education into her current work. If either of us is a computer science success, clearly it is her.

As I complete this dissertation I complete it knowing that I have centered the voices of women whose stories are not typically shared. More so, I hope to ignite discussion and change towards a more successful future for Black women in computer science. This hope begins in K-12 education with the integration of computer science into all K-12 schools. It is clear that the interest in computer science can be sparked at an early age. Just as important as initial interests, K-12 schools must support strong mathematical identities and perhaps provide options for advanced mathematical learning in elementary school. Whether mathematics or computer science alone, or a combination of the two, participants' identities as being capable of doing computer science work was sparked during those critical K-12 STEM related courses.

I now chose to consider myself a computer science success. I have not completed a computer science degree, but I have completed this dissertation and on some level have come full circle regarding my computer science aspirations. It is my charge to bring theory to praxis in any way I can during my day-to-day experiences. I will continue to advocate for change at every academic level. I will mentor and inspire everyone I can. Just as my participants ended their stories with thoughts and hopes for the future of African American women in computer science, I end this dissertation with hope for the future.

APPENDIX A

RESEARCH RECRUITMENT LETTERS

Letter to University Chairs

Dear {University Department of Computer Science, or Engineering Chair}:

My name is Yolanda Sanders, and I am a doctoral student from the College of Education at Loyola University Chicago. I am writing to recruit participants for my pilot study for research that will highlight the experiences of African American women in computer science. Will you please forward this information using your alumnae list? I am completing this study under the supervision of Dr. Lara Smetana, Ph.D., in the School of Education, at Loyola University of Chicago.

Numerous research articles focus on the lack of diversity in computer science, but few have highlighted the voices of African American women. As a result, I am looking for participants who are African American female and have completed a degree in computer science (and/or computer engineering, or other related majors) from a predominantly White institution within the last five years. I hope that my work will help to spark discussions and better inform academic practices at institutions.

To get details that genuinely describe the unique experiences of African American women in computer science, I would like to hold a series of short interviews with participants. This study is entirely voluntary, and all information will remain confidential.

Please forward this information to your alumnae, who may then contact me directly and/or share this information with others.

I can be reached via email at ysander@luc.edu, or phone at 312-834-4191. I have also attached a copy of the participant consent form for your review, as well as a flyer that can be shared. Please pass this information along to your members. You can also contact my faculty sponsor, Dr. Lara Smetana, at lsmetana@luc.edu (312-915-6273).

Thank you very much for your time, and consideration.

Sincerely,

Yolanda Sanders

Doctoral Student, Curriculum and Instruction

Loyola University Chicago

ysander@luc.edu

Letter to Organizations

Dear *Dr.* ....:

My name is Yolanda Sanders, and I am a doctoral student from the College of Education at Loyola University Chicago. I am writing to invite members of *organization* to participate in my study for research that will highlight the experiences of African American women in computer science. I am completing this study under the supervision of Dr. Lara Smetana, Ph.D., in the School of Education, at Loyola University of Chicago.

Numerous research articles focus on the disparity of African American women in computer science, but few have highlighted the voices of African American women. As a result, I am looking for participants who self-identify as African American female and have completed a degree in computer science (and/or computer engineering) from a predominantly White Institutions from 2000-2019.

In order to get details that truly describe the unique experiences of African American women in computer science, I would like to hold a series of interviews with each participant. This study is completely voluntary, and all information will remain confidential.

Please forward this information to members of your organization. Please ask members who are interested, or know of other women who may be interested to please contact me via email at ysander@luc.edu, or phone at 312-834-4191. I would also be more than happy to have a short amount of time at an upcoming meeting to discuss my research plan in person, and answer any questions. You can also contact my faculty sponsor, Dr. Lara Smetana, at lsmetana@luc.edu (312-915-6273).

Attached is a copy of a flyer that may be posted, and the participant consent form for your review.

Thank you very much.

Sincerely,

Yolanda Sanders

Doctoral Student, Curriculum and Instruction

Loyola University Chicago

ysander@luc.edu

Letter to Individuals

Dear *[Name]*

My name is Yolanda Sanders, and I am a doctoral student from the College of Education at Loyola University Chicago. I am conducting a pilot study for research that will highlight the experiences of African American women in computer science. I am completing my study under the supervision of *Dr. Lara Smetana, Ph.D.,* in the School of Education, at Loyola University of Chicago.

Numerous research articles focus on the lack of diversity in computer science, but few have actually highlighted the voices of African American women. As a result, I am looking for participants who are African American female and have completed a degree in computer science (and/or computer engineering, or other related majors) from a predominantly White institution within the last 5 years. It is my hope that my work will help to spark discussions and better inform academic practices at institutions.

In order to get details that truly describe the unique experiences of African American women in computer science, I would like to hold a series of short interviews with participants. This study is completely voluntary, and all information will remain confidential. If you are interested in this study please contact me. Also, if you know of anyone who is an African American female and have completed a degree in computer

science (and/or computer engineering,etc.) from a predominantly White institution within the last 5 years, please share this information with them, and ask them to contact me if they are interested.

I can be reached via email at ysander@luc.edu, or phone at 312-834-4191. I have also attached a copy of the participant consent form for your review, as well as a flyer that can be shared. You can also contact my faculty sponsor, Dr. Lara Smetana, at lsmetana@luc.edu (312-915-6273). Feel free to pass this information along to other individuals who may be interested, or any of your professional organizations.

I look forward to hearing from you. Thank you very much for your time, and consideration.

Sincerely,

Yolanda Sanders Doctoral Student,

Curriculum and Instruction

Loyola University Chicago

ysander@luc.edu

APPENDIX B

SOCIAL MEDIA RECRUITMENT

Social Media

Sharing

Twitter or LinkedIn:

Please help me find participants for my dissertation study about African American women who have degrees in computer science. Details are included in my recruitment materials. Found at this link: https://tinyurl.com/AAWinCSstudy

Share this info. Thanks!

Message boards that may allow more characters:

Hello,

I am a doctoral student at Loyola University Chicago. I am recruiting participants for my dissertation study about African American women who have degrees in computer science. Details are included in my recruitment materials. Even if you are not interested or ineligible please pass this information on to those who may be interested or eligible. Also, encourage them to share it with others who may be interested. Found at this link: https://tinyurl.com/AAWinCSstudy

Please share this info with others. Thanks

APPENDIX C

CONSENT TO PARTICIPATE IN RESEARCH

Project Title: African American Women and Computer Science Education

Researcher(s): Yolanda Sanders, Doctoral Student at Loyola University Chicago

Faculty Sponsor: Dr. Lara Smetana, Ph.D.

Introduction: You are being asked to take part in a research study being conducted by Yolanda Sanders, doctoral student, under the supervision of Dr. Lara Smetana in the School of Education, at Loyola University of Chicago. You are being asked to participate in this study because you have self-identified as an African American female with a computer science related degree that was obtained from a predominantly White institution, from 2000-2019. Please read this form carefully and ask any questions you may have before deciding whether to participate in the study.

Purpose: The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI).

Procedures: If you agree to be in the study, you will be asked to:

- Participate in up to three one on one interviews that will be audio recorded. The first interview will last approximately 60 minutes. A second follow-up interview will be approximately 45 minutes. During these interviews, you will be asked to recount your experiences related to being a student in your computer science

program. The third interview will last approximately 30 minutes. During this interview you will be asked to reflect on your experiences during this process.

• All interview meetings will be audio recorded on a password protected device. After the interview, the researcher will transcribe recordings then delete the audio.

• The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional optional reflections of your computer science education

experience, as prose (a written reflection, notes, journal entries), poetry, an illustration, or some other form.

Risks/Benefits:

There are no foreseeable risks involved in participating in this research beyond those experienced in everyday life. This study may be beneficial to you as it allows for positive self-reflection of your accomplishments. Although pseudonyms will be used your voice will be centered, and your story of success will be shared with others. This study is beneficial to society because it seeks to center the experiences of those whose stories may not have been previously told. This could potentially provide insist as to what universities need to do to improve the quality of education in computer science departments.

Confidentiality:

 To protect your identity throughout the study, identifying information will be

removed from all data and a pseudonym will be used to identify you in all data gathered and in data summaries. You may select your own pseudonym.

 Following each activity, audio files will be transcribed. Once transcribed audio recordings will be deleted. Transcriptions will be saved on a password-protected Drive that only I will be able to access. Five years following the study, these files will be deleted.

 Data generated for this study will be used to refine an interview protocol and may be used in subsequent publications related to this study.

Voluntary Participation: Participation in this study is voluntary. If you do not want to be in this study, you do not have to participate. Even if you decide to participate, you are free not to answer any question or to withdraw from participation at any time without penalty.

Contacts and Questions:

If you have questions about this research study, please feel free to contact the researcher, Yolanda Sanders, at ysander@luc.edu (312-834-4191). You can also contact her faculty sponsor, Dr. Lara Smetana, at lsmetana@luc.edu (312-915-6273). If you have questions about your rights as a research participant, you may contact the Loyola University Office of Research Services at (773) 508-2689.

Statement of Consent:

Your signature below indicates that you have read the information provided above, have had an opportunity to ask questions, and agree to participate in this research study. You will be given a copy of this form to keep for your records.

_____

Participant's Printed Name

_____

Participant's Signature Date

_____

Researcher's Signature Date

Loyola University Chicago: Lakeside Campuses

The Protection of Human Subjects

Institutional Review Board for

Date of Approval:

6/4/2019

3/5/2020

APPENDIX D

PARTICIPANT SCREENING

Participant Screening Script

African American Women in

Computer Science

Project Title: *African American Women and Computer Science Education* **Researcher(s):** *Yolanda Sanders, Doctoral Student at Loyola University Chicago* **Faculty Sponsor:** *Dr. Lara Smetana, Ph.D.*

Phone Screening with Potential Participant Calling Me

This will only occur if potential participants contact me first, and I answer.

I will explain that I am a doctoral student at Loyola University Chicago, and review the purpose of the study, risks, and benefits as well as answer any questions they have.

Purpose:

The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI).

Procedures:

If you agree to be in the study, you will be asked to:

- Participate in up to three one on one interviews that will be audio recorded.

The first interview will last approximately 60 minutes. A second follow-up interview will be approximately 45 minutes. During these interviews, you will be asked to recount your experiences related to being a student in your computer science program. The third interview will last approximately 30 minutes. During this interview you will be asked to reflect on your experiences during this process.

- All interview meetings will be audio recorded on a password protected device. After the interview, the researcher will transcribe recordings then delete the audio.
- The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional **optional** reflections of your computer science education experience, as prose (a written reflection, notes, journal entries), poetry, song, photos, any form of art, or some other form.

Risks/Benefits:

There are no foreseeable risks involved in participating in this research beyond those experienced in everyday life. This study may be beneficial to you as it allows for positive self-reflection of your accomplishments. Although pseudonyms will be used your voice will be centered, and your story of success will be shared with others. This study is beneficial to society because it seeks to center the experiences of those whose stories may not have been previously told.

This could potentially provide insist as to what universities need to do to improve the quality of education in computer science departments.

I will then ask: Do you think you are interested in being a participant.

If interested say: I want to ensure that all participants share some of the same characteristics so I would like to ask you a few general questions if that is okay.

If okay, I will ask the following yes or no questions, but If no, I will thank them for their time and end the call.

Questions:

1) Do you identify as African American female?
2) Do you have a bachelors, masters, or doctorate degree in computer science, computer engineering, or a related technology major?
3) Did you receive that degree from a predominantly White institution?
4) Did you complete that degree within the years of 2000-2019?

If any answers to the questions are no say: Thank you so much for your time. Unfortunately, my study will involve participants with all of those characteristics. (Answer any additional questions if needed. Inform the person they may feel free to share my information with others.)

If yes say: Great. I would like to invite you to be a participant. You may have seen the consent form with the information you previously received, however, I would like to share another copy with you. We can schedule an interview time after you have had time to review the consent form. May I send it via email?

- Collect email information.

If the participant would like to schedule an interview time, now that is fine, but the consent form must be received prior to the beginning of the interview

Phone Screening with PI Calling Potential Participant

This will only occur if potential participants contact me first, and leave a message for me to call them back.

No Answer: No Message will be left.

IF SOMEONE ANSWERS THE PHONE

Hello,

Am I speaking to (*potential subject's name*)?

- *If NO, ask if the desired person is available. If not available, then indicate you will call back, say Thank You and hang up. No additional information will be provided in order to not violate the potential subject's privacy.*
-

ONCE THE POTENTIAL PARTICIPANT IS ON THE LINE

Hello,

m I speaking to (*potential subject's name*)? *If YES, then continue:*

My name is Yolanda Sanders**.** I am a doctoral student at Loyola University Chicago. I received a message from you that you might be interested in my study about African American women and computer science education, and I wanted to reach out to you briefly share information about the study. Is this a good time?

- *If no, say is there a better time to reach you? Gather date and time information.*
- *If yes, continue as below.*

Purpose:

The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI).

Procedures:

If you agree to be in the study, you will be asked to:

- Participate in up to three one on one interviews that will be audio recorded. The first interview will last approximately 60 minutes. A second follow-up interview will be approximately 45 minutes. During these interviews, you will be asked to recount your experiences related to being a student in your computer science program. The third interview will last approximately 30 minutes. During this interview you will be asked to reflect on your

experiences during this process.

- All interview meetings will be audio recorded on a password protected device. After the interview, the researcher will transcribe recordings then delete the audio.
- The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional **optional** reflections of your computer science education experience, as prose (a written reflection, notes, journal entries), poetry, song, photos, any form of art, or some other form.

Risks/Benefits:

There are no foreseeable risks involved in participating in this research beyond those experienced in everyday life. This study may be beneficial to you as it allows for positive self-reflection of your accomplishments. Although pseudonyms will be used your voice will be centered, and your story of success will be shared with others. This study is beneficial to society because it seeks to center the experiences of those whose stories may not have been previously told. This could potentially provide insist as to what universities need to do to improve the quality of education in computer science departments.

Do you think you are interested in being a participant or do you have any questions at this time? Answer any questions.

If interested say: I want to ensure that all participants share some of the same

characteristics so I

would like to ask you a few general questions if

that is okay. If okay, ask the following yes or no

questions:

1) Do you identify as African American female?
2) Do you have a bachelors, masters, or doctorate degree in computer science, computer engineering, or a related technology major?
3) Did you receive that degree from a predominantly White institution?
4) Did you complete that degree within the years of 2000-2019?

If no, thank them for their time and end the call.

If any answers to the questions are no say: Thank you so much for your time. Unfortunately, my study will involve participants with all of those characteristics. (Answer any additional questions if needed). Inform the person they may feel free to share my information with others.

If yes say: Great. I would like to invite you to be a participant. You may have seen the consent form with the information you previously received, however, I would like to share another copy with you. We can schedule an interview time after you have had time to review the consent form. May I send it via email?

Collect email information.

If the participant would like to schedule an interview time, now that is fine, but the consent form must be received prior to the beginning of the interview.

Email Screening response to contacts:

Hello {Name}

Thank you for contacting me. As you may have read in my recruitment information I am a doctoral student at Loyola University Chicago. I am completing a study about African American women and computer science education.

Purpose:

The purpose of this research is to highlight the experiences that have influenced the success of African American females who have obtained degrees in computer science from predominantly White universities (PWI).

Procedures:

If you agree to be in the study, you will be asked to:

- Participate in up to three one on one interviews that will be audio recorded. The first interview will last approximately 60 minutes. A second follow-up interview will be approximately 45 minutes. During these interviews, you will be asked to recount your experiences related to being a student in your computer science program. The third interview will last approximately 30 minutes. During this interview you will be asked to reflect on your experiences during this process.
- All interview meetings will be audio recorded on a password protected device. After the interview, the researcher will transcribe recordings then delete the audio.

- The goal of this research is to capture the narratives of African American women and their experiences as a computer science major at a predominately White institution. As a result, you are invited to share additional **optional** reflections of your computer science education experience, as prose (a written reflection, notes, journal entries), poetry, song, photos, any form of art, or some other form.

Risks/Benefits:

There are no foreseeable risks involved in participating in this research beyond those experienced in everyday life. This study may be beneficial to you as it allows for positive self-reflection of your accomplishments. Although pseudonyms will be used your voice will be centered, and your story of success will be shared with others. This study is beneficial to society because it seeks to center the experiences of those whose stories may not have been previously told. This could potentially provide insist as to what universities need to do to improve the quality of education in computer science departments.

I want to ensure that all participants share some of the same characteristics:

1) African American female.
2) Have a bachelors, masters, or doctorate degree in computer science, computer engineering, or a related technology major.
3) Received that degree from a predominantly White institution?
4) Received that degree within the years of 2000-2019?

If you are still interested, let me know if the above characteristics apply to you. If so,

please review and return the attached consent form. I would like to schedule an initial interview as soon as possible. Feel free to let me know your availability.

If you do not meet the requirements of this study I hope you will pass this information on to others who may be interested.

Thank you so much for your time.

In Person Screenings will only be completed at the end of information sessions if invited to do so by organizations, so no additional script is needed. Also, inclusion requirements are listed on the consent form.

REFERENCES

Alexander, Q. R., & Hermann, M. A. (2016). African-American women's experiences in graduate science, technology, engineering, and mathematics education at a predominantly white university: A qualitative investigation. Journal of Diversity in Higher Education, 9(4), 307.

Allen-Ramdial, S., & Campbell, A. (2014). Reimagining the pipeline: Advancing STEM diversity, persistence, and success. *BioScience, 64*(7), 612-618. doi.org/10.1093/biosci/biu076

Alper, J. (1993). The pipeline is leaking women all the way along. *Science,* 260(5106), 409-11.

Ball, C., Huang, K., Cotten, S., & Rikard, R. (2017). Pressurizing the STEM pipeline: an expectancy-value theory analysis of youths' STEM attitudes. *Journal of Science Education and Technology, 26*(4), 372-382. doi.org/10.1007/s10956-017-9685-1

Bennedsen, J., & Caspersen, M. E. (2008). Optimists have more fun, but do they learn better? On the influence of emotional and social factors on learning introductory computer science. *Computer Science Education*, *18*(1), 1-16. doi: 10.1080/08993400701791133

Berry, T. R. (2005). Black on Black education: Personally engaged pedagogy for/by African American pre-service teachers. *The Urban Review*, *37*(1), 31-48.

doi.org/10.1007/s11256-005-3560-8

Berry, T. R. (2009). Women of color in a bilingual/dialectal dilemma: Critical race feminism against a curriculum of oppression in teacher education. *International Journal of Qualitative Studies in Education*, *22*(6), 745-753. doi: 10.1080/09518390903333913

Berry, T. R. (2010). Engaged pedagogy and critical race feminism. *Educational Foundations*, 24(3), 19–26.

Berry, T. R. (2014). Internationalization, Internalization, and Intersectionality of Identity. *JCT: Journal of Curriculum Theorizing*, *30*(1), 4–14.

Berry, T. R. (2015). Me and Bill: Connecting Black curriculum orientations to critical race feminism. *Educational Studies*, 51(5), 423–433. doi:10.1080/00131946.2015.1076687

Berry, T. R., & Candis, M. R. (2013). Cultural Identity and Education: A Critical Race Perspective. *Educational Foundations*, *27*, 43-64.

Berry, T. R., & Cook, E. J. B. (2018). Black on black education 2.0: Critical race perspectives on personally engaged pedagogy for/by Black pre-service teachers. *Teaching Education*. doi: 10.1080/10476210.2018.1514000

Berry, T. R., & Mizelle, N. (Eds.). (2011). Introduction. In T. R. Berry, & N. Mizelle (Eds.), *From oppression to grace: Women of color and their dilemmas within the academy [ebook edition]*. Retrieved from https://ebookcentral-proquest-com.flagship.luc.edu

Berry, T. R., & Stovall, D. O. (2013). Trayvon Martin and the curriculum of tragedy: Critical race lessons for education. *Race Ethnicity and Education*, *16*(4), 587-602.

Beyer, S. (2014). Why are women underrepresented in computer science? Gender differences in stereotypes, self-efficacy, values, and interests and predictors of future CS course-taking and grades. *Computer Science Education*, 24(2/3), 153-192.

Black girls code: About the founder. (2018). Retrieved from http://www.blackgirlscode.com/about-bgc.html

Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: a tool to enhance trustworthiness or merely a nod to validation?. *Qualitative health research*, *26*(13), 1802-1811.

Bishop, J. P. (2012). "She's always been the smart one. I've always been the dumb one": Identities in the mathematics classroom. Journal for Research in Mathematics Education, 43(1), 34-74.

Brodsky, A. E. (2008). Fieldnotes. In L. M. Given, *The SAGE encyclopedia of qualitative research methods* (pp. 341-342), Thousand Oaks: SAGE.

Brown II, M. C. & Dancy II, T. E. (2009). Predominantly white institutions. In K. Lomotey (Ed.), *Encyclopedia of African American education* (pp. 524-526). Thousand Oaks, CA: SAGE Publications, Inc.

Buolamwini, J. (2016). *How I'm fighting bias in algorithms* [video file]. Retrieved from https://www.ted.com/talks/joy_buolamwini_how_i_m_fighting_bias_in_algorithms?language=en

Bureau of Labor Statistics, U.S. Department of Labor. (2018). Computer and information technology. *Occupational Outlook Handbook.* Retrieved from https://www.bls.gov/ooh/computer-and-information-technology/home.htm

Business-Higher Education Forum. (2017). *Invest to Improve: The Cybersecurity Talent Deficit.* Business-Higher Education Forum.

Buzzetto-More, N. A., Ukoha, O., & Rustagi, N. (2010). Unlocking the barriers to women and minorities in computer science and information systems studies: Results from a multi-methodolical study conducted at two minority serving institutions. *Journal of Information Technology Education: Research*, 9, 115-131.

Carspecken, P. F. (2019). The missing infinite: A history and critique of mainstream and counter-mainstear methodologies. In R. Winkle-Wagner, A. N. Gaskew, , & J. Lee-Johnson (Eds.), *Critical theory and qualitative data analysis in education* (pp. 14-45). New York: Routledge.

Charleston, L. J., George, P. L., Jackson, J. F., Berhanu, J., & Amechi, M. H. (2014). Navigating underrepresented STEM spaces: Experiences of Black women in US computing science higher education programs who actualize success. Journal of Diversity in Higher Education, 7(3), 166.

Charmaz, K. (2011). A constructivist grounded theory analysis of losing and regaining a valued self. In F. J. Wertz, K. Charmaz, L. McMullen, R. Josselson, R. Anderson, & E. McSpadden, *Five ways of doing qualitative analysis,* (pp. 165-204). New York:Guilford Publications.

Chavous, T., & Cogburn, C. D. (2007). Superinvisible women: Black girls and women in education. *Black Women, Gender & Families*, 1(2), 24-51.

Cheryan, S., & Plaut, V. C. (2010). Explaining underrepresentation: A theory of precluded interest. *Sex roles*, *63*(7-8), 475-488.

Cheryan, S., Drury, B. J., & Vichayapai, M. (2013). Enduring influence of stereotypical computer science role models on women's academic aspirations. *Psychology of Women Quarterly*, *37*(1), 72-79.

Cheryan, S., Plaut, V. C., Handron, C., & Hudson, L. (2013). The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women. *Sex roles*, *69*(1-2), 58-71.

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others?. *Psychological Bulletin*, 143(1), 1-35.

Childers-McKee, C., & Hytten, K. (2015). Critical race feminism and the complex challenges of educational reform. *Urban Review*, 47(3), 393-412.

Commodore, F., Baker, D., & Arroyo, A. (2018). Black women college students : A guide to student success in higher education (Key issues on diverse college students). Routledge, Taylor & Francis Group.

Crenshaw, K. (1989). Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory and Antiracist Politics. *University of Chicago Legal Forum,* 139–167.

Cresswell, J., & Poth, C. (2018). *Qualitative inquiry & research design: Choosing among five approaches*. California: SAGE.

Creswell, J. W., & Creswell, J. D. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks: SAGE.

De Lima Salge, C., & Berente, N. (2017). Is that social bot behaving unethically? *Communications of the ACM,* 60(9), 29-31.

DeCuir, J. T., & Dixson, A. D. (2004). "So when it comes out, they aren't that surprised that it is there": Using critical race theory as a tool of analysis of race and racism in education. *Educational researcher*, 33(5), 26-31.

DeDoose [Online Computer software]. (2019). Retrieved from http://www.dedoose.com

Delgado, R. (1989). Storytelling for oppositionists and others: plea for narrative. *Michigan Law Review* 87(8), 2411-2441.

Delgado, R. (2000). Introduction. In R. Delgado, & J. Stefancic, *Critical race theory: The cutting edge (2nd. Ed.), (pp. xv-xix).* New York: NYU Press.

Delgado, R., & Stefancic, J. (2001). *Critical race theory: An introduction.* New York: NYU Press.

Delgado, Richard. (2003). Forward to the second edition, (pp. xiii-xv). In , A. K.Wing

(Ed.). (2003). *Critical race feminism: A reader* (2nd ed.). New York University Press.

Denner, J., Werner, L., & O'Connor, L. (2015). Women in community college: Factors related to intentions to pursue computer science. *NASPA Journal About Women in Higher Education*, *8*(2), 156-171.

Dixson, A. D., & Anderson, C. K.(2017). And we are still not saved: 20 Years of CRT and education. In A. D. Dixson, C. K. Anderson, J. K. Donnor (Eds.). *Critical race theory in education : All God's children got a song* (2nd ed.), (pp. 32- 54). New York: Routledge.

Dixson, A. D., & Rousseau, C. K. (2005). And we are still not saved: Critical race theory in education ten years later. *Race Ethnicity and Educatio*n, 8(1), 7-27.

Donnor, J. K. (2005). Racialized technology: Computers, commodification, and "cyber-race." In M. C. Brown, II, R. R. Land (Eds.). *Politics of Curricular Change* (pp. 91-102). New York: Peter Lang Publishing.

Dortch, D., & Patel, C. (2017). Black undergraduate women and their sense of belonging in STEM at predominantly White institutions. *NASPA Journal About Women in Higher Education,* 10(2), 202-215.

Evans-Winters, V. E., & Esposito, J. (2010). Other People's Daughters: Critical Race Feminism and Black Girls' Education. *Educational Foundations,* 24(1/2), 11-24.

Freeman, M. (2017). Modes of thinking for qualitative data analysis. New York: Routledge.

Frieze, C., Quesenberry, J. L., Kemp, E., & Velázquez, A. (2012). Diversity or difference? New research supports the case for a cultural perspective on women in computing. *Journal of Science Education and Technology*, *21*(4), 423-439.

Green, D., Pulley, T., Jackson, M., Martin, L. L., & Fasching-Varner, K. J. (2018). Mapping the margins and searching for higher ground: examining the marginalisation of black female graduate students at PWIs. *Gender and Education*, *30*(3), 295-309.

Groenewald, T. (2008). Memos and memoing. In L. M. Given, *The encyclopedia of qualitative research methods* (pp. 505-506), Thousand Oaks: SAGE.

Harris, C. I. (1993). Whiteness as property. *Harvard Law Review, 106(8)*, 1709-1791.

Henry, A. (1998). 'Invisible' and 'Womanish': Black girls negotiating their lives in an African-centered school in the USA. *Race Ethnicity and Education*, 1(2), 151-170.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*.Washington, DC: AAUW.

Hogan, A., & Roberts, B. (2015). Occupational employment projections to 2024. *Monthly Labor Review*, 1–28.

Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). "We do science here": Underrepresented students' interactions with faculty in different college contexts. *Journal of Social Issues*, *67*(3), 553-579.

Jackson, D. L. (2013). A balancing act: Impacting and initiating the success of African

American female community college transfer students in STEM into the HBCU environment. *The Journal of Negro Education*, 82(3), 255-271.

Jackson, D. L. (2013). A balancing act: Impacting and initiating the success of African American female community college transfer students in STEM into the HBCU environment. *The Journal of Negro Education*, *82*(3), 255-271.

Joseph, J. (2012). From one culture to another: Years one and two of graduate school for African American women in the STEM fields. *International Journal of Doctoral Studies,* 7, 125-142.

Josselson, R. (2011). Narrative research: Constructing, deconstructing, and reconstructing story. In F. J. Wertz, K. Charmaz, L. M. McMullen, R. Josselson, R. Anderson, & E. McSpadden, Five ways of doing qualitative analysis: Phenomenological psychology, grounded theory, discourse analysis, narrative research, and intuitive inquiry (pp. 224 – 242). New York: Guilford.

Jung, L., Clark, U. Y., Patterson, L., & Pence, T. (2017). Closing the gender gap in the technology major. *Information Systems Education Journal*, *15*(1), 26.

Kim, J. (2016). *Understanding narrative inquiry: The crafting and analysis of stories as research* [Kindle edition]. Thousand Oaks: SAGE.

Kim, K. A., Fann, A. J., & Misa-Escalante, K. O. (2011). Engaging women in computer science and engineering: Promising practices for promoting gender equity in undergraduate research experiences. *ACM Transactions on Computing Education (TOCE)*, *11*(2), 8.

Kulturel-Konak, S., D'Allegro, M. L., & Dickinson, S. (2011). Review of gender differences in learning styles: Suggestions for stem education. *Contemporary Issues in Education Research*, 4(3), 9-18.

Ladson-Billings, G. (1995a). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into practice*, *34*(3), 159-165.

Ladson-Billings, G. (1995b). Toward a theory of culturally relevant pedagogy. *American educational research journal*, *32*(3), 465-491.

Ladson-Billings, G. (2013). Critical race theory-what it is not!. In M. Lynn, & A. Dixson, A. *Handbook of critical race theory in education,* (pp. 34-47). New York:Routledge.

Laosethakul, K., & Leingpibul, T. (2010). Why females do not choose computing? A lesson learned from China. *Multicultural Education & Technology Journal*, *4*(3), 173-187.

Leath, S., & Chavous, T. (2018). Black women's experiences of campus racial climate and stigma at predominantly white institutions: Insights from a comparative and within-group qpproach for STEM and Non-STEM majors. *Journal of Negro Education*, 87(2), 125–139.

Lee-Johnson, J., & Henderson, L. (2019). Using social media to (re)center Black women's voices in educational research. In R. Winkle-Wagner, A. N. Gaskew, & J. Lee-Johnson (Eds.), *Critical theory and qualitative data analysis in education* (pp. 222-235). New York: Routledge.

Linder, C. (2011). Exclusionary Feminism: Stories of Undergraduate Women of Color. *NASPA Journal About Women in Higher Education*, *4*(1), 1–25.

Lockard, C. B., & Wolf, M. (2012). Occupational employment projections to 2020. *Monthly Labor Review*, 135, 84.

Margolis, J., Estrella, R., Goode, J., Holme, J., & Nao, K. (2010). *Stuck in the shallow end* [E-book]. Massachusetts: The MIT Press. Retrieved from https://ebookcentral.proquest.com

Margolis, J., Goode, J., & Bernier, D. (2011). The Need for Computer Science. *Educational Leadership,* 68(5), 68-72.

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal Of Educational Psychology,* 108(3), 424-437.

Matsuda, M. J. (1989). When the first quail calls: multiple consciousness as jurisprudential method. *Women's Rights Law Reporter,* 11(1), 7-10.

McGee, E. O., & Bentley, L. (2017). The troubled success of Black women in STEM. *Cognition and Instruction*, 35(4), 265-289.

McKinley, B., Brayboy, J., & Chin, J. (2019). A match made in heaven tribal critical race theory and critical indigenous research methodologies. In J. T. DeCuir-Gunby, T. K. Chapman, and P. Schutz (Eds.). *Understanding critical race research methods and methodologies* [Kindle edition], (pp. 51-62). New York: Taylor and Francis.

McPherson, E. (2014). Informal in science, math, and engineering majors for African American female undergraduates. *Global Education Review,* 1 (4). 96-113.

McPherson, E. (2017). Oh you are Smart: Young, gifted African American women in STEM majors. *Journal of Women and Minorities in Science and Engineering*, 23(1), 1-14.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco: CA.

National Association of Colleges and Employers. (2018). *Fall 2018 Salary Survey*. Retrieved from https://careerservices.wayne.edu/pdfs/2018-nace-salary-survey-fall.pdf

National Science Foundation. (2017). 2017 Women, minorities, and persons with disabilities in science and engineering. *National Center for Science and Engineering Statistics.* Retrieved from www.nsf.gov/statistics/wmpd/.

National Science Foundation. (2019). 2019 Women, minorities, and persons with disabilities in science and engineering. *National Center for Science and Engineering Statistics.* Retrieved from https://ncses.nsf.gov/pubs/nsf19304/digest

Norris, C., & Jackson, L. (1992). The effect of computer science instruction on critical thinking skills and mental alertness. *Journal of Research on Computing in Education*, *24*(3), 329.

Ong, M., Smith, J. M., & Ko, L. T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal*

of Research in Science Teaching, *55*(2), 206-245.

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., & Gary, S. (2009). The contribution of HBCUs to the preparation of African American women for STEM careers: A case study. *Research in Higher Education*, 50(1), 1-23.

Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. *International journal of qualitative studies in education*, *8*(1), 5-23.

Pratt-Clarke, M. (2010). *Critical Race, Feminism, and Education: A Social Justice Model.* New York: Palgrave Macmillan.

Russell, M. L., & Russell, J. A. (2015). Black American undergraduate women at a PWI: Switching majors in STEM. *Negro Educational Review*, 66(1-4), 101.

Saldaña, J. (2016). *The coding manual for qualitative researchers*. SAGE Publications. Kindle Edition.

Sandelowski, M. (2008). Member check. In L. M. Given, *The SAGE encyclopedia of qualitative research methods* (pp. 501-502)*,* Thousand Oaks: SAGE.

Sax, L. J., Lehman, K. J., Jacobs, J. A., Kanny, M. A., Lim, G., Monje-Paulson, L., & Zimmerman, H. B. (2017). Anatomy of an enduring gender gap: The evolution of women's participation in computer science. *The Journal of Higher Education*, *88*(2), 258-293.

Sax, L. J., Zimmerman, H. B., Blaney, J. M., Toven-Lindsey, B., & Lehman, K. J. (2017). Diversifying undergraduate computer science: The role of department chairs in

promoting gender and racial diversity. Journal of *Women and Minorities in Science and Engineering*, 23(2).

Schwandt, T. A. (2015). *The SAGE dictionary of qualitative inquiry*. Los Angeles: SAGE.

Smith, P. J. (2003). Failing to mentor sapphire. In A.K. Wing (Ed.), *Critical race feminism: A reader* (2nd ed.), (pp. 120-130). New York: New York University Press.

Solórzano, D., & Yosso, T. (2002). Critical Race Methodology: Counter-Storytelling as an Analytical Framework for Education Research. *Qualitative Inquiry*, 8(1), 23-44.

Spence, D. P. (1986). Narrative smoothing and clinical wisdom. In T. R. Sarbin (Ed.), *Narrative psychology: The storied nature of human conduct* (p. 211–232). Praeger Publishers/Greenwood Publishing Group.

Stack, C. B. (1975). *All our kin: Strategies for survival in a black community*. Basic Books.

Talley, K. G., & Ortiz, A. M. (2017). Women's interest development and motivations to persist as college students in STEM: a mixed methods analysis of views and voices from a Hispanic-Serving Institution. *International Journal of STEM Education*, *4*(1), 5.

Thomas, V., & Jackson, J. (2007). The Education of African American Girls and Women: Past to Present. *The Journal of Negro Education*, 76(3), 357-372.

Varma, R. (2010). Why so few women enroll in computing? Gender and ethnic differences in students' perception. *Computer Science Education*, 20(4), 301-316.

Villa, E. Q., Wandermurem, L., Hampton, E. M., & Esquinca, A. (2016). Engineering Education through the Latina Lens. *Journal of Education and Learning*, 5(4), 113-125.

Walkington, L. (2017). How Far Have We Really Come? Black Women Faculty and Graduate Students' Experiences in Higher Education. *Humboldt Journal of Social Relations,* 39, 51-65.

Wang, J., Hong, H., Ravitz, J., & Ivory, M. (2015, June). Gender differences in factors influencing pursuit of computer science and related fields. In *Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 117-122). ACM.

Wertz, F. J., Charmaz, K., McMullen, L., Josselson, R., Anderson, R., &. McSpadden, E. (2011). *Five ways of doing qualitative analysis.* New York:Guilford Publications.

Wing, A. K. (1990). Brief reflections toward a multiplicative theory and praxis of being. *Berkeley Women's Law Journal*. *6*(1)181-201.

Wing, A. K. (1999). *Race and Gender Issues: Critical Race Feminism*. Journal of Intergroup Relations, 26(3), 14–25.

Wing, A. K. (2003). Introduction. In A.K. Wing (Ed.), *Critical race feminism: A reader* (2nd ed.), (pp. 1-19). New York: New York University Press.

Winkle-Wagner, R. Gaskew, A. N., & Lee-Johnson, J. (2019). The missing link in data analysis: An introduction to the use of critical theory to guide data analysis. In R. Winkle-Wagner, A. N. Gaskew, & J. Lee-Johnson (Eds.), *Critical theory and qualitative data analysis in education* (pp. 3-13). New York: Routledge.

Winkle-Wagner, R., Sule, T., and Maramba, D. (2019). Analyzing Policy Critically. In R. Winkle-Wagner, A. N. Gaskew, & J. Lee-Johnson (Eds.), *Critical theory and qualitative data analysis in education* (pp. 193-201). New York: Routledge.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race ethnicity and education*, 8(1), 69-91.

Yosso, T. J. (2006). Critical race counterstories along the Chicana/Chicano educational pipeline. New York: Routledge.

Zoom [Computer software]. (2019). Retrieved from https://zoom.us

VITA

Yolanda B. Sanders graduated from the Academy of Our Lady High School and entered the University of Illinois at Urbana-Champaign in 1988. In 1990 she transferred to the University of Illinois at Chicago. From there she received a Bachelor of Arts degree in Communication and Theater. Attending graduate school at Chicago State University she was awarded the degree of Master of Science in Education in 1994.

Yolanda then began working as a full-time employee of Chicago Public Schools in the fall of 1995. She spent the next twenty years working as an elementary school teacher of grades third through eighth. Holding teaching endorsements across a gamut of subjects including middle school Mathematics, English Language Arts, and Social studies, she spent the greatest amount of her career teaching her favorite subject, science. During her time in the classroom, she not only focused on the academic achievements of her students, but she also worked to mentor National Board Teacher Candidates in her certificate area of Middle Childhood Generalist.

She acquired a Master of Education Degree in Educational Leadership from DePaul University, Chicago in 2013. In 2015 she began working for the Chicago Public Schools, Department of STEM (science, technology, engineering, and mathematics) as a STEM Specialist. In the summer of 2016, she entered the Graduate School at Loyola University, Chicago. She was promoted within the Department of STEM to the district-

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DISSERTATION COMMITTEE

The Dissertation submitted by Yolanda Sanders has been read and approved by the following committee:

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