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BLACK WOMEN PURSUING DOCTORATES IN MATHEMATICS EDUCATION: AN EXAMINATION OF STORIES OF THEIR MATHEMATICAL EXPERIENCES

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ACCEPTANCE

This dissertation, BLACK WOMEN PURSUING DOCTORATES IN MATHEMATICS EDUCATION: AN EXAMINATION OF STORIES OF THEIR MATHEMATICAL EXPERIENCES, by NATHALIE NICHOLLE DAMES, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education and Human Development, Georgia State University.

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BLACK WOMEN PURSUING DOCTORATES IN MATHEMATICS EDUCATION: AN EXAMINATION OF STORIES OF THEIR MATHEMATICAL EXPERIENCES

by

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Under the Direction of Dr. Christine D. Thomas and Dr. Janice B. Fournillier

ABSTRACT

The research shows a lack of representation of Black women in mathematics education. The purpose of this study was to explore Black women's perspectives on how their mathematical experiences influenced their decisions to pursue a doctoral degree in mathematics education. To address this issue the following research questions were explored: What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences? How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education? For this study purposeful sampling was used to select seven participants, that classify themselves as Black women and are currently in a doctoral program in mathematics education. Individual and group interviews conducted with the participants were analyzed using a grounded theory approach to gain an understanding of their mathematical experiences as learners with respect to their trajectories in becoming doctoral students in mathematics education. The Black women that participated in this study had positive feelings about their mathematical abilities. This resulted in confident mathematical identities. The mathematical environment included classrooms with supportive teachers, classmates that were mainly Black, and an even split between the genders. Once this environment was challenged a crisis occurred which caused them to lose confidence in themselves. All of the participants began teaching secondary mathematics as a career change from their initial undergraduate degree. Their initial graduate degrees were in conjunction with

their decision to pursue a career as a mathematics educator. The decision to pursue a doctoral degree was out of a personal desire to advance academically as well as desire to effect change within their community. The findings of this study support an achievement motivation framework. This research presents an initial understanding of how perspectives of mathematical experiences influence their decision to pursue doctoral degrees in mathematics education.
INDEX WORDS: Black, Women, Mathematics, Mathematics education

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1 INTRODUCTION

As an early PhD student in mathematics education, I read "Why so Few? Women in Science, Technology, Engineering and Mathematics" (Hill, Corbett, & St. Rose, 2010), one of many articles discussing growing concern about the absence of women and minorities in STEM fields. However, when I looked around in my own courses, I saw many women as well as minorities. This difference raised an important question: "What is so different in this program?"

The university I attended is located in an urban city within the southeastern region of the United States, and the program was a doctorate of philosophy in teaching and learning with a concentration in mathematics education. Many of my program's participants had backgrounds in teaching secondary mathematics; many of them were women, and the majority of these women were Black. Consequently, when I read an article lamenting the absence of women in STEM, I was initially confused. However, the article was referring to such PhD programs' populations at large, which meant that places like my school are far from the norm—in fact, they are the exception. Soon, I began to question what made the women in my program so atypical. What led them to this program, and what mathematical experiences did they have prior to entering it? More specifically, my interest was on the Black women students. As a Black woman, I wondered what common mathematical experiences led each of us to pursue PhDs in mathematics education. Thus, I decided to focus my study, not merely on women, but on an even smaller portion of the STEM population: Black women. I wanted to understand what motivated Black women to pursue mathematics. For the purpose of this study, the term *Black women* refers to any woman that self-identifies as Black. I chose this terminology instead of a term like *African Americans* in an effort to include women from the African Diaspora who, though they consider themselves Black, they do not identify themselves as African American. In addition, this term

was selected to include all persons from a variety of backgrounds who align themselves with Black people, and who feel they share common ethnic and cultural experiences.

There are indeed Black women who have a keen interest in mathematics—particularly mathematics education—and, as is evident in my program, they have chosen to pursue doctorates of philosophy in the field. Since these women decided to enter a profession that is considered the gateway to future careers in STEM, it is important to understand their experiences in mathematics. Moreover, these experiences influenced their decision to pursue doctorate degrees in mathematics education. As such, this study centered on personally narrated stories about the mathematical experiences of Black women in pursuit of doctorates of philosophy (PhDs) in mathematics education.

Problem

Unfortunately, there is a limited amount of research-based literature engaged in the discussion of the mathematical experiences of Black women. As McGee and Martin (2011) have stated, "the voices of Black learners themselves are often absent from the larger discourse on achievement and persistence outcomes, particularly of those who have successfully negotiated the mathematics, science, and engineering pipelines" (p. 1351). There has, however, been a great deal of research focused on the achievement gap and other deficit models that are used to discount those deemed to lack proficiency in mathematics (Blackford & Khojasteh, 2013; Gutiérrez, 2008). At the same time, there has been a recent interest in current literature concerning the success of Blacks in mathematics. Borum and Walker (2012) examined the experiences of Black women with PhDs in mathematics, and their findings suggest that mentorship, a supportive program, and study groups were instrumental to the success of these women in their doctoral studies. Ellington and Frederick's (2010) study included Black junior

and senior level college mathematics majors who credited their success to advanced mathematics courses, accelerated academic programs, and family, peers, and teachers. Yet, in spite of this important research, there is still scant information within the current body of literature about the mathematical experiences of Black women pursuing doctorate degrees in mathematics education. More research is needed, particularly since its findings could address the issue of the relative absence of Black women in mathematics and other STEM fields. Indeed, one of the goals of this study was to increase the literature on Black women's participation in mathematics.

Purpose Statement

The purpose of this study was to explore Black women's perspectives about how their mathematical experiences influenced their decisions to pursue doctoral degrees in mathematics education. My approach to this study was to collect the narratives of Black women who are currently pursuing PhDs in mathematics education. These narratives served as my data. I gained rich and thick descriptions of the participants' experiences as learners of mathematics through their stories (Bogdan & Biklen, 2007; Chase, 2005; Foote & Bartell, 2011; Kramp, 2004; Milner, 2007). Through an analysis of their stories, I investigated their motivations for pursuing mathematics and their descriptions of their learning experiences. I designed a grounded theory approach (Anfara & Mertz, 2006; Charmaz, 2006; Higginbottom, 2014; Strauss & Glaser, 1967) , which is consistent with gaining an understanding of their mathematical experiences as learners with respect to their trajectories for becoming doctoral students in mathematics education. As Kramp (2004) stated, "stories preserve our memories, prompt our reflections, connect us with our past and present, and assist us to envision our future" (p. 107). Because of these women, who discuss the lived experiences that led them to become mathematicians, future generations now have an account of what it took them to make a place for themselves in mathematics education.

Research Questions

The following research questions guided this study:

1. What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences?
2. How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?

Conceptual Framework

I examined the experiences that motivated the participants in their quests to gain doctorates in mathematics education. Indeed, there are many types of motivational factors that could be considered. One motivational construct I used to guide this study was achievement motivation. Murray (1938), who was one of the first to write on achievement motivation, identified three important factors: "a need for achievement, an approach motive, and infavoidance (the avoidance motive)" (as cited in Schatt, 2011, p. 2). Achievement motivation emerges from a redefinition of drive or degree of motivation. Busato, Prins, Elshout, and Hamaker (2000) define achievement motivation as "the striving tendency towards success with the associated positive effects and towards the avoidance of failure and the associated negative effects" (p. 1058). Al-Shabatat, Ahmad, and Nizam (2011) defined achievement motivation as "an individual's tendency to desire and work towards accomplishing challenging personal and professional goals" (p. 99). Some factors linked to influencing achievement motivation include personality factors, situational factors, and goals. Personality factors include persistence, the ability to delay gratification, and competitiveness. Situational factors include expectation of success, incentives control, and opportunity. Though goals also play a crucial part in achievement motivation, those goals must be specific, challenging yet achievable, and positive.

Goals also reflect a belief that success is gained by improving one's abilities through hard work and applying great effort to the task at hand (Watabe & Hibbard, 2014). There are still many flaws with this theory of motivation; it is difficult to link all of the possible factors together and there are no specifications for cross-cultural use (Al-Shabatat, et al., 2011). Harper (2010) introduced the anti-deficit achievement model as a way to study successful Black students in STEM. The model focused on the areas of precollege socialization and readiness, college achievement, and post-college persistence in STEM. According to Harper (2010), "The anti-deficit achievement framework is informed by the theories from psychology, sociology, and education, each of which can be explored in an *instead-of* fashion" (p. 68).

Though I was careful not to impose this theory onto my participants, there were some overlaps between its components and my findings. By looking closely at achievement motivation, I was able to use the theory as a conceptual framework to guide (but not dictate) the focus of the interviews and analysis of the data. In order for this research to take a somewhat nonbiased approach, I utilized grounded theory to see what has not yet been presented. Consequently, this study contributes to the literature with new theoretical knowledge that illuminates motivations for Black women to grow and achieve in mathematics. There are limitations within some educational theoretical frameworks that subscribe to the notion of deficit-driven approaches that are based within assumptions of race-based inferiority. Therefore, it was vital to use approaches that are not deficit-driven and were thus able to offer the participants a voice in the study (Nobles, 2008). As Saavedra and Perez (2012) so eloquently affirmed, "theories do not exist solely for analyzing the experiences of others, they coexist within us and through us" (p. 431).

Critical Race Feminism

Critical race feminism (CRF), which is rooted in critical race theory (CRT), provided another supportive framework for the study that examined my participants' experiences. CRT "emerged to address specific social, political, educational, and economic concerns of race" (McKay, 2010, p. 26). What CRT failed to fully address, however, was the issues of women from an anti-essentialist view (Wing, 1999; 2009; Evans-Winters & Esposito, 2010). From an essentialist view, different aspects of a Black woman's identity are thought of as additive instead of multiplicative. In other words, identity is negligible. However, followers of CRF argue that this is not the case. One cannot subtract any portion of one's identity, making them simply black or simply a woman. This theory was crucial for me as a researcher; I was able to examine multiple aspects of a participant's identity and the ways in which it contributed to their experiences. These alternative or counter narratives were precisely what the women of this study presented. Their stories of achievement in mathematics, and particularly in the area of mathematics education, helped to formulate counter-narratives to those that failed to include Black women in the area of mathematics education.

Mathematical Identity

The analysis of the participant's perspectives allowed me to identify mathematical identity as another important framework. Various scholars (Boaler and Greeno, 2000; Martin, 2000; Sfard and Prusak, 2005; Bishop, 2012) have defined mathematical identity. Boaler and Greeno (2000) defined identity as a part of the learning process. The ways in which students locate or identify as members of the mathematics classroom community contributes to the formation of this identity. Martin's (2000) framework for identity had multiple levels that included individual, school, community, and sociohistorical levels. Within the individual level, the key themes were "personal identities and goals; perceptions of school climate, peers and

teachers; beliefs about mathematics abilities and motivation to learn; beliefs about the instrumental importance of mathematics knowledge; and beliefs about differential treatment from peers" (p. 29). Sfard and Prusak's (2005) defined identity as "a collection of stories or narratives that are reifying, endorsable and significant" (p. 16). Bishop (2012) added to these definitions by incorporating the idea that identities are both collectively and individually defined. As the participants described their mathematical experiences, they consistently expressed their attitudes, expectations, and beliefs about their abilities, which made the notion of mathematical identity prevalent. For this reason, a discussion of empirical studies related to mathematical identity appears in the literature review as well as in the discussion.

Significance

This dissertation shared stories of Black women's mathematical experiences and how these women engage in the subject to become doctors of mathematics education. The findings help to extend the current research on Black women and their achievements in mathematics in general. Exploring these experiences might help mathematicians and mathematics educators to make necessary changes in curricula, instruction, and policies that work to support Blacks in mathematics. The results of this study could also provide insight to stakeholders and policy makers about the experiences that contribute to the success of Black women in mathematics at various levels. This study may contribute to understanding how certain experiences serve to discourage Black women from pursuing degrees in mathematics education.

By using grounded theory, my research findings are more ecologically valid. As a result, the findings of the study more accurately reflected the mathematical experiences of Black women in mathematics education. The constructs generated are more context-specific, detailed,

and tightly connected to the data. By using grounded theory, I was able to identify and categorize experiences inductively rather than impose pre-existing topologies from dissimilar data.

Conclusion

Although there are an increasing number of studies on the achievement of Blacks in mathematics, there also appears to be a limited amount of literature about Black women in mathematics education, a subject that is considered a gateway for minority students interested in STEM fields. The purpose of this study was to explore Black women's perspectives on how their mathematical experiences influenced their decisions to pursue doctoral degrees in mathematics education. Chapter 2 provides a review of the literature related to mathematics and Black women in the discipline. Chapter 3 focuses on methodological considerations and explains the methods utilized throughout this study. This is followed by the results of this study, a discussion, and the conclusion.

2 LITERATURE REVIEW

This study was designed to explore the mathematical experiences of Black women in pursuit of doctoral degrees in mathematics education, and how those experiences influenced their pursuit of a doctorate of philosophy in mathematics education. According to Museus and Liverman (2010), "Understanding how to increase rates of success among URM [underrepresented minority] students in STEM is an increasingly important task for higher education researchers and practitioners" (p. 24). One possible avenue for gaining more understanding of how to increase underrepresented minorities' success in STEM is to explore the mathematical experiences of mathematics educators. For instance, Museus and Liverman (2010) examined how the mathematical experiences of Black women influenced their decisions to pursue doctoral degrees in mathematics education. However, there remains a limited amount of research-based literature that engages in the discussion of the mathematical experiences of Black women. As McGee and Martin (2011) noted in their study of Black college students, "a deeper appreciation of what it means to be Black and academically successful in contexts where Black students are few in number and where negative societal- and school-level beliefs about their ability and motivation persist" is necessary (p. 1350).

Indeed, the stories of Black women should be examined in order to explain what it took to achieve their academic levels in the hope of possibly improving the academic achievement of others in mathematics education. In particular, when examining science, technology, engineering, and mathematics (STEM) fields and classrooms, there needs to be more research on the factors that contribute to Black women deciding to enter mathematical fields at all levels, including undergraduate, graduate, and faculty pursuits (Johnson, 2011). In order to begin the exploration, this literature review discusses the concept of mathematics as a gatekeeper. It will

then, explore the stories of the underrepresented and underserved in mathematics by examining the programs used to reach those populations. A review of women in mathematics and Black women in mathematics will follow. Finally, I discuss achievement motivation as a conceptual framework used to analyze the mathematical experiences of the participants. For the purpose of this review, the term *Black women* encompasses any study that denoted the participants as Black or African American women. In the review of the literature, studies directly related to women and specifically Black women in mathematics education were significantly limited; therefore, the overview of literature was expanded to include women and Black women in mathematics.

The review employs analyses and critiques of several studies as they relate to Black women in academia, STEM, and specifically mathematics and mathematics education. In addition, it includes women's experiences related to their achievements and ways they overcame obstacles. There are very few studies that focused specifically on the experiences of Black women pursuing a doctorate degree in mathematics education; however, this study attempts to encompass an assortment of aspects as they relate to the following research questions:

- What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences?
- How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?

Mathematics as a gatekeeper

Mathematics has a long history as a perceived gatekeeper of STEM fields (Bourdieu, 1998; Davis, 1993; Gutstein, 2010; Stinson, 2004). Current literature related to this phenomenon has focused on the current administration's political education agendas, and the importance of mathematics' gatekeeping status is most evident in the high stakes placed on this component of

education by the U.S. government. For example, a critical component of the Race to the Top Grant's initiatives reveals that stakes are focused heavily on STEM fields: states are rewarded with additional points towards the winning scores needed to secure crucial grants. Additionally, the Obama-Duncan education agenda included an "Educate to Innovate" campaign, whose focus was to "increase STEM literacy so that all students can learn deeply and think critically in science, math, engineering, and technology [and] expand STEM education and career opportunities for underrepresented groups including women and girls" (The White House, 2009, as cited in Gutstein, 2010, p. 11). In this study, I focused on the experiences of Black women in mathematics education, and this literature speaks to the study by highlighting ways that current administrations' political agendas affected programs that were offered to Black women (as well as other minorities and underserved populations) to foster their inclusion in mathematics.

> In his comments on the power of mathematics as a gatekeeper, Bourdieu (1998) stated: Often with a psychological brutality that nothing can attenuate, the school institution lays down its final judgments and its verdicts, from which there is no appeal, ranking all students in a unique hierarchy of all forms of excellence, nowadays dominated by a single discipline, mathematics. (p. 28)

Ability tracking is one way that mathematics is used as a gatekeeper. Ability tracking is the "practice of placing students in stratified classes based on the students' perceived abilities" (Welner, 2002, p. 565). Some students are tracked as early as kindergarten, and this tracking typically follows students all the way through high school, generally resulting in a "separation of students along racial, ethnic, and socio-economic lines" (Ansalone, 2010, p. 11). More often than not, Hispanics and African Americans are placed in special education and general educational tracks. Indeed, as Ansalone (2010) has reminded us, "Tracking facilitates the separation of social

classes as they attempt to compete for advantages in the distribution of school resources and credentials" (p. 6). Since students are tracked from elementary school depending on how well they perform in math and science, many minorities do not have a chance to enter the STEM track. Mathematics test scores are often used as the track indicator, and minorities statistically score considerably lower on mathematics tests than their White counterparts. Consequently, according to Snipes and Waters (2005), "remedial mathematics classrooms contain large numbers of African American students; however, advanced mathematics classes mainly serve White students" (p. 107).

The movement to undo the ability tracking system was faced with tough opposition because some stakeholders wanted to protect the intellectual property that their children were afforded via the tracking system (Futrell & Gomez, 2008). Within the structure of educational hierarchy, mathematics is privileged as one of the premier fields whose students are considered high achievers. Achieving an elevated literacy in mathematics helps students understand "how mathematics skills and concepts can be used to understand the institutional structures of our society" (Gutstein & Peterson, 2005, p. 24). Being mathematically literate includes being able to reason logically, to think in both concrete and abstract terms, to integrate mathematical thinking across a wide range of topics, and to appreciate its usefulness in daily life (Davis & Hersh, 1998; Ernest, 2004; Skovsmose, 2005). Mathematics is one of the main subjects that represent a form of intellectual property where the value is assigned by test scores and an ability to access higher level of mathematics (Snipes & Waters, 2005). This literature spoke to this study's purpose of exploring how Black women's mathematical experiences were influenced by ability tracking, and how they successfully navigated these tracks to achieve high levels of mathematical ability.

The participants of this study all had work experiences as mathematics educators. After reading about mathematics' use as a divisive tool and the subsequently harmful effects, I began to wonder why instructors continue to teach mathematics. According to Davis (1993):

> We teach it for its own sake, because it is beautiful; because it reveals the divine; because it helps us think logically; because it is the language of science and it helps us to understand and reveal the world; because it helps our students to get a job, either directly, in those areas of social or physical science that require mathematics, or indirectly, insofar as mathematics, through testing, acts as a social filter, admitting to certain professional possibilities those who can master the material. We teach it also to reproduce ourselves by producing future research mathematicians and mathematics teachers. (p. 190).

Noyes (2007) added that mathematics is taught for the academy, employment, general education, citizenship, social justice, and the information age. Volmink (1994), stated that "to deny some the access to participation in mathematics is then also to determine, a priori, who will move ahead and who will stay behind" (p. 51). This literature provides insight into why mathematics is taught, and gives focus to those who have typically been denied access to mathematics.

Although mathematics has a history of serving as a gatekeeper and promoting social inequality, it is important to study mathematics, and particularly mathematics education, in order to understand how those who are marginalized (such as Black women) are able to navigate (and, in some ways, eliminate or transcend) these barriers. In this study, I explored the mathematical experiences of Black women hoping that it would offer to the literature some theories associated with their abilities to navigate the field. However, I believe a discussion about mathematics as a gatekeeper must include an explanation of who has the key to the gate and who is often left on

the outside. This leads to an examination of the literature presented on the underrepresented and underserved in mathematics education.

The underrepresented in mathematics

The literature presents many concerns about the importance of the inclusion of minorities and women in mathematics education (Finley, 2002; Hill et al., 2010; Kleinfeld, 1998; McCullough, 2011; Walters & McNeely, 2010). Women and minorities are both considered underrepresented and underserved populations. In 1989, the National Council of Teachers of Mathematics (NCTM) released a statement concerning the economic necessity of equity in within the field. In fact, there have been several large-scale initiatives taken to promote the inclusion of women and minorities, but it is also crucial to identify and understand the components of school programs with similar aims. As a component of this literature review, I examined such institutions and programs that have successfully promoted mathematics among the underrepresented and underserved. Examining such initiatives is important to my study, since the majority of the mathematical experiences I explored occurred at school.

While there has not been much research conducted on schools with successful mathematics programs, there is a large body of research focused on successful math teachers and the ways in which they have obtained success in their individual classrooms. According to Gutierrez (1999), the characteristics of a successful mathematics department that serves minority students or those from low socioeconomic status include "a rigorous and common curriculum, active commitment to students, commitment to a collective enterprise and innovative instructional practices" (p. 266). The most important of all these strategies, which was used to develop the success of the students within the mathematics department, was teacher collaboration (Gutierrez, 1999). As a part of this collaboration, teachers focused on building

meaningful relationships with students and understanding how students worked in mathematics. Though students needed only two years of the subject, the teachers have built relationships with them, and have encouraged a growing number to continue with Calculus, thus increasing the general success of the mathematics program.

Kennedy and Schumacher (2005) describe a three-year program developed to encourage women and minorities to continue to take upper-level mathematics courses in high school and pursue math-related degrees in college. This study took place in the high schools surrounding Bryant University in Smithfield, Rhode Island, and the participants were ninth graders enrolled in advanced mathematics courses. The schools' curricula were based on the Math Accelerating Professionals (MAP) Program.

In order to validate the data, the program proposed by Kennedy and Schumacher (2005) had various objectives each year. Year One's objectives were to:

> pair each high school with a local company in its town, design a preliminary mathematical teaching module associated with a business topic, initiate a college-student mentoring program with the local high schools, and provide opportunities for social interaction of all involved parties (p. 190).

Year Two of the program added "visits by professors to high school where they addressed the students" (Kennedy & Schumacher, 2005, p. 191). In the third year they included "a professional development day for the high school faculty members and a daylong enrichment program for the students" (Kennedy & Schumacher, 2005, p. 191).

The goals for the first two years were selected to show that the target enrollment was higher than the baseline enrollment. The goal from Years Two to Three was designed to increase the enrollment by at least 105% of the baseline. The last goal was to increase the number of

students taking Calculus or Pre-calculus prior to graduating high school. All goals were achieved, and the additional goal to have a few students decide to study upper-level mathematics was reached. With the assistance of a college and a well-organized program, one school was able to obtain some success in the area of mathematics by getting students excited about the subject. Within this program, the amount of teacher involvement as well as student commitment was a driving force behind the program being able to achieve all of its goals.

A similar program that demands high expectations of all students involved is the International Baccalaureate (IB) Program. Mayer (2008) conducted study of an IB program at a high school in California, investigating "how [an IB program] operated, who it served, if it were implemented according to the prescribed IB model, if it were impacting students' academic achievement and in fact sending students to 4-year universities" (p. 214). The Jefferson School had an open admission policy, which allowed anyone the opportunity to enter their IB program and be academically successful. Mayer concluded that, with "academic support, high levels of academic achievement can be fostered among students from diverse academic, socioeconomic, and ethnic backgrounds" (p. 209). The study also concluded that "successful AP and IB programs were characterized by teachers' beliefs in their students' abilities to meet the high expectations of the curricula as well as support mechanisms designed to foster positive peer support groups and college-oriented activities" (Mayer, 2008, p. 212).

In order to help students, who were not well prepared for the program, instructors and administrators implemented different types of scaffolding, included counseling, academic enrichment programs, and social supports. All of the guidelines of the IB program are followed through the implementation of the scaffolding, which allowed teachers to help their students meet the high level of expectation of the program. Although they may not be considered a

success in terms of scores, these programs were successful in allowing more minority students to take part in the IB program, which helped them feel successful, and gave some of them the encouragement they needed to pursue college educations.

Picucci and Sobel (2002) examined the strategies of three high schools in Texas that have increased the participation of minority students in their AP Calculus programs. They examined "the infrastructure of these programs, including their recruitment procedures, student and teacher support mechanisms, professional development efforts, curricular and instructional decisions, leadership and educative philosophies, and collaborative efforts within schools and districts" (p. 1). The schools that participated in the study had more than 4,000 students who resided in the district; the federal free or reduced lunch program was available to more than 40% of the population; and no magnet or alternative schools were included (Picucci & Sobel, 2002). In addition, of all Texas public high schools operating during the 1998-99 academic year, the chosen schools ranked in the 60th percentile or higher for the percentage of juniors and seniors taking AP Calculus (Picucci & Sobel, 2002). These schools' success was attributed to the different roles and responsibilities placed on all participating parties.

The district's role was to create a culture of high achievement by planning and collaborating to support high achievement, increase enrollment, increase the training of teachers, make sure the curriculum was aligned, and provide the needed resources to make the schools successful. The role of the outside agencies was to work with the district to recruit and prepare teachers as well as to recruit students. The teachers' role was to address their affective and academic needs. This included speaking to the students in a way to promote their future success and capability to excel in the advanced-level courses. The students' roles were to take initiative in deciding to take the advanced courses, and to maintain motivation to continue in them.

There were several recommendations for stakeholders, various policy makers, and teachers, some of which included knowing that minority students are able to be successful in advance mathematics courses and holding those students accountable for their own success. The teachers also needed time to prepare to teach those advanced mathematics courses and all prerequisites, which would be best accomplished through collaborative planning (Picucci & Sobel, 2002). One of the most important recommendations was to hold students to high expectations by setting standards for enrollment within those courses. All of these characteristics have been mirrored in a thorough search for successful mathematics programs conducted by Paek (2008).

In Paek's (2008) study, the three main goals were: 1) to increase the understanding of current successful programs for future use, 2) identify common themes used to improve the success of students, and 3) to provide research-supported evaluation methods. In order to address these goals, Paek (2008) found three major approaches that focused on the improvement of student learning and achievement as well as escalating teacher abilities within the mathematics classroom. These included "summer bridge programs, requiring and supporting more rigorous mathematics courses, and providing intense and ongoing support throughout the school day" (Paek, 2008, p. 89).

Highlighted summer bridge programs included the Academic Youth Development (AYD) Initiative and Step Up to High School (a Chicago Public Schools program). AYD presents material in preparation of Algebra I in various ways, including real-world applications. Step Up selects marginal students for participation and focuses mainly on building student-teacher and student-student relationships (Paek, 2008). Both programs were successful in helping the students build their confidence in their mathematics abilities.

Other practices included requiring the students to successfully complete certain courses prior to graduation. In order to make sure the students were able to accomplish the goal, vertical alignment of the curriculum was necessary. The El Paso Collaborative for Academic Excellence (EPCAE), Norfolk Public Schools in Norfolk, Virginia, and Grant High School in Portland, Oregon, have all instituted such programs in their schools (Paek, 2008). Eastside College Preparatory School in East Palo Alto, California, was noted for their high expectation of every student to take at least Pre-calculus prior to graduation. To help all students achieve this goal, tutorials were built into the school day, students met with academic advisors, and were offered courses to help them focus on reasoning and analytical skills. Other schools used project-based learning as a mathematics teaching method as well as to make sure that all students participated in an internship with the surrounding community. To build success in Algebra I, Evanston Township High school in Evanston, Illinois, has implemented daily support using small group work within the classroom, student aids, and morning tutorials.

Through the improvement of teacher participation at the district level, and in teachers' ability to instruct certain populations, districts were able to redefine the roles and responsibilities of mathematics teachers. Allowing teachers to receive more constructive feedback instead of judgmental evaluations has also allowed teachers to open their classrooms to those offering feedback, thus improving their own instruction. This openness was fundamental to the success of the program.

Peak's (2008) study presented several characteristics of a successful mathematics program at various schools across the country. The success of these programs was based on the implementation of programs that assessed the students with their level of achievement and helped teachers be better equipped to teach them. One of the most important factors is the

motivation of both the teacher and the student. Though the teachers have shown their motivation through their involvement in the additional programs, it takes the motivation of the student to take advantage of those opportunities.

Miller, Snow, and Lauer (2004) discussed that one of the major concerns with implantation of students programs for success in mathematics was motivation. Two colleges hosted programs for students in local high schools. As a part of these programs, the students were able to gain motivation in the area of mathematics and increased their success on various mathematics achievement tests. The methods used to increase motivation included mentoring and submersion in the college experience through the summer program. The students were also held to high expectations by the college faculty. Students met those high expectations with the support of the staff—yet another example of how student motivation and teachers' willingness to provide additional help led to the success of an advanced mathematics program.

Boaler's (2006) research was conducted on an urban high school in California that outperformed other schools in mathematics and reduced the achievements gap amongst minorities. This study followed groups of students from their first year to their senior year. In this study, teachers used different strategies that focused on equity in teaching. For example, all students at Railside High School were placed in the same class. There was no differentiation between the lower-level students and the advanced students as there were at the other schools. At Railside, students worked together on "complex conceptual problems," while the students at the two other schools followed a "traditional method" (Boaler, 2006).

Railside students had a variety of ways to feel successful, and therefore felt success more often. With this sense of accomplishment, they were motivated to work harder. For instance, teachers graded students in a variety of ways, some of which was conducted by group

observation. Teachers encouraged students to make sure everyone in their group understood the problems they were required to solve, and groups were graded on their discussions. At the beginning of the program, many of the high achievers did not want to spend their time helping the underachievers, but they soon realized that even the underachievers had valuable contributions to the interpretation and methods for solving the problems. Those so-called underachievers were motivated—as were all the students—to learn due to the high expectations placed on the class by the teacher as well as by each other. One of the other methods used to ensure student success was block scheduling. Aside from introductory algebra, which was taught over the course of the entire year, all courses were taught within one semester. By creating a block schedule, students were allowed more time to make up classes they previously failed as well as take more advanced mathematics courses if applicable.

Another major contributing factor to the success of the Railside program was the collaboration between the teachers within the mathematics department. Railside teachers had extremely high expectations for the students, and they held the students accountable for their own success. They also helped students meet those high expectations by making themselves available and respecting the students' personal lives. However, students had to make the choice to seize these valuable opportunities. Though some students may make the decision to attend more selective schools to help themselves become successful, the characteristics of a high school with a successful advanced mathematics program are based on the teachers' expectations and willingness to provide additional help as well as student motivation. Understanding these characteristics afforded me a place of reference for the mathematical experiences shared by my participants. However, before this literature review moves to focus exclusively on women, it will discuss the formation of mathematical identity as it is formed within mathematical experiences.

Mathematical Identity

Another important component in the exploration of Black women's experiences in mathematics is mathematical identity, of which there are various definitions. Anderson (2007) utilized Kirshner's enculturation metaphor of learning to "address how students' practices within a mathematics classroom community shape and are shaped by, students' sense of themselves, their identities" (p. 7). The participants of this study were high school students attending a small rural school. Half of the participants had decided to take accelerated elective math courses while the others did not take any math courses. Identity was described using four faces: engagement, imagination, alignment, and nature. In his findings, Anderson stated that the ways in which a student engaged with math, such as developing their own strategies and meaning for solving math problems, allowed students to view themselves as "capable members of the community engaged in mathematics learning" (p. 9). The image the participants had for themselves determined if they felt that they had a need for mathematics in the future. The future the students saw for themselves was also a component of their alignment. If they felt that they were going to college and that math was necessary for that endeavor, they would often take upper-level mathematics beyond the basic requirements. At the same time, however, the nature component of identity was composed of those abilities that the participants of this study felt they were given at birth, such as innate ability. According to this study, the nature component of identity "provides the most unsound and unfounded explanation for students' participation in the mathematics community" (p. 11).

Black, Williams, Hernandez-Martinez, Davis, Papaka, and Wake (2010) examined the mathematical identities of two students taking advanced mathematics courses. The two participants represent contrasting examples of "when troubles come, aspirations remain the same

and when trouble comes, aspiration adjust" (p. 59). Using narrative analysis along with cultural historical activity theory, the findings of this study suggest "the significance of a leading activity and leading identity in mediating one's position in alignment or misalignment with cultural models about mathematics and learning mathematics" (p. 59). The female's leading activity was becoming an engineer. The cultural models on which the participant drew were the usefulness of mathematics and its being fun and challenging as well as difficult. The participant was characterized as having a "positive disposition towards doing mathematics" (p. 63). Once this participant reached a point of struggle within statistics, she changed her cultural models and began viewing math as a "series of assessment tasks where one engages in strategies to maximize success" (p. 63).

Boaler and Greeno's (2000) study showed that the majority of the high school students participating in advanced mathematics courses who hated or disliked the subject were in traditionally taught classes as opposed to discussion-oriented classes. They contributed this lack of interest to the students' wanting to be able to "think, negotiate and understand the procedures they encountered" (p. 190).

Cobb, Gresalfi, and Hodge's (2009) study of identity utilized an interpretive scheme which includes the constructs of normative identity, which was established within the classroom as a doer of mathematics; and personal identity, which was developed through participation in classroom activities. This scheme was closely related to the school and intrapersonal levels of Martin's (2000) framework for mathematical identity. The interpretive scheme allowed for a relatively straightforward approach to relating the personal identities the students are developing to the culture of the classroom (Cobb et al., 2009). A sample of analysis using this framework was provided. The subjects of that study were 11 eighth-grade students in two math courses:

algebra and design experiment. In their findings, they noted students "viewed themselves as limited to exercising disciplinary agency" since "the students' primary obligation as they understood it in the algebra classroom was to produce correct answers by enacting prescribed methods on written notation" (p. 61). This view was in contrast to the students who were in a design experiment course in which they viewed their obligation as to "identify trends and patterns in data that give rise to insights into the phenomenon under investigation" (p. 62). These students seemed to understand what qualified as an acceptable solution, and viewed authority as shared within the classroom. Cobb et al.'s (2009) findings suggest that the development of personal identities by students "can be directly related to the classroom microculture that constitutes the immediate context of their mathematical development" (p. 64).

In Horn's (2008) work it was argued that mathematical identities extend beyond a single mathematics classroom or teacher. This study focused primarily on high school students and utilized a sociocultural framework to examine the persistence of students within their mathematical experiences. This study was sparked by an idea that "students who demonstrated shifts in their identities over their four years of high school might support an investigation between the social meaning of curriculum organization and students' mathematical identities" (p. 210). This study also focused on turnaround students, who were defined as "students who enter into high school underprepared to succeed in college preparatory mathematics yet manage to do so" (p. 230). One conclusion reached by this study was that positive identities could be attributed to a curriculum that supported a wider range of competent student performance. Another conclusion reached was that the resources available to the students made a difference in their abilities to develop positive mathematical identities.

Martin's (2000) study utilized the conceptual framework of mathematical identity as described by him while exploring the experiences of high school students. He found that African American students of high achievement in the area of mathematics demonstrated a "high level of achievement-oriented individual agency and bold defiance of the negative influences that surrounded them" (p. 123). The participants also "expressed high levels of confidence in their mathematical abilities" (p. 123), and considered the subject to be valuable. Although the participants were critical of their teachers, they did not allow what they perceived as the teachers' short-comings (i.e., boring lectures and/or classes that were too easy), to detract from the positive and appreciative views that they had for those teachers. Unfortunately, however, these students were also exposed to teasing and taunts from classmates concerning their academic success. Nevertheless, Martin (2000) leaves us with an important point to consider:

> If African American students develop strong academic identities that encourage high achievement, they may be motivated to do well in mathematics. If students draw strength from their success in mathematics, they may be motivated to do well in other subjects as well. (p. 125)

All of the studies previously presented focused primarily on high school students. The mathematical identities that these students had were a reflection of their classroom environments, including curriculum, teacher and peer support, as well as how they viewed themselves and their academic abilities.

McGee's (2015) study focused on the mathematical identities of high-achieving Black college students. Utilizing fragile and robust mathematical identity framework, McGee examined the mathematical identities and their approaches to this achievement as a way to "understand how these students made meaning of the racial bias in their mathematics participation over the

course of their schooling, including the K–12 years" (p. 606-607). The experiences described by the two participants of this study suggest that "racist experiences take place in the mathematics classroom, adding to the research on how school mathematics is used to perpetuate social inequities and how Black students navigate racialized spaces while achieving and maintaining success" (p. 620). The achievements of these participants included earning three master's degrees and a PhD in applied mathematics as well as earning a master's degree in bioengineering. The early motivations for both participants' success was based on the expectations of others, but later became more self-motivated. The identities of the participants fluctuated over time; in the face of a challenge to identity, their responses were more emotional when their identity was fragile, but more stable when they had a more robust identity. They both utilized various tactics to deal with racialized environments, including speaking out against injustice and using their current position to help other students achieve success.

Up to this point, I have discussed the role that mathematics has and continues to play as a gatekeeper, as well as the way in which schools are able to serve the underrepresented and underserved in mathematics education. This leads the discussion to mathematic identity, and in order to shift towards the focus of this study, I now focus specifically on women. In the following section, I will explore several question including: how do women make their way in a system that is used as a separation criterion, which typically results in their exclusion and what obstacles must women overcome, and what are their strategies for success?

Women in Academia

Before examining the literature specifically on Black women, it was important to look at what the literature had to say about women who were either in pursuit of or have obtained a graduate degree in order to gain some insight into those experiences and how they may differ

between women. Mountford-Zimdars and Sabbagh (2013) discussed the many obstacles presented to those who decided to enter graduate school. Some of the issues included the admission process, social constructs determining access and experience, and the higher educational system in its entirety. These issues were seen as important to the graduate school experience and, according to this study, they specifically resulted in fewer women being enrolled in graduate school.

Other studies of women in graduate school focus on issues associated with parenting as graduate students. Springer, Parker, and Leviten-Reid (2009) discussed the limited knowledge about and access to parental support in graduate school. They conducted a survey of sociology graduate departments at the top 63 Sociology Programs in the US in order to find out "what supports were available to graduate student parents, both at the departmental and institutional (campus-wide) level" (p. 440). The findings suggested "there are few formal institutional supports tailored to the needs of graduate student parents [and] there is limited knowledge on the part of faculty regarding supports that may exist for graduate students with children" (p. 441). This lack of support could also be seen by the limited resources available to parents—including the lack of lactation rooms and changing tables—that made it appear that children were not welcomed on campus. The findings also suggested that women who decided to have children during graduate school might find the decision harmful to their careers. The harm that was discussed included a lack of tenure-track positions offered to women who decided to have children, as well as a lack of those in tenure-track positions being able to obtain tenure after becoming parents (Springer et al., 2009).

Elg and Jonnergard (2010) also studied women in graduate school; specifically, 12 female PhD students at a Swedish university. They examined the women's struggles to graduate

and become established within their departments. Using institutional theory and gender research on organization and academia, Elg and Jonnergard (2010) wanted to "increase the understanding of how forces on different levels interact as women try to establish themselves in academia" (p. 210). Their findings suggest, “that graduated female PhDs may be more often forced to change employers, have fewer career alternatives and have less support from prevailing formal and informal organisational structures” (p. 222).

As noted in Fotaki's (2013) study of women in the academy, “feminist sociologists were the first to identify institutional factors in universities as an extension of social structures of patriarchy and the root cause of women's unequal treatment in higher education" (p. 1255). Fotaki’s (2013) goal was "to better understand the position of woman as non-place in academia... [and] ...to examine how external events may be reproduced in subjects themselves and become parts of their identities as female academics" (p. 1256). There were 23 women interviewed for the study from nine UK management and business schools. The findings of the study included "respondents feeling like an outsider in their institutions because of unfair allocation of work, lack of progression, exclusion from pre-existing networks or because they often felt unwelcomed and undermined, silenced or objectified in such settings" (p. 1262). Other findings suggested that “experience[s] of overt discrimination and/or marginalization caused many interviewees to doubt themselves, feel depressed, disempowered, ‘emotionally battered,’ ‘paralyzed,’ and ‘very threatened’" (p. 1267). Fotaki's (2013) study made many contributions, including those "concerning women's (maternal) body and materiality at work," methods to "help us understand how norms in academe operate to reinforce existing power relations," and, lastly, the linking of

> The stories of women feeling silences and being treated as immanent to their bodies with how these stories become inscribed in their accounts of themselves and ultimately in their psyches where they worked on women and are then reiterated and reproduced. (p. 1271)

Fotaki was careful to mention that the issues women faced were not new, and simply trying to eradicate the inequality without looking at who is producing knowledge acceptable to the academy would be inadequate. They argued that there must be more emphasis placed on the male-dominated conceptions of knowledge and the need to change that conception.

According to the presented literature, women in academia face many issues, including biases to entering graduate school, parenting as a graduate student and/or faculty member, and issues of graduating from a graduate program. They also presented findings that suggest additional areas of concern related to finding employment, gendered knowledge, and strategies for infiltrating academic barriers. Additionally, issues of unequal pay and promotion within the academy were also presented. Women who decide to be a part of the academy have numerous obstacles to overcome; however, a few have been able to transcend these barriers and enter the academic arena. It is important to note the many obstacles women have faced when entering more specialized and male-dominated fields in the academy, from both a student's point of view as well as from members of the academy. More specifically, women in STEM may have their own set of obstacles and challenges that include these issues, and possibly others.

Women in STEM

In an effort to narrow such a broad topic, the focus will now shift to women in STEM fields. As in the case with women in academia, many individuals—particularly minorities and women—have experienced hurdles to entering STEM fields (Gorman, Durmowicz, Roskes, & Slattery, 2010). This section will include literature with the focal point of women in STEM and

the obstacles they often face in their fields. The literature review now shifts to include gender comparison studies (Smeding, 2012), the societal effects on STEM involvement on women (Eccles, 2011), and the effects of policy on increasing women's participation in STEM fields (Walters & McNeely, 2010).

McCullough (2011) concluded that there must be even more hurdles for women to jump through when entering STEM leadership fields. Some of the problems they have faced include "implicit biases and discrimination, family obligations, and the lack of role models and mentors" (p. 8). Due to the limited number of people who are interested in STEM fields, women are vitally important. Consequently, the US cannot afford to turn away talented and interested women. However, the need for women goes beyond merely increasing numbers; there is a need for leaders and role models for future generations of women in STEM (McCullough, 2011).

There is also research that examined women pursuing graduate degrees. More specifically, a study conducted by Smeding (2012) explored women in graduate school by comparing the gender stereotypes of female humanity students to those of engineering students. The study also examined how these stereotypes related to math performance. Smeding's findings suggested that one explanation for the success of women in spite of the stereotypes is that STEM women have a weaker implicit stereotype than both humanities women as well as engineering and humanities men. Having a weaker implicit stereotype indicates that these women bring less unconscious attributions of particular qualities to members of either group.

Eccles (2011) created a theoretical model to study women in mathematics. Part of the model proposed that researchers view women in mathematics as assets as opposed to a deficits, and they examined both social/cultural structures and personal agency as contributors to this choice. Although Eccles (2011) and her colleagues emphasized the reasons for which minorities

and women were less likely to enter STEM fields in comparison to White males and Asians, by not discounting the role that social class as well as other structures play in determining the range of options presented.

Gorman et al. (2010) asked: "what can be done to encourage, enable and empower women to engage and be successful in the STEM disciplines?" (p. 2). In their research, they used case studies to examine an institution in hopes of finding out "what works" to create success for women in STEM majors. One of the many aspects of the university culture that contributed to the success of the students was mentoring. They studied a team of women mentors who developed many of the initiatives that allowed the school to reach success with limited resources. They also studied other pivotal components of "what works": mentorship leaders, faculty, students, high schools, and middle schools—all of which created a mentoring web that greatly contributed to student success, according to the researchers.

Walters and McNeely (2010) examined the issue of the disproportionate number of women represented in STEM fields within academia. They also discussed the enforcement of Title IX to help eliminate this gender bias. In general, Title IX "bans gender discrimination in educational institutions that receive federal funds" (p. 318). The authors choose to focus on a variety of categories related to the limited number of women in STEM areas within academia and the regulatory language within Title IX that helped combat areas of discrimination, including compensation, hiring, promotion, pregnancy and care of dependents, work environment/support, and sexual harassment. While the authors do not assume that this one law is the solution to gender inequality in academia, they consider Title IX's implementation as a step in the right direction.

In countries such as Nigeria, the need for women in STM (Science, Technology and Mathematics) has caused major changes in entrance requirements for such programs. According to Aguele, Idialu, and Aluede (2008) a nation's success is built upon women (who make up more than half of the Nigerian population) who are able to make meaningful advancements in these areas. For this reason, they decided to alter the cut score for entrance into their STM track to allow more women to be included in those programs.

These studies show that there are many obstacles for women in STEM. Although many stated the problems women face in the field, such as various biases and discrimination, lack of role models, and gender stereotypes, some of them also discussed possible solutions, such as mentoring, Title IX enforcement, and appropriate decision-making to advance the inclusion of women in STEM fields. It is now appropriate to examine studies of women in mathematics to see if there have been particular issues identified for women in mathematics. This is important because success in mathematics is necessary for success in any STEM field; in fact, mathematics is often the gateway course that opens the world of STEM to women.

Women in Mathematics

A desire for a sense of belonging and clear institutional practices were common themes throughout the present literature concerning women in mathematics. Although they are often successful in mathematical sciences, women sometimes see themselves as either not belonging in the field, or view belonging in the field as a threat to their femininity (Solomon, 2012). Some women carefully examine their identity when deciding to pursue mathematics due to the idea that mathematics is a male-dominated field. Some have even claimed that this has led to women deciding on invisibility as a way of protecting themselves (Solomon, 2012). For example, Solomon's (2012) study, which consists of interviews conducted with undergraduate students in

the UK, explores "the role of reflexivity in the figured world of mathematics and the identity spaces that it affords by considering voices of challenge and critique in terms of the part they play in heteroglossic self-narratives" (p. 181). The two interviews were analyzed using separate narratives, and each narrative focused on the "storying of self in terms of time and critical events and reflexive responses to those events" (Solomon, 2012, p. 177). Findings about one of the participants in the study suggest that "competitiveness, isolation, and group work for mutual support" (Solomon, 2012, p. 179) fill the world of undergraduate mathematics for women. Findings from the second participant "[draw] on discourses about mathematics as gendered and ... [the struggles with] separating out brain from body and providing her with a picture of herself as a female mathematician" (Solomon, 2012, p. 181). One limitation of the study was Solomon's role "as a researcher of mathematics education," which made him "a potential addressee with views that might be anticipated" (2012, p. 177). However, this work showed the various dynamics that women in math must navigate relating to gender and self as obstacles and groups as modes support.

Good, Rattan, and Dweck (2012) explored some of the reasons behind women opting out of mathematics by testing the two hypothesis. The first was "that both men's and women's feelings of membership and acceptance in the math domain—their sense of belonging—can predict their desire to pursue math in the future (p. 700). The second hypothesis was:

> that two messages students may hear in their math environments (the message that math ability is a fixed trait and the stereotype that women have less of this ability than men) may be critical factors that work together to erode women's, but not men's, sense that they belong in math and, hence, their desire to pursue math in the future. (p. 700)

After looking at the gender gap in the number of female faculty in science departments, Good et al. (2012) argued that women lacked the "desire to pursue math-based disciplines" (p. 700). The field of psychology suggests, “the desire to pursue a given course of study can be highly unstable and greatly influenced by environmental factors" (p. 700). The participants were all very high-achievers in mathematics, but the results suggest that the more a person reported a "sense of belonging in math, the more they reported an intention to pursue math in the future" (p. 708). As the sense of belonging in math increased, there were fewer reports of anxiety among the participants of the study. The increase in math belonging also resulted in a stronger belief in the math’s usefulness, as well as a stronger confidence in a participant’s mathematical abilities.

Solomon, Lawson, and Croft (2011) stated that "gender discourses and institutional practices interact to constrain the range of identities that are available to mathematics learners such that girls appear to lack a niche in this particular world" (p. 565). This study examined issues among women mathematics undergraduates who have resisted this notion of identities in the traditional way and challenged what it means to be women in the field. The particular issues they chose to examine were relationships with tutors, gendered roles in the learning context, and legitimacy and understanding. Parts of their study’s findings suggest that women frequently have negative experiences with university mathematics, including failed attempts to receive help from instructors and tutors. In the study, female students responded more negatively than men to questions that were posed therein, and when interviewed they gave examples of the negative experiences they had with instructors or tutors.

On the other hand, Solomon et al.’s (2011) findings also suggested that some women are successful in mathematics without identifying with the masculine norms of the discipline. Those norms included boys who acted as if they were equal to the teacher (as evidenced by the kinds of

questions they pose as well as their willingness to respond when asked questions). Boys are also viewed as more willing to take chances in the classroom, including questioning the teachers and causing interruptions. There also appears to be fewer negative consequences for such behavior; in some cases, rewards for those whom question the teacher and cause interruptions are given. The participants of the study challenged this status quo of masculinity in mathematics, but were still able to analyze critically their situations. Additionally, the participants credited their relationships with tutors as integral to their mathematical confidence and success.

The studies that represent this literature review represent women in the contexts of the academy, STEM, and specifically mathematics. As the research focus shifts to Black women, it is necessary to understand the significance of this particular group. Black women face a unique set of obstacles based not only on gender, but also on race and/or ethnicity. As an integral part of my study, it was important to review literature that focuses on this dichotomy. For the purposes of this study, the term "Black woman" will include any woman from the African Diaspora as well as any woman who self-identifies as Black.

Examining the stories of Black women from their own perspectives in order to explore the experiences that influence their academic achievement could allow for the possibility of improving others' academic achievement in mathematics. In particular, when examining STEM fields and classrooms, there needs to be more research on the factors that contribute to Black women's deciding to pursue mathematical fields on all levels, including undergraduate and graduate study, as well as faculty positions (Johnson, 2011). The literature in this chapter will now examine Black women in the academy, Black women in STEM, and Black women in mathematics.

Black Women in the Academy

When exploring the mathematical experiences of Black women in doctoral programs, it was helpful to have an understanding of Black women's experiences in various positions within academia. There are many avenues one can take when examining this particular group of women, one of which is to study those who have been able to achieve academic success.

There are indeed several definitions of success offered from research conducted on Black women. Although not explicitly stated, the majority of the definitions examine success from an academic point of view. In a study conducted with six Black female faculty members, the women defined success as publication, giving back, and undertaking a journey (Edwards, Beverly, & Alexander-Snow, 2011). Understanding this journey or the experiences that led to this success further illustrates the need for this study.

One study about a Black female scholar who was the first non-White woman in her college's 100-year history to serve as both a department chair and the associate dean found that her success encompassed more than her positions. As the participant of the study states, "my success isn't because of just who I am, but because of what I've done, what I've studied, and what I've been able to internalize" (Dowdy & Hamilton, 2011, p. 200). From the point of view of this female scholar, her success includes the many experiences in her journey to success—a fact that further emphasizes the necessity for understanding more about the experiences of the participants in my study and what has gotten them to this point in their lives.

Gosine (2012) has defined successful Blacks as "those who hold an occupation or position that requires university qualifications and [are] financially lucrative and/or socially constructed as prestigious within the context of Western society, or those currently pursuing

university credentials" (p. 709). Gosine's work examined the historical disconnect between antiracism education and successful, highly educated and upwardly mobile Black North Americans (Gosine, 2012). The results of this study seem to place much of the responsibility for that disconnect on a lack of research on successful middle-class Blacks, and therefore seems to support the study I conducted. The results of my study can add to the limited body of literature about Black women considered as highly successful and the experiences that led them to success.

Sharpe and Swinton's (2012) findings suggest that "Black women earn twice as many degrees as Black men and that younger Black female professors seem to face fewer barriers to success in the academy than their predecessors" (p. 341). Since Black women are beginning to gain more success in academic achievements, there needs to be a greater understanding of what accounts for their advancement. Gaining this understanding requires a focus on research where Black women are centered and their experiences are shared from their own perspectives. Although none of the studies presented focus specifically on Black women in mathematics education, I was able to gain some insight on the importance of experiences in relation to academic success. Furthermore, this review exposed a need for more research in this area, as well as the need for a focus on Black women. The literature presented thus far, supported the purpose of this study and the dearth of research on the experiences of Black women in mathematics education.

Factors that Contribute to Achievement for a Black Woman in Academia

There are general overlapping factors of academic achievement in the research on Black women in academia, and they include: institutional and organizational climates, scholarship and research agendas, rules that govern the academy, and professional mentoring (Generett & Cozart, 2011). Dowdy and Hamilton (2011) found that these attributes also included not allowing

negative feelings of isolation to deter their participants from their positions within the academy. Removing feelings of isolation can happen through mentoring programs and by having someone who may have faced similar obstacles to guide you through the process.

Mentoring is a concept that appears in many of the studies on Black women (Agosto & Karanxha, 2011; Croom & Patton, 2011; Dowdy & Hamilton, 2011; Edwards, et al., 2011; Grant, 2012; Mawhinney, 2011; Noy & Ray, 2012; Tillman, 2012). In a study of mentoring Black female doctoral candidates in educational leadership, Grant (2012) explains the importance of mentoring by using their narratives. The women claim that, in addition to mentoring, "other components such as nurturing, mothering, and cultural relevancy (same sex/race mentoring), as well as sister/friend (peer mentoring), roles" were necessary and useful to the participants (p. 109). Mawhinney (2011), who focused on othermothering, explored other factors related to mentoring. It was Mawhinney's belief that expectations from faculty members who participated in othermothering led students to achieve academic success. Othermothering is a concept that grew out of slavery, wherein orphaned children on plantations were cared for by other women or men. Black teachers often continue this tradition by "mothering the minds" of their Black students (p. 191). From the literature, it is clear that mentoring has been a key component to achievement for both faculty and students. Because the experiences of mentoring contribute to the success of many Black women, it was important to confirm whether these similar mentoring experiences contributed to students in their pursuit of a doctorate degree in mathematics education.

Overcoming Obstacles

As the significance of the study suggested, I not only wanted to document and present these experiences as a way to encourage others, but to identify present obstacles and some

strategies for navigating them. Agosto and Karanxha (2011) identified four types of resistance that were offered by critical race theory (CRT): "(a) reactionary behavior, (b) self-defeating resistance, (c) conformist resistance, and (d) transformational resistance that is internal or external" (p. 46). According to them, CRT is useful in education to:

> (a) name and discuss the pervasive, daily reality of racism in US society; (b) expose and deconstruct seemingly 'colorblind' or 'race neutral' policies and practices; (c) legitimize and promote the voices and narratives of non-White people as sources of critique of the dominant social order; (d) revisit civil rights law and liberalism to address their inability to dismantle and expunge discriminatory socio-political relationships; and (e) change and improve challenges to race neutral and multicultural movements in education. (p. 43)

Croom and Patton (2011) proclaimed that persistence and resistance are contributing components for Black women's overcoming these obstacles and garnering success. They also explain the use of both CRT and critical race feminism (CRF) to explore the personal and professional meaning of attaining a full professor status for Black women. "Moreover, it explained how "counter storytelling can be useful in centering the voices of Black women who have not been awarded full professor status, or have otherwise decided to forego pursuing full professor status" (p. 30). Turner, Gonzalez, and Wong (2011) used both CRT and CRF to focus on "race, racism and power … issues of concern to women of color" (p. 201). By using these frameworks, the researchers were able to "make visible the complicated discourses that women of color faculty negotiated with White faculty, discourses that normalized Whiteness as an invisible norm and standard" (p. 209).

Researchers in the literature used Black feminist thought (BFT) to discuss the lived experiences of Black female doctoral students. The lived experiences of Black female doctoral

students was discussed using Black feminist thought (BFT). Hamilton (2003) stated that when "applied to higher education, BFT is important in assisting African American female doctoral students to effectively deal with the wide array of micro aggressive indignities (i.e. racist attitudes and behaviors) encountered in their daily campus experiences" (as cited in Grant, 2012, p. 105). Noy and Ray (2012) used intersectionality as a framework for examining how gender and race affect the treatment graduate students receive from their faculty advisors. According to them, "Given research about the challenges students of color and women face, intersectionality suggests that raced and gendered experiences in graduate school may be multiplicative" (Noy and Ray, 2012, p. 885). These findings indicate that, not only do Black women have to face issues of race, but those issues are multiplied by additional dimension of gender. While the existing theories have their differences, they all focus on giving women an opportunity to have their stories told in a way that honors the participants and refutes the adopted deficient notions in some literature in an attempt to explain Black people's experiences in education.

In terms of the approaches used to study successful Black women, many were centered on the women's abilities to speak to their own successes by narrating their own stories. For this reasons, theories like CRT, CRF, BFT, and intersectionality were used to frame these studies. This particular study focused specifically on the mathematical experiences of Black women in mathematics education, but it is also necessary to examine Black women in STEM due to the connection between mathematical experiences and the decision to pursue careers in STEM fields.

Black Women in STEM

According to Hernandez, Woodcock, Schultz, Estrada, and Chance (2013) in order for students to advance in STEM majors, they must have optimal motivation, which the researchers

described as requiring a person to have both a personal interest in the content presented in the course as well as being able to focus on what would be covered on examinations. If a person had just one component, they would be unable to achieve the optimal level of motivation that would lead to long-term academic achievement (Hernandez, et al., 2013).

Museus (2010) identified individual persistence as a key factor to obtaining success in STEM. This persistence was related to the campus environment: "To increase URM [underrepresented minorities], student persistence, and degree attainment rates in STEM fields, college and university leaders must better understand the various ways in which they can cultivate campus environments conducive to success" (p. 18). He also noted that liberal arts colleges and HBCUs might be more equipped to foster the type of environment needed for URM to obtain degrees in STEM fields. This was further studied by Perna, Gasman, Gary, Lundy-Wagner, and Drezner's (2010) case study of Black female STEM majors attending an HBCU. They found that both institutional practices as well past success within those institutions affected the obtainment of STEM degrees by Black women. This supported the need for more research on the mathematical experiences of Black women in pursuit of doctoral degrees in mathematical education.

Overcoming Obstacles in STEM

One of the major obstacles to success in STEM fields for Black women was the sense of belonging either to the institution at which they were studying or as members of the STEM field (Hernandez, et al., 2013; Johnson, 2012; Perna, et al., 2010). Ong, Wright, Espinosa, and Orfield (2011) defined the "double bind" affect as "the unique challenges minority women faced as they simultaneously experienced sexism and racism in their STEM careers" (p. 175). Johnson (2011) elaborated on the "double bind" affect by stating that:

> As a result of being in both the racial and ethnic and the gender minority groups, women of color experienced isolation from peers and a lack of support from faculty, while various socio-cultural factors influenced the ways women of color negotiated the culture, values, and practices in the sciences" (p. 80).

This study exposed the ways in which the mathematical experiences of Black women have allowed them to negotiate the culture values and practices associated with mathematics.

To help overcome the obstacle of not having a sense of belonging, several studies presented strategies and programs. From the K-12 level programs such as the Pre-engineering Program at the University of Akron, the Detroit Area Pre-College Engineering Program, and Say YES to a Youngster's Future were each offered as examples of programs that were successful in promoting STEM to K-12 minority students (Edwards et al., 2011). Another program offered at the undergraduate level was the living learning program (L/L). The study conducted by Soldner, Rowan-Kenyon, Kurotsuchi Inkelas, Garvey, and Robbins (2012) suggests "STEM-focused L/Ls may be one useful intervention in the promotion of student success, and that understanding their underlying mechanisms of action may lead practitioners to other ways they can act to bolster STEM degree production" (p. 331). On an individual level, the student must find ways to be persistent to obtain success; however, "peers and faculty are pivotal to persistence" (Harper, 2010, p. 71). This study offers more evidence to determine the types of strategies utilized by Black women in pursuit of a doctoral degree in mathematics education and in turn offers support for similar programs in the future.

Discussion of Theories for Achievements of Black Women in STEM

Researchers like Hernandez, et al. (2013), Johnson (2012), Soldner, et al. (2012) and Harper (2010) used several theories to study the achievements of Black women in STEM fields.

Some of these included goal theory, social cognitive career theory, and transformative research (Hernandez, et al., 2013; Johnson, 2012; Soldner, et al., 2012). Harper's (2010) report introduced the anti-deficit achievement model as a way to study successful Black students in STEM:

> Instead of relying on existing theories and conceptual models to repeatedly examine deficits, researchers using this framework should deliberately attempt to discover how some students of color have managed to succeed in STEM. The anti-deficit achievement framework is informed by the theories from psychology, sociology, and education, each of which can be explored in an *instead-of* fashion. (p. 68)

Successful Black Women in Mathematics

Kleinfeld (1998) pointed out that women out-perform men in many areas except for science and mathematics. A 1992 report issued by the American Association of University Women entitled "How Schools Shortchange Girls" disturbed her. According to Kleinfeld, although men outperformed women in the area of mathematics and received far more doctoral degrees in that area, the gap was indeed closing. Kleinfeld noted that more young women were taking advanced mathematical courses in science and mathematics as well as taking more Advanced Placement courses in both areas. Though I am not sure I would agree with most of Kleinfeld's comments about the existing gaps, it is important to note that, as she has pointed out, the gaps are narrowing.

Manzo's (1994) article about success for African American women receiving PhDs in the area of mathematics comments on the stories of Dr. Linda Hayden, her mentor, and students that she herself mentored. Most of the students who were in the PhD program remembered being influenced as young children to obtain such a prestigious degree; nevertheless, some of the students remarked that support and encouragement of their advisors is the reason they were able

to complete such a difficult program (Manzo, 1994). As Hayden pointed out, while there are safety nets for students in the PhD program, the program remained "rigorous" (Manzo, 1994).

Gabrielle Finley's (2002) article about four African American women who earned PhDs from Howard University in 2002 includes Dr. Naiomi Cameron, who credited the beginning of her interest in mathematics to being placed in Algebra I in the sixth grade, making her one of the youngest in her class. She also credits her success in the program to the supportive faculty at Howard University. Dr. Lynnell Matthews also states that her interest in the subject began at an early age, and with the encouragement of one teacher, she decided that math would be her college major. While at Howard, she found the support of the faculty and her classmates as the key to her successfully completing the program. Drs. Jillian McLeod and Iris Moche believe that a support system of some type is needed to be successful in this male-dominated arena (Finley, 2002).

This study focuses specifically on Black women within the mathematics education field. Although there have recently been more studies on the success of Blacks within the field of mathematics (Ellington & Frederick, 2010; Foote & Gau Bartell, 2011; Herzig, 2010; McGee & Martin, 2011), these studies have focused on the successes of Black women in mathematics education as opposed to studying any deficits. By examining the success of these individuals, the authors are offering counternarratives to the so-called dominant narrative of mathematical deficiencies for Blacks. Borum and Walker (2012) studied the experiences of Black women with PhDs in mathematics. Their findings suggest that mentorship, a supportive program, and study groups were instrumental to the success of these women in their doctoral studies. Ellington and Frederick's (2010) study included Black junior and senior level college mathematics majors.

Their participants credited their successes in mathematics to advanced coursework, accelerated academic programs, and family, peers, and teachers.

Factors That Contribute to the Achievement of Black Women in Mathematics

As seen throughout the research on successful Black women, there are many contributing factors. Ellington and Frederick (2010) found that such factors "converge around family experiences, school experiences, [the] role[s] of participants, and [the] role[s] of the larger community" (p. 67). One of the factors involved in school experiences that emerged from the participants in the study were that the "majority of these students [had] access to accelerated programs [that] occurred in the third grade" (p. 76). A component of the larger community's role was a sense of belonging at the institutions in which the students attended. As Herzig (2010) referenced, "It has been argued that students' integration into the academic and social communities of their departments and programs is critical for their persistence in graduate study; further supporting the importance of developing a sense of belonging in graduate mathematics" (p. 199). The participants in Herzig's study had three major themes that emerged concerning belonging to the community of graduate mathematics. These themes were: "the importance of having and being role models, the challenges they felt 'fitting in,' and their unwillingness or inability to focus on mathematics to the exclusion of all else" (p. 185). Foote and Bartell's (2011) study on emerging scholars in mathematics education found that the following themes were consistent in their works on equity and diversity: "being the 'other,' 'bearing witness' to othering experiences, and 'orienting' experiences" (p. 63). This study focused specifically on Black women in mathematics education. As indicated, their factors for success mainly centered on their experiences. These factors for success supported the need for more studies on Black women and their experiences in mathematics education. One avenue utilized to frame this study conceptually

was the participants' motivation to pursue this course of study. This leads us to an examination of achievement motivation.

Achievement Motivation

One construct of motivation used to guide this study was achievement motivation. Murray (1938) was one of the first researchers to write about achievement motivation, and he included three important factors in its definition: "a need for achievement, an approach motive, and infavoidance (the avoidance motive)" (as cited in Schatt, 2011, p. 2). Achievement motivation emerged from a redefinition of drive or degree of motivation, and Busato, Prins, Elshout, and Hamaker (2000) define it as "the striving tendency towards success with the associated positive effects and towards the avoidance of failure and the associated negative effects" (p. 1058). Al-Shabatat, Ahmad, and Nizam (2011) have defined achievement motivation in terms of an individual difference; in other words, it is "an individual's tendency to desire and work towards accomplishing challenging personal and professional goals" (p. 99).

Other factors linked to influencing achievement motivation include personality factors, situational factors, and goals. Personality factors include persistence, the ability to delay gratification, and competitiveness. Situational factors include the expectation of success, incentives, control, and opportunity. Goals also play a crucial part in achievement motivation, but those goals must be specific and challenging, but also achievable and positive. These goals also reflect a belief that success is gained by improving one's abilities through hard work and applying great effort to the task at hand (Watabe & Hibbard, 2014). Comprehensive though it may be, there are still many flaws with this theory of motivation; for example, it is difficult to link all of the possible factors together, and there are no specifications for cross-cultural use (Al-Shabatat, et al., 2011).

Conclusion

My research was limited to Black women in pursuit of a doctorate degree in mathematics education and their mathematical experiences. The purpose of this study was to explore Black women's perspectives on how their mathematical experiences influenced their decisions to pursue a doctoral degree in mathematics education. The empirical, qualitative study conducted focuses on seven Black women who are currently in pursuit of a doctoral degree in mathematics education. While there is limited literature that focuses primarily on Black women in mathematics education, the results of this study offer mathematicians and mathematics educators an opportunity to gain more insight into the perspectives of Black women who are pursuing PhDs in the field. This literature review provided an overview of what has been studied, but also demonstrated the need for more research on Black women in mathematics education.

3 METHODOLOGY

The purpose of this study was to explore Black women's perspectives on the ways in which their mathematical experiences influenced their decisions to pursue doctoral degrees in mathematics education. The questions framing this study were:

1. What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences?
2. How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?

In this chapter, I provide an overview of the assumptions incorporated in the research by use of a qualitative interview study. I go on to provide an explanation for the use of grounded theory methodologies as a form of analysis. Next, I explain methods of data collection and analysis. Finally, I discuss issues related to credibility and the limitations of the study.

The main goal in constructivist grounded theory is to understand the meaning behind human behavior, and for this interview study, constructivist grounded theory methodologies were used. This study also utilized qualitative interviews as a means of "understanding experiences and reconstructing events" (Rubin & Rubin, 2004, p. 3). The need for this type of in-depth interviewing was necessitated by the purpose of this study, to explore the experiences of the participants (Rubin & Rubin, 2004). By using constructivist grounded theory methodology during the data collection and analysis process, I was able to begin with the stories of Black women in mathematics education gathered through investigative interviews, and allow what is relevant to the mathematical experiences of Black women in mathematics education to emerge (Charmaz, 2006). To describe the mathematical experiences of Black women in pursuit of a doctorate of philosophy degree in mathematics education and how those experiences influenced

their decision to pursue it, a constructivist grounded theory approach to the data collection and analysis was used.

Grounded theory

Constructivist grounded theory emphasizes the phenomena a study is hoping to explore while taking into account the ways in which the participants' shared experiences and relationships influence data collection and analysis. The methods used in constructivist grounded theory include familiarizing oneself with the data, identifying codes and engaging in the process of constant comparison, the use of open coding, the development of hypotheses, and simultaneously collecting more data that clearly address the research questions (Charmaz, 2006). Using a constructivist approach allowed me to explore how the mathematical experiences of Black women influenced their decisions to pursue a doctoral degree in mathematics education by using not only my understanding of the experiences of these Black women, but also taking into account the multiple aspects surrounding these experiences. While utilizing a constructivist grounded theory approach to this study, I took into consideration my own preconceived ideas. As a researcher, I took into consideration my own presuppositions as a Black woman in pursuit of a PhD in mathematics education, and reflected on how they affected my research in all aspects. This included how I interviewed the participants and my preexisting assumptions about what led them to pursue PhDs in mathematics education.

Researcher's Role

When utilizing a grounded theory approach, it is important to understand how the expectations and values of the researcher influence the conclusions made about the study (Charmaz, 2006). I describe myself as a Black woman who was enrolled in a PhD program in the area of mathematics education. I have worked as a secondary mathematics educator for the last

12 years, and my undergraduate background is in mathematics. My hope was that my background would help make my participants more comfortable with me and allow them to be more open about their mathematical experiences. One component of constructivist grounded theory is the importance of acknowledging the subjectivity of the researcher without trying to eliminate it (Charmaz, 2006). I utilized the bracketing interview technique, which allowed me to determine my subjectivity. Rolls and Relf (2006) argue that the value of bracketing interviews is that "unconscious agenda can best be made visible and considered" (p. 301).

Through bracketing interviewing (2006), I was interviewed using the same prompts I intended to use with the participants. This process allowed me to illuminate any preconceived notions or biases I brought to the interviews. It also helped me engage in constant comparison through the revision of the initial interview questions and techniques, which allowed for interviews that are more conversational. As I examined my subjectivity, I became more aware of my connection to these subjects. Although the participants' stories are not an exact mirror image of mine, my story is not separate from theirs. In fact, I was able to use my experiences to help my participants identify with me. Their ability to identify with me allowed them to be more comfortable telling their stories to me.

I was not very confident in mathematics early in my academic career. I recall struggling with my times tables during the 3rd grade as well as having several disciplinary issues throughout my early elementary school years. It was not until I was tested and designated as gifted in the 5th grade that this story began to change. I still had issues with discipline in courses such as my 7th grade science course, but overall I was able to excel academically. I also developed an interest in music by participating in the band during my middle school years. My interest in music

continued throughout high school. Due to my gifted classification, I was able to take algebra in the eighth grade as well as participate in other social studies electives.

After the eighth grade, I continued on an accelerated math track throughout high school. I also applied for and attended a highly selective magnet program that focused on international relations. My high school was extremely diverse, I had classmates from all over the world, and yet I did not feel out of place, since the magnet program was relatively small, and I took all of my non-elective courses with the same students. Though we moved often during my childhood, I was typically able to stay in the same schools. However, this changed once I entered the 10th grade. My parents gave me the opportunity to move out of state. Aside from math, I was struggling in all of my classes, so I made the decision to move, in part, out of a fear of failure. Once I moved, I immediately noticed a change in demographics. Although all of my classes were still advanced and accelerated, they were now filled with Black students (with the exception of one White male student and the two female Hispanic students).

Once I moved, I was able to excel in my advanced courses, mainly because they were a review of materials that I had already covered in my previous school. I had always had to work for my grades, but in this new environment, I performed somewhat better. I received A's and B's in my math classes. Math was never easy to me, but it was always something I felt capable of doing. During my senior year, I was fortunate enough to participate in a dual enrollment program for Calculus because my current schedule would not allow me to take AP Calculus at my high school. That was my first taste of college, and I was lost. Though I was able to make a C in the course (a grade that would transfer to any local college) I understood very little in the course.

Once I entered college, I decided to retake this Calculus course, and found that I was finally able to grasp the concepts. However, the A I received was my only A that semester, so I

continued taking more math courses, and by the end of my sophomore year I had officially decided to major in mathematics. I also decided to take a few education courses as a backup, since I was not sure what I could do with a mathematics degree. I graduated from college with a bachelor of arts in mathematics as a well as a certification to teach secondary mathematics. From there I began my teaching career.

I always had a desire to be one of the few Black women to obtain a PhD in mathematics, so after a few years of teaching, I decided to go back to school to pursue a master's degree in mathematics with the goal of continuing in a PhD program once I was done. Once in my master's program, I felt very isolated, and wondered how and when anyone would utilize what I was doing to help others, particularly other Black students. Who would even understand my research focus besides another mathematician? For this reason, once I completed my master's degree, I changed my pursuit from a PhD in mathematics to one in mathematics education. I felt that obtaining this degree would be more useful, and my research there would be more practical.

Research Design

I used constructivist grounded theory methods because they "[consist] of systematic, yet flexible guidelines for collecting and analyzing data to construct theories 'grounded' in the data themselves" (Charmaz, 2006, p. 2). There has yet to be a theory that adequately explains the mathematical experiences of Black women in mathematics education, and this study hoped to construct a theory that more adequately explores this phenomenon. By using grounded theory, I was able to identify and categorize experiences inductively rather than imposing pre-existing topologies from dissimilar data.

Methods

The recruitment process

To determine a list of possible participants, I contacted the mathematics education department and requested that the department chair send an email containing the preliminary questionnaire (Appendix A) to all mathematics education PhD students during December 2014. By January 2015, I received responses from seven participants. After reviewing the preliminary questionnaire, all seven respondents met the criteria for this study, and I sent an email thanking them for their interest and informing them of their selection to participate in the study. The email also requested a time that would be best for them to meet during January, February, or March 2015, along with a copy of the informed consent form.

Participants

Purposeful sampling, which is "the selection of participants with shared knowledge or experience of the particular phenomena identified by the researcher as a potential area for exploration" (as cited in Breckenridge & Jones, 2009, p. 6), was used to select seven participants for this study. This type of sampling is:

> Deliberately and unashamedly selective and biased… There is little benefit in seeking a random sample when most of the random sample may be largely ignorant of particular issues and unable to comment on matters of interest to the researcher. (Cohen, Manion & Morrison, 2011, p. 157)

Using theoretical sampling with purposeful sampling helps to insure that the participants are knowledgeable about the phenomena of interest. Theoretical sampling involves using the data to construct tentative ideas about the data, then examining the ideas through further inquiry. Using this type of sampling allows the researcher to "develop the properties of her developing

categories or theory not to sample randomly selected populations or to sample representative distributions of a particular population" (Charmaz, 2006, p. 189). The selection criteria of my participants yielded a sample that was relatively homogenous; therefore, a smaller sample size was appropriate within this study. The participants selected meet the following criteria:

1. Is a self-identified Black female
2. Is currently in a doctoral program pursuing a PhD in mathematics education
3. Attends a traditional college or university
4. Has completed at least one semester of their graduate program

For the purpose of this study, my interest lies in the mathematical experiences of women who classify themselves as Black and who are currently in a doctoral program in mathematics education. The other selection criteria used ensured that women were far enough into their program, and that they were able to reflect on their mathematical experiences in meaningful ways. Diversity in the backgrounds of the participants was accomplished; however, after conducting the interview, transcribing and coding the transcripts, conducting a group interview and necessary follow-up interviews, the properties and categories generated through the analysis process were so rich that I did not seek additional participants (Breckenridge & Jones, 2009). Table 1 describes the participants in this study.

Table 1

Description of Participants

Participant	**Profession**	**Undergraduate Degree**	**Master's Degree**	**Program Level**
Sakinah	Educator	Mathematics	Mathematics Education	First Year
Raven	Educator	Economics	Mathematics Education	Completing Coursework
Brandi	Educator	Elementary Education	Mathematics Education	Coursework Completed
Melody	Educator	Chemical Engineering	Educational Leadership	Completing Coursework

Angel	Educator	Mathematics	Secondary Education	Coursework Completed
Kimberly	Educator	Mathematics	Instructional Technology	Coursework Completed
Jackie	Educator	Mathematics	Master's of Education Teacher Leadership	Coursework Completed

Setting/Site

All participants attended the same university located in the southeastern part of the United States. The school is regionally accredited to ensure the quality of their program. The College of Education, in which the participants were students, offers undergraduate, graduate, and non-degree programs for professionals in education, human development, and other health-related fields. The college graduates approximately 1200 student each year, of which 500 become educators. This university is one of the top 10 institutions in the United States to confer doctoral degrees in education to African American graduates, and is among the top 20 institutions in conferring master's degrees in education to African American graduates. The institution's rankings contributed to the participants' experiences; unlike many other institutions in this country, there were a number of other Black students within their programs. All interviews occurred at places that ensured privacy. Each participant and the locations of the interviews were given pseudonyms.

Data Collection

Theoretical sampling was also utilized throughout the data collection process. Although I had a plan for data collection, I needed to collect additional data to further substantiate my theory. This need to further substantiate my theory resulted in a revision of the data collection instruments for the interview, group session, and follow-up interviews. For this study, sources

for data include a preliminary questionnaire, initial interview, group session, and follow-up interviews. Each data source used to answer these research questions is explained in Table 2.

Table 2

Data Sources

Research Question	Questionnaire	Initial Interview	Group Session	Follow-up Interviews
What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences?	✓	✓	✓	✓
How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?	✓	✓	✓	✓

Initial Interviews

The initial interviews began in January 2015 and concluded by February 2015. At the beginning of the initial interview, each participant reviewed and signed the informed consent form. The initial interviews were conducted in a responsive interview format (Rubin & Rubin, 2005). The research goal that uses this model of interviews does so for depth of understanding. Prompts were also used to facilitate the interview (see Appendix B); however, the interviews became more conversational between the interviewer and interviewee, as was the goal. According to Rubin and Rubin (2005), the responsive interviewing technique "emphasizes that

the interviewer and the interviewee are both human beings, not recording machines, and that they form a relationship during the interview that generates ethical obligations for the interviewer" (p. 30). I worked to build this relationship by sharing common experiences with my participants. By asking open-ended questions, I hoped to "create contexts in which participants are encouraged to reflect retrospectively on an experience they have already lived through and describe this experience in as much detail as possible" (DeMarrais, 2004, p. 56). The prompts that were selected for this study were adapted from one conducted on women in mathematics (D. L. Anderson, 2001). Anderson's (2001) participants were women at various levels in mathematics. Anderson described the experiences that led to the participants' success in mathematics. For the purposes of my study, the questions were revised to address Black women in mathematics education. After going through the initial interview question with myself as a participant, I revised the question to ensure that the focus was fully on the mathematical experiences of the participants. Each interview was audio recorded, and interviews ranged from 30-90 minutes. All interviews took place at a location selected by the interviewee that allowed for privacy. Participants were also given a copy of the transcribed interview.

Group Session

The group session occurred with six participants in March 2015. I used semi-structured discussion prompts to facilitate the group discussion (See Appendix C), and I presented additional questions according to the findings of the initial interviews. Participants were asked to describe some of their mathematical experiences, how those experiences affected their decision to pursue a doctorate degree, as well as how the decision might influence their future choices. These interviews were used as a crucial component to theoretical sampling, which involves using the data to construct tentative ideas about the data and examining those ideas through further

inquiry. This session provided an opportunity for the participants to reflect on some of their mathematical experiences and explore how others' experiences influenced their decisions to pursue doctorates in mathematics education. This session was audio- and video-recorded, and took place at a location chosen by the interviewer that allowed for privacy. This session lasted for approximately 90 minutes.

Follow-up interviews

Follow-up interviews were conducted in April 2015, and were used as an opportunity to gain more insight and further clarify findings. The interviews also gave participants an opportunity to add additional information to statements made in the initial interviews. Follow-up interviews lasted between 15 and 30 minutes, and since the majority of my follow-up questions were addressed in the group session, follow-up interviews were conducted with only three of the participants. Semi-structured interview questions followed given prompts and specifically addressed any statements that needed further clarification from the initial interview (Appendix D). Follow-up interviews were conducted either via phone conversations or in person.

Time Frame of data collection and Analysis

There were three phases of data collection and analysis (Table 3). This division was the result of a need to have all participants initially interviewed prior to conducting the group session.

Table 3
Phases of Data Collection

	Phase I	**Phase 2**	**Phase 3**
Questionnaire	Completed by 7 participants		
Initial Interview		7 interviews	

	(7 audio recordings)	
Group Session		6 participants (audio and video recording)
Follow-Up Interviews		3 Audio recordings

The first phase of data collection was the recruitment process. This lasted for six weeks. The second phase, in which the initial interviews were conducted, lasted two months. During this time, I began using Dedoose to organize and facilitate the analysis of collected data. The third phase, which consisted of the group session and follow-up interviews, lasted for 1 month. Appendix E outlines the timeline of data collection.

Data Analysis

For this project, I used grounded theory methods to analyze my data. This process of analysis includes familiarizing oneself with the data, identifying codes and engaging in the process of constant comparison, the use of open coding, and the development of hypotheses while simultaneously collecting more data and refining the interviewing techniques. The use of memos will also provide me with the opportunity to focus on emergent categories and stimulate thought during the data collection and data analysis processes. I utilized Dedoose as my computer-assisted qualitative data analysis software, which managed and analyzed the collected data. This software was used after the initial transcription process, which was conducted using Microsoft word.

A major component of this research process was the use of memos, which provided me opportunities to focus on emergent categories and stimulate thought during the data collection and data analysis processes. The types of memos utilized for this study included conceptual or theoretical memos as well operational ones. Conceptual memos asked what was going on,

described the development of a category, and helped to develop ideas on the possible pathways for integrating the theory (Charmaz, 2006). One such memo related to the idea of competition. Some of the codes related to participants' wanting to compete with their classmates, or how others wanted to compete with them (although they were uninterested in doing so). I was unsure whether this code should be categorized within "Thoughts of Self" or "Mathematical Ability." I used my memos as a way to describe the development of a category. Operational memos were mainly used to remind myself of methodological procedures, such as asking additional questions of the participants, or reminding myself not to interject my story.

Another important aspect of the data collection and analysis process was the use of constant comparison, a method of comparing newly collected data with previous data. I utilized constant comparison by using the findings of my initial analysis of the initial interviews to modify the questions I asked during my group interview and follow-up sessions. This method was also utilized throughout the coding process. Constant comparison methods allowed for the emergence of categories that may be unique to Black women pursuing a PhD in mathematics education, as well as codes that can be described in terms of the existing literature on success in mathematics. Codes that emerged from the initial interviews and group session allowed for the creation of categories and themes based on their common elements. These theories were tested by applying them to all of the data, and I constantly questioned whether these themes represented an exhausted consideration of all possible themes presented in the data.

Throughout the process, I followed the following coding procedures to help analyze the data that I had collected. The coding procedure utilized for this study includes *in vivo*, *process*, *initial*, *focused*, *axial*, and *theoretical coding*. The coding was divided into two cycles. The first cycle coding consisted of in vivo, process, and initial coding. The second cycle of coding

consisted of focused, axial, and theoretical coding. The coding methods associated with the first cycle of coding call for the splitting of data into "individually coded segments" (Saldana, 2009, p. 42). The second cycle coding methods are used to "literally and metaphorically constantly compare, reorganize, or 'focus' the codes into categories, prioritize them to develop 'axis' categories around which others revolve, and synthesize them to formulate a central or core category that becomes the foundation for explication of a grounded theory" (p. 42). The following will provide a breakdown of each of the coding methods.

In vivo coding allows for the extraction of indigenous terms by using the "word or short phrase from the actual language found in the qualitative data record" (Saldana, 2009, p. 75). This type of coding allowed me to "prioritize and honor the participant's voice" by using their own words as codes (p. 75). These codes were used in the initial stages of analysis to be sure I had grasped what was important to the participants (Charmaz, 2006). An example of this type of code was "math was a language," "[math] was never a problem," and "really easy."

The next type of coding that was employed was process coding, which happened simultaneously with initial and axial coding. Process coding comes from "simple observable activity and more general conceptual action" (Saldana, 2009, p. 77). Codes of this type are typically words that end in "-ing." This type of coding is particularly useful when searching for "ongoing action/interaction/emotion taken in response to situations, problems often with the purpose of reaching a goal or handling a problem" (Corbin & Strauss, 2008, p. 96-7). Process codes from this study included "asking for help," and "working with others." Along with the in vivo codes, these codes were numerous, but were reduced during the second cycle of coding (Saldana, 2009).

The next type of coding discussed is initial coding. The goal of initial coding is "to remain open to all possible theoretical directions indicated by your readings of the data" (Charmaz, 2006, p. 46). This type of coding provides a starting point for the researcher to analyze and determine additional information that may be necessary for furthering the study (Saldana, 2009). These codes may be removed and reworded as the researcher conducts the study. Initial coding may also show the researcher possible gaps in the research. For interview transcripts, Charmaz (2006) suggests line-by-line initial coding. This initial coding process also calls for the development of properties and dimensions categories, which can further explain the processes revealed in the analysis (Saldana, 2009). I was careful to search for codes that directly related to my research question concerning Black women's mathematical experiences and how this influenced their decisions to enter the PhD program. Some of these codes included "being good at math" and "overcoming obstacles." At the conclusion of the first coding cycle, I had over 400 codes. These properties and categories assisted in the development of theories in the second coding cycle that consisted of focused, axial, and theoretical coding.

Focused coding follows initial coding and is used to search for codes that are used most often in the initial coding cycle. This was done by using the analyze code application feature of Dedoose. This narrowing down of codes allows for the "development of major categories or themes from the data" (Saldana, 2009, p. 155). As a component of focus coding, "data similarly coded are clustered together and reviewed to create tentative category names with an emphasis on process through the use of gerunds" (Saldana, 2009, p. 156). Next, analytic memos were utilized to help generate and refine those categories as well as explain the thought processes that contributed to their development. These codes helped me to "assess comparability and transferability" of the codes to the data generated from other participants (Saldana, 2009, p. 158).

Examples of this type of category was “Thoughts of Self,” was used to group codes such as “feelings about math,” “expectations,” and “having confidence.” The categories that were developed within this process were *feelings, expectations, confidence, ability, classroom diversity, class placement, my teachers, enrichment, competition, meeting an obstacle, working differently, moving beyond, teaching, wanting, affecting change, advancing academically, being a Black woman,* and *selecting math ed*. Though these were not the only categories that were developed, they spoke most directly and consistently to the research questions. Throughout the creation of these categories, I was also engaged in axial coding. Axial coding extended the work of focused and initial coding.

Although axial coding is considered a burdensome step that potentially undoes the work completed during the initial coding processes, it does allow for regrouping the data that was split during the initial coding process. This coding process allows calls for the “grouping of similarly coded data reduc[ing] the number of initial codes you developed while sorting and re-labeling them into conceptual categories” (Saldana, 2009, p. 160). The process leads us to theoretical coding.

Theoretical coding, which “accounts for all other codes and categories formulated thus far in grounded theory analysis” (Saldana, 2009, p. 163) was developed to “[integrate] and synthesis the categories derived from coding and analysis to now create a theory” (p. 164). The core category developed by theoretical coding described the main concept developed from the data as well as variation from the data. The processes of analytical and theoretical coding were used to develop the themes and answers to the research questions. From this study, the following themes were developed: *mathematical crisis, mathematical identity,* and *environment.* They were then used to address the question: what perspectives do Black women who are in pursuit of a

doctorate of philosophy degree in mathematics education have about their mathematical experiences? The final theme addressed the question: how have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?

Credibility

Credibility for an interview study can be achieved in a variety of ways, including selection of the participants, thoroughness, and accuracy and transparency (Rubin & Rubin, 2004). The issue of credibility was first addressed with the selection of the participants. The participants who were selected were all women who self-identified as Black and had firsthand experience in pursuing a PhD in mathematics education. They were also knowledgeable about the mathematical experiences they had prior to entering the PhD program. Finally, they offered a variety of perspectives to describe their experiences. Credibility was achieved through the thoroughness and accuracy. Thoroughness was achieved by altering the interview questions throughout the interview process to more accurately address the research questions. Accuracy was achieved by rechecking the transcription against the recordings multiple times and by encouraging the participants to make any corrections to the transcriptions via member checks. Transparency was accomplished by the description of the data collection and analysis processes.

Dependability

To substantiate the dependability of the research, the following checks were used in the design and analysis of the data. These checks included referential adequacy: "Referential adequacy (Eisner, 1991) is achieved through the retention of participants' word choice in coding and categories (at times retained in the original language), as well as the frequent use of quotes to illustrate categories" (Morrison & James, 2009, p. 155). This process was followed throughout the analysis of the data and included in the findings. Other checks included using the interviews

of more than one participant, and, finally, the codes and categories were reviewed alongside current literature on Black women in mathematics education.

In order to ensure quality, it becomes essential to provide complete transparency of the data collection processes. It is also important to consider validity, reliability, and trustworthiness. For validity, the idea of "truth" must be considered. The idea that there is one unified truth is not a concept readily accepted by grounded theorists, who believe that truth is subjective and largely based on perceptions. Therefore, they find it difficult to claim that one's approach to a study is absolutely valid. Reliability is not a goal of grounded theories. To establish trustworthiness, I must establish credibility, transferability, dependability, and confirmability.

Limitation of the Study

One limitation of the study is that I, the researcher, am a member of the community I studied. Although this may appear to some as a limitation, for the purposes of this project it was an asset. This allowed my participants to be more comfortable in communicating their experiences with me. To ensure that I was not placing my preconceived notions into the study, I took several precautions, including bracketing. Although this did not rid the study of all possible subjectivity, it did allow for an upfront approach to these preconceptions.

The choice of participants also presented a limitation. Many of the participants expressed great confidence in their mathematical abilities from a very early age. While no one mentioned any times of great struggle prior to elementary school, they all mentioned that they were good math students. The questions then became: what gave them this sense of confidence in the early stages of school? If applicable, what sorts of things were being done prior to school to make that difference? One limitation of this study was that I did not have documents to support the participants' claims of their mathematical abilities. Using school records or placement tests could

have added more validity to their statements. In addition, being able to interview the parents of the participants to ask about those early years may have also helped to address the origin of this initial sense of confidence. Another limitation of this study was the fact that the information was based on the memories of the participants. Although it is my belief that the participants were truthful in their responses, they may have failed to accurately recall some of their previous mathematical experiences.

Ethical Issues

Several precautions were taken to address the ethical issues of this study. Pseudonyms were employed to protect the identification of the participants. Recordings and transcriptions of interview data and observations were stored on the researcher's password and firewall-protected computer. Written data was kept in a locked filling cabinet at the home of the researcher. Data collected from each participant was not comingled with that of other participants of the study.

4 FINDINGS

Two sections present the findings of this study. The first section gives a portrait of each participant describing her mathematical experiences. The second section address each research question by providing an overview of the themes and categories that emerged from the analysis of their mathematical experiences.

Portrait of the Participants

Sakinah: No one can compete, confident, college mathematics educator

Sakinah viewed herself as a good student and academically better than others. She was always told she was smart and she believed it: "I was always smarter than anyone else." She began her elementary and secondary schooling in her native Jamaica, and grew up with a parent who was not only very stern, but also had high expectations. Sakinah had to achieve more than her mother. She was at the top of the class, and like so many of the 'chosen ones,' credits her primary school teacher for her successful entrance into one of the top high schools in her district. Indeed, she enjoyed doing math: "Just doing problem sets was just fun.... I like that it wasn't this uncertainty with English." She was also determined to solve every problem: "There better not be one [problem] I couldn't figure out because there is a trick somewhere and I found the trick and I did it."

Migration to the United States did not interfere with Sakinah's academic success in high school. The education she had in the Caribbean placed her on a good path, and she was ahead of the group, completing 11^{th} and 12^{th} grade work in the 10^{th} grade. In fact, the courses offered were far below her ability level, and Sakinah felt that no other students could compete with her. Her strong sense of mathematical confidence was ever present.

However, Sakinah's confidence was shattered in college when family issues caused her to receive a D in a topology course. Nevertheless, she did not stay upset for long, and the experience did not affect her beliefs in her own mathematical abilities. Instead, it spoke to her determination to move beyond any issue. All of these experiences contributed to her development into a successful student of mathematics.

Sakinah's journey to teaching came out of a need to find a job that utilized her mathematical abilities. She initially wanted to teach high school, and decided to pursue a master's in mathematics education. However, after completing her practicum, she realized that teaching high school mathematics was not where she wanted to start her career as an educator. Therefore, after completing her degree, she decided to pursue a teaching position at a junior college, and chose to pursue her PhD in mathematics education as a gift to herself. The advancement of close peers who were becoming doctors and lawyers motivated her. Initially, issues of her dialect interest resulted in a decision to pursue mathematics. Sakinah felt that math was a language she could speak that did not reveal her background as a person from the "ghetto." She also thought that being a Black woman and having a PhD behind her name would make a difference in the workplace, and her opinions would be greater respected. Sakinah's prior positive experiences with mathematics and her competitive nature also had an effect on her decision to pursue her PhD in mathematics education.

Raven: innate ability, top of her class, appreciates working hard

Raven truly enjoyed math. She felt that it was "really easy," and continued to have that feeling throughout her K-12 education. Not only did she believe math to be easy, she enjoyed math and school: "You give me 80 problems and say do those problems, I probably won't have a problem doing it because I actually enjoyed it... I always enjoyed [being] in school." Raven came

from a family of highly educated individuals, and a large part of her mathematical identity was based on living up to the expectations of her family: "People had already defined what they thought I should be and I was trying to live up to the expectations of my siblings." Raven experienced a small decline in her confidence level after taking a geometry class in high school where, unlike her previous mathematics courses, she struggled to grasp the concepts. However, she quickly regained her previous confidence, and that confidence continued throughout high school. In reference to her abilities, she commented that she was able to figure most math problems out with examples. In reference to her thoughts of her mathematical abilities related to others, she stated, "I had something that most people don't [have] which was an innate ability to calculate numbers and memorize numbers."

Raven was enrolled in advanced courses since elementary school. She discussed her experiences with tracking, which allowed her to remain in the advanced classes, and the elitism that she felt over her classmates: "The kids in the Class A group were the kids that were accelerated and advanced, and we basically knew that too. We felt like the kids that were in the D class were the kids that didn't do anything." Raven spent many of her summers throughout middle school and early high school involved in STEM summer programs at local colleges. She also participated in a high school dual enrichment program that had a focus on science and mathematics and allowed her to take sciences courses at a local museum. She enjoyed those opportunities to explore both subjects. In her classroom environments, she was typically the first person to complete her assignments: "I would get done with my classwork within like the first couple of minutes and nobody else would have gotten done." As such, there was little competition for her amongst her peers. When discussing her teachers, Raven gave them credit for being successful in their jobs, and commented that her teachers challenged her; it did not seem as

if they were simply there to get a paycheck: “They were there to actually teach us mathematics and they actually challenged us. They asked open-ended questions to have discourse in the classroom, which I think is important and we don’t have that anymore.” As far as diversity is concerned, she stated that her classrooms were majority Black throughout her schooling, and there were a good mix of boys and girls until she reached high school, where she noticed a gender shift. At that time, she began to notice more girls than boys in her advanced courses. Overall, she described a sense of belonging in her classrooms: “It felt like I was supposed to be there…I didn’t feel any kind of way about being Black in my math classroom.”

Raven attended a very prestigious predominantly-White institution for her undergraduate education, where she went from being at the top of her class to being surrounded by peers who were also at the tops of their classes. It was during this time that she began to realize “I am definitely a minority.” She struggled with not seeing the familiar sea of Black faces surrounding her, and she lost confidence in herself: “I might have been the only Black person in the class, and that messed with my self-esteem.” Although she began attending office hours and working with study groups, this only increased her diminished confidence. She was accustomed to being the first to finish an assignment, so now needing help caused her confidence level to plummet. She began to feel as if she “was not as smart as everybody else and just probably average.” It was during that time that she decided that she no longer wanted to take math. Raven’s obstacle was internal: she lost confidence in herself and no longer felt that she belonged in her courses, and being a minority played an important role in these feelings. The hard work she was now doing did not yield academically successful results. After facing this crisis, Raven decided to start thinking differently. She now began to value the hard work that she had to put in: “There is something about not having to work for what you get and having to work for it. Like, I

appreciate working hard and getting that C and that B rather than the A that I never worked for at all." Once Raven began to value hard work, she also began to view working with others differently. Now she takes time to seek out work groups:

> Before I would never consider working with groups or asking another student for help or you know having study sessions or anything like that because I would always just do it on my own. But now the first thing I do when I come into a classroom is look around to see if I recognize anybody.

Now she realizes that it is acceptable to get help, and in the case of her current studies, she cannot do it alone.

Raven described teaching as a profession that was not high on her list of career options, but after looking back over her own academic experience, she discovered that she enjoyed being in school, and she particularly enjoyed the mathematics classroom. She ultimately wanted to pass that joy on to others and decided to do so by becoming a high school mathematics teacher. "Feeling that way about it was quite easy to know that teaching math would probably still be fun for me because it's what I enjoy doing and if I could pass that joy onto somebody else that would be great." In order to achieve this goal, she needed certification, so she decided to pursue a master's degree in secondary education, which would enable her to teach. However, she did not stop there, but went on to get an additional master's degree in mathematics education. Earning this additional degree did not quench her desire for education; she still wanted the doctorate, so she decided to pursue her PhD in mathematics education. Upon entering the program, Raven experienced for the first time her self-reflection on her Black female identity. This identity was not something that she considered prior to entering her program, but she is now beginning to come to terms with its many layers.

> Before entering the program, I didn't self-reflect at all. I never actually thought about my identity as being Black. Which I'm still not sure if I quite classify myself as Black because of my African background and I definitely never thought about my identity as being a woman and what that carried when I enter a room and how people perceive me. Now I actually think about those kinds of things, that I'm Black or perceived as Black at first glance and I'm a woman, and how will that impact me teaching in my classroom or outside my classroom in a graduate class to my professor? I actually think about all these layers now.

Brandi: A visual learner, good test taker, and mathematics educator

Brandi identified herself as a visual learner who enjoyed a subject like math because it was visual. She was happy to share that "It [math] always came easy to me." She was also a good test taker, and enjoyed to read, but did not enjoy writing. That, however, did not prevent Brandi from being in top honors courses, where she experienced positive competition with classmates, which encouraged her to work faster to beat them. "I don't know if it came from the teacher or me and Jen, I just remember me and her racing to see who can finish the math workbook the fastest and she beat me by one page." She also had positive experiences with math teachers, which informed and influenced her own teaching style: "He [one of my math teachers] made math more fun with games and he also made everyone feel smart." Although Brandi was surrounded by people from a variety of backgrounds, she rarely took that into account, and simply saw them as her friends:

> I don't think I knew I was Black. I didn't grow up knowing I was Black and she was white because my friends were the people that I went to school with. They were Italian,

Greek, Mexican, and Honduran and so I grew up in a neighborhood with all these different nationalities. Nobody was black and White.

It was not until Brandi reached high school that she began to notice a racial divide. The school that she attended was in a predominantly-White neighborhood, and the community members began viewing her and her peers differently.

Although Brandi accelerated in high school, she ran out of course options once she reached 10th grade; during her 11th and 12th grade years she did not take any mathematics courses. When asked if there were any other, math courses offered, Brandi responded: "That was it. We didn't have anything else to take. You were done." This resulted in what I have referred to as a mathematical crisis for her. Not taking math courses for two years caused her to lose some of her math skills:

N: So did you do anything to enrich your math because at that point you would have stopped taking math in 10th grade so for those two years was there anything that you did to keep those skills going?

B: No

N: Did you retain them on your own?

B: No I didn't retain them. And I realized when I got to college I struggled.

At the undergraduate level, Brandi did not pursue mathematics as a major, and only took the necessary math courses for her to earn her bachelor's degree in elementary education with the goal of eventually going to law school. By the time she reached her senior year of college in the early elementary program, she thought she wanted to become an elementary school teacher until she completed her practicum: "I hated it. I hated it and I did not like those little children. They were whinny and I couldn't take it and I thought I had wasted 4 years of my life." It was

then that she concluded that primary school children were not the appropriate student population for her. After working with an afterschool program, she realized that she wanted to work with older students: "I always liked math but I felt like I needed to be with older children, so I went back to school and got my master's in math education." After receiving her master's and earning 30 credits, it was not important for her to pursue a PhD. In fact, she knew very few people who had one. However, after moving to a different state and speaking with her new mentor, she noticed that having a PhD was important in that geographical location: "It just wasn't what people did [where I was from]. But when I came here everybody was getting a PhD; it was like they were passing them out. So I said, well, you know, it means something here to have that PhD behind your name and that's really truly what made me go into a PhD program." Brandi decided to pursue her PhD in an area that she loved, mathematics education. Her desire was to be able to effect change with the teachers and students with whom she worked. This was something that she was unable to accomplish in her previous roles as a program director and director of mathematics programs. While Brandi's view of being a Black woman in the PhD is positive, she did make notice of the absence of her male counterparts.

Angel: Modest, gifted academically, determined

Angel did not feel that her abilities or success were worthy of notice. When Angel discussed her thoughts about mathematics, she did not speak of it as a skill: "Honestly, I didn't even realize that that was a skill. It didn't occur to me that other people didn't do the same thing." She felt that everything was simple when it came to math: "It was just easy.... It was never a problem…everything was easy." When it came to her abilities in mathematics, she referred to it as "something that I was good at…. I don't remember being at home struggling or failing any tests." Nevertheless, she considered herself to have a high ranking amongst her peers:

"We had a class of 262. I was number 82, which sounded really good to me because most of my friends were in the 200s or the 100s, so as far as I was concerned I was very smart." She also experienced her peers' desire to compete with her throughout school: "There was this boy in seventh grade. I'll never forget. If I got a 97, he got a 98. If I got a 99, he got a 100. So it was that type of competition."

Angel attended various private schools from first through eighth grade. Although she did not recall taking any course labeled as gifted or accelerated, as someone who has worked as a teacher, she now feels that they were indeed advanced. Due to financial considerations and social inadequacies at some of the schools, Angel's mother constantly moved Angel to different private schools before eventually sending her away to school. During her year away, Angel continued to perform well, but also missed an opportunity to apply for entrance into the top local high schools. When she returned, there were few options available, and she enrolled in a public high school. While her middle school classes were once ethnically diverse, the high school she now attended was majority Black.

In high school, Angel participated in advanced math course. When discussing her high school experiences, she referred to one teacher who really opened her eyes to her mathematical abilities. She was not applying herself before, but this teacher challenged her by encouraging her to try harder, and she embraced the challenge. It was at this point that she witnessed an increase in her performance on the SATs: "I didn't answer everything [at first] but when I did it again I got a 700. And that's when I started realizing I'm really good at math because he actually pointed it out." At this school, Angel also had the opportunity to enter a magnet program for Engineering, but she never told her mother about it because she wanted to stay in classes with her friends. Angel had spent the majority of her educational career in different schools, and the

stability of remaining with a group of friends for once was indispensable. However, by the time she was ready to graduate, she realized that this was not the best option. Although she did well in her classes, she knew that she could have performed well in the more advances courses.

Angel had a few challenges as she prepared to enter college. Initially, she entered college with the expectation of being in a special program that would offer her a number of academic support protocols, such as grade monitoring, tutoring, and additional forms of support. However, she registered for too many courses and missed several days. She also had difficulty understanding the course requirements such as how her grades were determined and what assignments to complete and when they were due. This resulted in a number of failed courses her first semester. Although she was able to improve during the following semester, her mother asked her to come home to a local and less expensive college. Afterward, she changed colleges and programs several times. Angel also became a mother during her second year of college, which understandably affected her coursework and forced her to make adjustments, but did not deter her from pursing her education. Initially, Angel wanted to pursue a degree in electrical engineering, but later changed to computer science, then actuarial sciences, and finally earned a degree in mathematics.

When describing the contributing experiences to Angel's pursuit of a PhD in mathematics, she cites that her decision began when she became a teacher. Angel's mother encouraged her to become a teacher after her own difficulty finding a job in the financial field, and having to studying to pass actuarial tests: "I liked my first teaching job and decided: hey, I can do this. So that's how I become a teacher. Never wanted to. Never thought about it." After deciding to teach, Angel discovered that a master's degree was close within reach: "I realized that if I took 12 more credits [than the certification program] I would actually have a master's

degree." She decided to take those additional courses, and later, to pursue her specialist degree in leadership. Earning this degree could allow her to become a principal in the future. A few years later, Angel's lack of academic activity was the final impetus for obtaining her PhD: "I'm watching too much TV. I'm wasting my life away. By now I realize: OK, you are gifted academically. You can't keep pretending like you're not." Angel described her entrance into the math education PhD program as a coincidence; she saw a flyer and decided to apply. However, she also had an interest in increasing the motivation of her students, and thought that she may gain pedagogical expertise in the program. Once she entered it, her passion to improve her classroom dynamic continued to grow. Angel describes her PhD journey as an eye-opening experience; she now understands that one's lack of academic abilities is not always solely attributable to the individual.

Melody: School kid, gifted, change maker

Being a "school kid" was an important factor in Melody's view of herself. She enjoyed math and enjoyed being in school. In her words: "I liked going to school, period." Her experiences were influenced by the path taken by her sister, who became an architectural engineer. She deeply admired her, and wanted to follow her example by becoming an engineer too: "I guess I have always followed her in whatever she wants to do. I want to do it too." Being accepted in the gifted program in school boosted her confidence, and allowed her to move beyond the normal curriculum.

Melody considered herself a good student with high abilities due to the accelerated courses she took and skipping the 2nd grade. Although she did not recall the specific process, she knew that she underwent testing and was allowed to skip a grade and be placed in gifted classes. She also recalled being tracked, which placed her in classes with intelligent African American

students: “I do remember being tracked so like the smart students took class together but it was all African Americans and it was mostly girls.” Race was not a factor that she considered while taking those advanced math courses. As she stated, “we were all Black, so I didn’t know that there was [anything to notice] …. It was what it was.” The predominance of Black classmates was consistent until she reached high school, where the population became mostly Asian. She also noticed that there were far fewer males—particularly Black males—in her accelerated courses. Melody also participated in enrichment opportunities, such as a summer program between her junior and senior year of high school, which had a focus on engineering as well as preparation for entering college. Though she was not herself competitive, she did experience the competitive nature of her classmates. She described one instance when a teacher released her and a male classmate to attend a pull-out reading experience during class: “I just remember he tried to compete but I was… not into that. I just wanted to do well.” Melody was also fortunate enough to have instructors who impacted her both personally and academically. In describing one of her favorite teachers, Melody discussed how, for the first time, she thought of her teacher as a woman who was not in some way related to her: “She was one of the first women that I noticed that was like a woman and a teacher and like she had a real life and just wasn’t in my family….I could look up to her.” Another of her favorite teachers, Ms. Wall, was also her Pre-calculus teacher. Melody formed a special relationship with her because of the additional time they spent together outside class; she also appreciated the sense of organization Ms. Wall presented in the classroom. In describing why she favored her, Melody stated:

> The way that she did her presentation of notes, the fact that she was available after school and she was our class advisor so I got really close with her just because I was doing other

> things and was kind of always in her room hanging out and so I liked her more for her personality.

Teachers like these two women gave Melody a great foundation, and helped her to enter a prestigious college. After high school, Melody attended a PWI and experienced many difficulties with her confidence. She attempted to use the same tactics she used in high school, but found that those tactics no longer worked. Before, she could simply determine the amount of work needed to earn a desired grade, but that strategy was no longer working, and she did not know how to fix it: "I really lost a lot of confidence those years. Because I just did not get what I thought I should have gotten with all the work and effort that I put in." In order for her to find success in college, she decided to work differently by relying on smaller study groups and joining minority organizations on campus. Eventually, she found the confidence to attend office hours and worked directly with her instructors. As her grades improved, she decided to become a teacher so that she could help other Black girls avoid similarly negative experiences. According to Melody:

> I really at that point thought it was still me and a part of the way it was me, but I said I don't want any other Black girl especially to go through what I went through and so I wanted to go back and teach because I don't want anybody else to feel the same way I did.

Melody decided to become a teacher to help other Black girls feel confident and prepared for college, and her avenue for achieving this goal started with becoming a math teacher.

As a math teacher, Melody noticed a number of issues at her school, and she decided that the best way to effect change was to be in a position of leadership: "If I am in an organization, I find that I want things to be how I want them to be and the way to do that is to effect some type

of change." At that point, she decided to pursue a master's in educational leadership, but after earning that degree, she realized that it might not help her make the kinds of changes she wanted. Melody thought that working directly with teachers may be a more effective way to inspire change, so she decided to pursue a PhD: "I can effect classroom change working with teachers more directly rather than being on the administrative end." Melody selected mathematics education because it was the area that most concerned her.

Kimberly: Good student, defiant, reach students

Kimberly's attitude about mathematics was that "math was easy…and fun." Kimberly recalled her abilities, as "I just knew how to do it…. [I was] just a good math student I guess." This sense of enjoyment and knowing how to "do" math resulted in a high level of confidence for Kimberly. She did not have a specific reason for her abilities in mathematics, but knew that she was a good math student.

Her ability to do math also influenced the courses she took. Kimberly considered herself an intelligent child, and took all honors classes. Her intelligence was reflected in her class placement as well as in her academic abilities. She recalled that her classes were tracked and the students were all African Americans until after the seventh grade, when she noticed more Caucasian students: "Seventh grade: it kind of stood out because you noticed that right now there is only one or two Black kids in the class, but then any other time I really didn't focus [on it]. I really just focused on the math." She also commented that she found it interesting that her classmates all worked together and that did not see racial differences. In referencing the study groups she and her classmates formed, she discusses their deep bonds, even as they practiced competition: "It [competition] was really just like that motivation to say you know we kept each other on task." If a student was struggling in the class, the others would help by forming study

groups. Kimberly commented that these study groups were comprised of everyone: "It was not just the black kids; it was like all of us in that class. We didn't see color then. Which was interesting." Kimberly was also a long-time member of the math team. She considered those experiences to be fun and spent time during the summers preparing for competition.

When deciding which college to attend Kimberly chose a predominantly-White institution (PWI) in the southeastern part of the United States. When describing her mathematical experiences in college, she describes her math courses as detrimental. She only spoke to the small population of Black students, and particularly the smaller number of Black women, in her courses. She also gave a detailed description of how instructors viewed her as not belonging there. In one instance, she described a math instructor's telling her that she was not in the right place. She responded with, "Can I see your roster? … I'm in the right place; my name is on the roster." She described this instructor as an "egotistical white man that had something to prove." She wondered: "why do I look lost? I look like every other college student. I just had on sweat pants. I rolled out the bed to get here at 7:40. So I'm just like everybody else that just rolled out the bed to get here." Experiences like this one encouraged her to defy others' assumptions by obtaining a degree in mathematics. In her words, "it was a challenge there with the math classes, but I was determined to get a math degree just to prove them wrong." She decided that she would get a tutor. Working with a tutor added to her level of confidence, and confirmed her belief that others' disbelief about her abilities had little to do with her ability, but with their own misguided perceptions:

> My tutor said I was wasting my money. But that [working with a tutor] was really for my confidence because it was like I was trying to figure it out. I've been good in math all the way through but yet when I get to college it's like I'm pulling Cs but then I come to

> realize it wasn't really about my ability it was really because I went to a predominantly-White school and it was more of 'you don't belong.'

Kimberly's suspicions were confirmed when she submitted her tutor's work for a homework assignment in an effort to see how it would be scored: "Even turning in his [the tutor's] work, I got marked down like really badly and then I went back. I said 'it's not about the work; it's about who I am'." Kimberly struggled to finish that course but eventually found instructors that graded her fairly and she continued to take courses with those instructors.

After graduating with a degree in mathematics, it was difficult for Kimberly to find herself. She had a few jobs working in the banking, finance, and computer industries, but she was unsure what to do with herself, so she decided to enter a field in which she had previous success, and decided to become a mathematics teacher: "I wasn't planning on teaching. But when I started teaching, I just really looked into education. Looked at how can I perfect my craft." Although it was not her plan to become a teacher when she initially got her degree in mathematics, once she decided to do so she continued to add to her academic knowledge by pursuing her graduate degree. Kimberly initially went back to her same undergraduate institution to earn a master's in instructional technology. Later, she continued on to receive a specialist degree in instructional design. After spending more time as a teacher, she realized that her students were not getting the information she was presenting to them, and she was searching for ways to help them truly grasp the concepts. She thought that a PhD program would give her better tools for reaching her students:

> I notice that what this program was offering was looking at what works in urban education. And so what this college was saying that they were offering was going to help

> my kids. So I was just really trying to figure out what's going to work for the type of kids I was servicing.

Once in the program, Kimberly discovered that it had the greatest number of Black women she had even seen moving through a PhD program, but she also noticed the lack of Black males enrolled.

Jackie: Smart kid, teachers love her, math teacher

Jackie exhibited confidence when it came to her mathematical abilities. In her words, "I definitely felt like I was able to do anything when it came to math." She also discussed her interactions with her teachers, and said that they loved her. She stated that, from her earliest memories, these teachers' confidence in her made her feel self-confident in her own mathematical abilities. This confidence was not only expressed by her teachers, but also by her parents: "My parents definitely made me feel like I was a smart kid." This confidence was also a result of the extracurricular activities in which Jackie participated. Due to very high test scores during her elementary years, Jackie was invited to participate in the school's math team. She spoke fondly of those experiences, which included staying after school to eat pizza and work on math problems.

When Jackie reflected on her high school classrooms, she remembered that her "class sizes were extremely small … and it was the same group of kids in all of my classes. So it's kind of like we grew up together." Although Jackie was not classified as gifted, she did recall that every math class she took was accelerated, which also contributed to her small class sizes and composition. During her elementary years, her school was diverse. At the time, her best friend was a Caucasian male who was also a member of the math team. By the time she was in high school, however, the student population was majority Black. Though she still had a great deal of

confidence in her mathematical abilities, she had also developed a great interest in music. During this time that she met her favorite math teacher, whose classes she took from her sophomore through senior years. She greatly enjoyed them, and earned scores high enough on the AP Calculus exam to receive credit for college coursework.

Jackie decided to attend a predominantly-White college to study aerospace engineering. Once there she immediately began to notice a difference when she attended a summer program designed for minorities to get acquainted with the school before the semester began. Soon, her initial aerospace engineering course would also challenge notions she had held since elementary school, where all her teachers loved her. As she stated,

> I remember my first aerospace class. I was in a group and there was 2 White guys, a White girl, and myself within the group. The 2 guys got an A, the girl got a B, and I got the C, and we were all in the group project together. I was like, man, what is going on? This is so different. Everybody loves me.

Although this was something she noticed, Jackie did not let it bother her. In fact, she did not like the aerospace engineering program, and decided to take a year off from school: "I know that my college really took [the desire of] me wanting to go to school out of me." Though she did not return to that institution, she did attend another school where she pursued and earned her degree in mathematics. While there, she was able to regain some of the confidence she lost: "I gained confidence in myself again. We started study groups and I even started tutoring like to earn money working tutoring in mathematics. I definitely felt like I knew what I was talking about." Jackie felt that, ultimately, making the change to mathematics was the best decision she could have made.

After graduating from college with a degree in mathematics, however, Jackie struggled to find a steady job, and decided to pursue teaching with her husband's encouragement: "My husband just kept saying 'you're good with kids. You should be a teacher'." Nevertheless, Jackie had reservations about teaching. Her biggest concern was that it would be a horrible profession because the students would not respect her: "I didn't want to be a teacher because I was like, the kids are going to hate me. They are not going to listen to me. It's going to be the worst thing in the world." Nevertheless, after applying and being accepted for a teaching job, she realized that "it wasn't as bad," and she "liked it a lot." After spending some time teaching, Jackie had an opportunity to reflect on her academic self, and realized that she was not a bad student in college; although she lost confidence at one school, she experienced some great teachers in her earlier years, ones who motivated and encouraged her. This also influenced her decision to become an educator.

After receiving a master's degree in mathematics education and progressing through the program with ease, Jackie decided to continue on to her PhD. When deciding to get her PhD in mathematics education, she first examined the subjects in which she thrived, and who she was as both a student and an individual:

> I thought that it was a huge commitment. And so I wanted to see what I was passionate about. What would I be good at? And I first looked at curriculum and instruction. Is this what I am good at? And what it ultimately came down to was: who am I? I'm a math teacher you know and this is what I want to get my degree in. I want to be the best math teacher there is.

In Jackie's reflection on being a Black woman in the PhD program, she spoke of her family, where there are a number of highly educated Black women, and how she impressed them; though, in reality, she was more impressed by their accomplishments:

> I have a 98-year-old aunt who is a teacher. Who is a math teacher! And I'm thinking back then 98 years-old [that] when she was a teacher it had to be a lot more hard for her [and] she has her master's degree. I have all these aunts that have their, you know, 'higher education' and they're looking at me like I'm doing something that's so extraordinary. I'm not doing anything that my family hasn't done or women before me haven't done.... I just feel like it's pointed out to me a lot that I'm a Black woman, and I'm like, well dag [dang], there's a whole lot of Black women in [this program].

Although Jackie understood that pursuing a PhD was meaningful, she personally did not feel that the need for the distinction was necessary. In her experience, there were a number of women who came before her and who all achieved great educational accomplishments during their time. In addition, at that time, she was surrounded by a number of Black women who were currently enrolled in the same PhD program as she. For this reason, she did not feel the need for anyone to make distinctions toward her.

The participants of this study were all Black women in pursuit of a PhD in mathematics education. The stories they presented provide their perspectives on the mathematical experiences that ultimately led them to pursue their PhDs. Although there are some similarities in the experiences of the participants, such as their positive attitudes towards mathematics, there were also differences, such as their college experiences, and the journeys they took to become educators. As a way to explore the research questions of this study, the next section will analyze these stories via the major themes and categories they revealed.

Perspectives about Mathematical Experiences?

One research question addressed by this study was: what perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences? These experiences include a number of factors specific to the individuals, their self-perceptions, their environments and the ways in which those environments challenge self-perception, and how these individuals deal with crises and challenges. The themes that emerged from coding and categorizing the women's perspectives about their mathematical experiences were *mathematical identity*, *mathematical environment*, and *mathematical crisis*. Each participant addressed how she viewed herself in her mathematical experiences. They also described their mathematical environments as well as some challenges to their identities, which will be defined here as a "crisis."

Mathematical identity

The participants of this study shared a detailed description of their thoughts about their mathematical identities as they progressed from the stages of elementary education through their entrance into the PhD program. When sharing their experiences, the participants spoke of their identities in a number of ways. As a component of this discussion, several categories emerged as we discussed their mathematical identities. These categories included attitudes, expectations, and abilities. It was also apparent that these categories overlapped throughout our conversations. For example, their attitudes were reflected in their abilities, which was evident in their confidence. On the other hand, their expectations of themselves and others were revealed through their abilities, attitudes, and confidence.

Attitudes. One category that was revealed from the interview data related to attitudes towards mathematics. *Attitudes* describes comments reflecting the participants' thoughts about

their mathematical selves. The women in this study all revealed strong positive attitudes, which were categorized as confidence. According to the women in this study, their experiences with math included attitudes of math being easy, fun, and something they liked to do. All participants stated that they found math easy throughout their K-12 experiences. From their perspectives, it was important to have positive attitudes associated with math, which expressed a high level of confidence in the subject. Their mathematical experiences revealed an ease with which math was completed and enjoyed. Each participant had mathematical experiences in different places and at different points in history, but they all had strong similarities in their positive attitudes about their mathematical experiences.

Expectations. Another category related to mathematical identity as revealed from the participants' perspectives was *expectations*. Three of the participants, Sakinah, Raven, and Melody, explicitly expressed that the expectations of their families and teachers greatly affected their mathematical experiences. They revealed how expectations of a mother, teachers, and sibling encouraged them to push forward in their educational experiences. Some of the expectations were external, such as Sakinah's mother expected her to do better than she herself had done. Other expectations were internal, such as Melody's desire to follow the footsteps of her older sister. Although the expectations did not focus specifically on math, the support system around them encouraged them to be the very best they could be and to live up to positive expectations of academic success.

Ability. *Ability* was the last category revealed while coding the data related to mathematical identity. *Ability* describes a participant's perspectives on their abilities in their math courses. Kimberly and Angel presented their mathematics abilities as natural. Angel and Brandi described being able to perform well on tests. Both Raven and Sakinah knew that they

had the ability to solve problems even when they were difficult. They both illustrated being able to use their resources when they could not simply rely on their natural abilities, which they both also admitted possessing. Raven's abilities were innate, while Sakinah had the ability to follow along with her instructors, which she used to help those around her.

The students' mathematical abilities were related to their ability to perform well in math, for the most part. However, they were unable to say exactly why they excelled at math. Many of the participants simply stated that they knew how to do it, and they did not experience any struggles with it. When they reached a problem or topic about which they were unsure of, they knew how to use their resources for help. The participants thought of their ability to do well in math as common. All of the participants had an attitude of confidence in their mathematical abilities. A few of the participants expressed expectations of themselves or others, which led them to pursue success in mathematics, and school. Their attitudes and abilities were also closely related. All of the participants experienced success in mathematics at an early age, which led to a strong mathematical identity categorized by attitudes of confidence, expectations, and abilities.

Mathematical Environments

In addition to mathematical identity, mathematical environment was another theme that revealed after coding the mathematical experiences of the participants. Each participant of this study shared a detailed description of the mathematical environments they experienced prior to their decision to enter the PhD program. As we discussed those environments, the following categories emerged: *class placement*, *classroom diversity*, *my teachers*, *competition*, and *enrichment*. I will begin with a discussion of *class placement*.

Class placement. Class placement describes the types of classes the participants took throughout their K-12 education, as well as the diversity of those classes and the schools. All of

the participants were placed in advanced or gifted classes. Raven, Brandi, Melody, and Kimberly identified their consistent placement in advanced classes as tracking. The participants described being placed in top, honors, and accelerated courses, or, as one simply stated, "The classes with the smart students." All of their descriptions indicate that, not only were they in advanced courses, there was also a continuity in the types of classes into which they were placed. The tracking discussed by the participants indicated that they were consistently tracked into the highest courses the school offered. This brings our attention to classroom diversity.

Classroom diversity. *Classroom diversity* refers to the diversity of the classes taken by the participants. Their comments focused primarily on the races and genders of their classmates. Although some of the participants experienced some variety in the racial identities of their classmates early on in school, all of the participants except Brandi commented that their classroom were majority Black by the time they reached high school. The participants expressed their comfort in these classroom environments. They also noticed either a balanced amount of male and female students, or slightly more female students in their advanced math classes. To be in advanced math courses as a Black female was normal to them.

My teachers. Another key contribution to the participants' experiences in the mathematics classroom were their teachers. The category of *my teachers* was used to describe the participants' experiences over a long period of time, from those with their primary school instructors to their college professors. With the exception of Kimberly, all of the participants recalled at least one positive experience with a teacher that stood out to them. The math teachers of these participants helped to encourage, motivate, and inspire the participants. Although not every teacher stood out to them, the participants all had at least one positive experience with their math teacher. Some of these experiences also shaped the types of teachers they became.

Competition. In addition to the types of classes and the individuals in them, other classroom experiences defined that environment for the participants. One such experience was competitiveness within the classroom. The category of *competition* described the competitive nature of the participants or of their peers. The women of this study all had some experiences with competition. They shared their perspectives on their competitive experiences in a number of ways, including feeling that they were better than everyone else, their lack of interest in being competitive and using competition as a way to motivate themselves and others. These competitive experiences did not push these women away from math; in some cases, it actually helped to motivated them and push them forward. Although not everyone entertained the competitive nature of their classmates, none of the participants viewed this competiveness in a negative light. In fact, some of the participants continued their competitive natures by participating in enrichment opportunities.

Enrichment. The category of *enrichment* described any of the participants' activities outside the regular classroom that related to STEM. Enrichment opportunities afforded the participants additional math experiences outside of their typical days, which enriched their in-class experiences. These experiences also added to their confidence in mathematics and their positive attitudes about the subject.

In describing the mathematical experiences of all of the participants, their mathematical environments were influenced by class placement, classroom diversity, teachers, competition, and enrichment opportunities. Throughout primary and secondary school, the participants took advanced math courses. The classrooms' diversity was that of predominately Black students for the majority of the participants, and an evenly split male-to-female ratio. The participants had at least one teacher who had a positive impact on them, and many participants had positive

experiences with competition. The majority of the participants also participated in some form of enrichment opportunity, which allowed for additional positive math experiences.

Mathematical Crisis

At some point along each participant's educational journey, they experienced what I have called a *mathematical crisis*. At this time, each participant experienced a decline in her academic performance. Some of their beliefs about their academic identities were challenged. The following categories emerged as we discussed this experience of a mathematical crisis: *meeting an obstacle*, *working differently*, and *moving beyond*.

Meeting an obstacle. The category *meeting an obstacle* characterized the participants' experiences when they faced various obstacles to their academic success. Participants often related the kinds of obstacles experienced to the courses they were offered, family issues, differences between high school and college work, differences in environments, and acceptance by instructors. For most of the participants, this obstacle began in college. The lone exception was Brandi, whose lack of course offerings in high school resulted in a lack of preparation for college mathematics. Angel met her obstacles while she was in college, but they were not completely academic in nature. Those obstacles included poor college advisement and juggling the new responsibilities of being a mother. Sakinah expressed an obstacle due to outside factors. Her issues with family resulted in housing issues, which led to her not achieving her accustomed academic success. Angel and Sakinah's obstacles were family-related, and only caused momentary setbacks. Raven, Melody, Kimberly, and Jackie all had academic obstacles related to their environments. The differences between high school and college environments and instructor acceptance were the most detrimental to the participants, particularly those who did not have the accustomed support of an all-Black classroom. Additionally, the study skills and

habits learned in high school did not result in the same level of academic success. Lastly, the supportive confidence-building relationships they previously shared with instructors were no longer prevalent in their college settings, all of which resulted in a loss of confidence for these participants.

Working differently. Although only some of the participants experienced a loss of academic confidence because of an obstacle, they all sought help to overcome those obstacles. The category *working differently* grouped the participants' experiences related to seeking help and finding ways to overcome their obstacles. Only those participants who experienced an academic obstacle discussed working differently to overcome it.

For the participants of this study, working differently meant working with others. This is not to say that they did not work with others before, but they did begin deliberately using this tactic of community to overcome obstacles. The tactics discussed by the participants showed how they decided to regain their confidence. It also demonstrated their ability to self-reflect and take steps to learn to navigate an environment that was new to them. In addition to the participants' deciding to work differently, they also rebuilt their confidence by moving beyond the situation.

Moving beyond. The category *moving beyond* was used to describe the transition that each of the participants made to move beyond the struggle. Raven discussed how, after the obstacle and learning to work differently, she now seeks people with whom to work. Melody described how the struggles she experienced caused her to choose a career as a teacher. Kimberly stated that working with the tutor taught her that it was not her ability that was determining her grades, but her racial identity, which encouraged her to persist against the odds and complete her math degree. Jackie commented that her time as a teacher allowed her some much-needed self-

reflection, and she realized that she was a good student even after the obstacle, which convinced her that she should strive to become the type of teacher she once had, one who pushed her students.

Obstacles, working differently, and moving beyond, categorized the participants' mathematical crises. All of the participants experienced an academic obstacle related to course offerings, family, or college environments. Of those who had an obstacle related to college environment, they had to decide to work differently and move beyond the challenge. In their discussion of moving beyond the obstacle, the participants described how they used those negative experiences in positive ways. The crises faced by the participants did not define them nor their mathematical capabilities.

Mathematical Experiences

This study described the mathematical experiences of Black women in pursuit of PhDs in mathematics education. This study contributes to the literature on Black women in mathematics education and their paths to earning a PhD. The findings related to the mathematical identities, environments, and crises of the participants. All of the participants had a strong positive sense of their mathematical identities throughout their K-12 educations. This supported the expressions of positive attitudes about their mathematical abilities. Those positive attitudes can also be categorized as confidence in mathematics. Their confidence allows them to live up to the expectations of others. The findings also point to the mathematical environments that each participant experienced. The inclusion of the environments was supported by the categories of *classroom diversity*, *class placement*, *my teachers*, *enrichment*, and *competition*. The participants were typically placed in advanced math courses, and were surrounded by other Black students. They did not notice their Blackness in most their K-12 educations because they were surrounded

by other academically successful Black students. Their classroom environments allowed for a sense of normalcy in their self-perceptions of mathematical aptitude.

Lastly, the findings document times of mathematical crises. These were categorized by meeting an obstacle, the decision to work differently, as well as the decision to move beyond crisis. For four of the participants, a mathematical crisis initially challenged their mathematical identity, and most cited the differences in their mathematical environment as a contributing factor. This challenge allowed the participants to learn to work differently and in so doing, they were able to develop skills that allowed them to use community as a support. While moving beyond the obstacle, some of the participants used their experiences as motivating factors to later enter the field of mathematics education.

Influences of mathematics

The second research question this study addressed was: how have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education? To address this question, several categories emerged that were collectively defined as *influences of mathematics*. Throughout the conversations about the mathematical experiences of the participants, there were many experiences leading to the pursuit of a PhD in mathematics education. Some were direct while others were not, which lead to the theme of *influences of mathematics*. There were several influences that resulted from the participants' mathematical experiences, illustrated by the following categories: *teaching*, *advancing academically*, *wanting*, *selecting math education*, *affecting change*, and *being a Black woman*.

Teaching. *Teaching* described how the participants decided to pursue teaching careers, as well as their teaching experiences. All of the participants decided to become math teachers, though none of them initially went to college with the intent to do so. In fact, only Brandi had an

undergraduate degree related to education. For Brandi, who started in elementary education, her choice came out of a desire to work with older students, but not necessarily in mathematics education. Melody's and Raven's decisions were self-motivated. Melody wanted to help other Black girls, and while Raven really enjoyed math, it was initially the last career she thought she would choose. Sakinah, Angel, Kimberly, and Jackie came to teaching while seeking steady employment. Despite these differences, however, once they entered the field, they all decided to continue and develop their teaching skills by pursuing graduate degrees in various educational fields.

Advancing academically. *Advancing academically* was used to describe why participants decided to pursue graduate degrees. All of the participants decided to pursue a degree in conjunction with teaching mathematics. For most, this degree was part of their process of becoming a teacher. This was different from their reasons for entering the PhD program, which was described by the category *wanting*.

Wanting. *Wanting* was used to describe why these Black women decided to pursue PhDs. The reasons for the pursuit of the PhD can be described as influences of others as well as personal reasons. Raven, Melody, Angel, and Kimberly all recall wanting a PhD for personal reasons. The desire to pursue one resulted from wanting due to the influence of others as well as for personal reasons.

Selecting math education. *Selecting math education* describes how the participants came to the decision to focus on mathematics education. The participants were all academically sound, but they preferred mathematics. This category was used to describe the instances in which math became their sole focus. For many of the participants, selecting math education for their PhD focus was a natural progression from their decision to select teaching mathematics as their

profession. However, this career choice was also a result of their prior experiences with mathematics. The participants' positive mathematical identities, as well as their previous mathematical environments, helped to shape their decision to teach the subject. Their prior mathematical experiences also influenced how they hoped to use their PhDs.

Affecting change: *Affecting change* was used to describe what the participants hope to do with their PhDs. The participants of this study wanted PhDs for various reasons; however, they all wanted to effect change once they had the credentials of the PhD. The changes they were looking forward to were to take place either in the institutions in which they currently worked, in their classrooms, or by working with teachers.

Being a Black woman. The participants also expressed the impact of Blackness on their career goals. *Being a Black woman* defined their thoughts about their academic careers, and specifically in relation to obtaining PhDs in mathematics education. All of the women who participated in this study reflected on Black womanhood in pursuit of a PhD. For some of them, this did not have any affect. For others, these reflections encompassed having a bigger voice, self-identification as a Black woman, the limited presence of Black men, understanding the inequities in the education of Blacks and other marginalized groups, as well as recognizing the accomplishments of other Black women.

How have those experiences influenced their pursuit?

The participants of this study were influenced in their pursuit of a doctorate of philosophy in mathematics education by their teaching, their desires to advancing academically, wanting a PhD, selection of math education as a focus, affecting change, and being a Black woman. All of the participants came from mathematics educator backgrounds, career choices that were greatly influenced by their prior experiences with mathematics. Though teaching was a profession that

many of the participants fell into, the decision to remain and to pursue PhDs in mathematics education was facilitated by their entrance into the profession.

After the initial entrance into teaching, many of the participants wanted to continue their education, and had a desire to advance academically for a number of reasons, including becoming an improved educator, working to better service their students, and out of the necessity of additional certification, which was needed to teach as well as increase their salaries. Although some participants mentioned increased pay as an influence in their decision to go for other advanced degrees, that was not mentioned in their wanting to pursue PhDs. The participants of the study expressed an interest in the PhD as a means of academic advancement, achieving respect, and as the norm for those in their profession. For most of them, selection of math education as their focus came out of a comfort in their professional lives as well as in their competence in the subject itself.

The participants spoke to how this type of program could help better serve the populations with whom they work in their respective classrooms, and this was contributing factor to their entrance into the program. In many cases, being a Black woman in their programs also overlapped with wanting a PhD. They also mentioned others' looking to them and their decision to enter a PhD program as a major accomplishment that others would acknowledge.

5 DISCUSSION AND RECOMMENDATIONS

This final chapter includes an overview of the problem, the purpose statement, the research questions, and a review of the methodology. Next, I offer a discussion of the major findings related to the literature. Finally, I offer recommendations for action and future research.

Summary of the Study

This study has now added to the limited amount of research-based literature discussing the mathematical experiences of Black women. The purpose of this study was to explore Black women's perspectives on how their mathematical experiences influenced their decisions to pursue doctoral degrees in mathematics education. My approach to this study was to assemble the narratives of the mathematical experiences of Black women who are currently pursuing doctorates of philosophy in mathematics education. Therefore, the approach to data collection for this study involved collecting the stories of each participant's mathematical experiences. I hoped to gain rich and thick descriptions of the participants' experiences as learners of mathematics through their stories (Bogdan & Biklen, 2007; Chase, 2005; Foote & Bartell, 2011; Kramp, 2004; Milner, 2007). This study answered the following questions:

1. What perspectives do Black women who are in pursuit of a doctorate of philosophy degree in mathematics education have about their mathematical experiences?
2. How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education?

To address these questions, seven women participated in the data collection process, which included a questionnaire, individual interviews, a group interview, and follow-up interviews. The analysis of the data collected utilized a grounded theory approach, which made the findings of my research more ecologically valid because they more accurately reflected the

mathematical experiences of Black women in mathematics education. In addition, the themes and categories generated are context-specific, detailed, and tightly connected to the data surrounding Black women in mathematics education. Furthermore, by using a grounded theory approach, I was able to identify and categorize experiences inductively rather than impose pre-existing topologies from dissimilar data. The themes that emerged to address the first research question include mathematical identity, mathematical environment, and mathematical crisis. The theme, influences of mathematics, emerged to address the question: How have those perspectives of their experiences influenced their pursuit of a doctorate of philosophy in mathematics education? The findings from the analysis of the data from each participant of this study contribute to the themes of mathematical identity, mathematical environment, mathematical crisis, and influences of mathematics.

The experiences of these seven Black women offer insight into their mathematical experiences and how those experiences influenced their decision to pursue PhDs in mathematics education. These experiences have led these women to successful academic careers and various advanced degrees. The Black women who participated in this study had a confident mathematical identity expressed through positive attitudes about their abilities. Their mathematical environments were categorized by advanced math courses in classrooms with supportive teachers, classmates who were mainly Black, and an even split between genders. Once this environment was challenged, however, a crisis occurred, which caused them to lose confidence in themselves; however, their community assisted in restoring this confidence. All of the participants began teaching secondary mathematics as a career change from their initial undergraduate degrees, and their initial graduate degrees were in conjunction with their decision to pursue this career. The decision to pursue a doctoral degree emerged from a personal desire to

advance academically as well as effect change within their communities. The findings of this study support an achievement motivation framework.

Discussion

Al-Shabatat, Ahmad, and Nizam Al-Shabatat et al. (2011) defined achievement motivation as "an individual's tendency to desire and work towards accomplishing challenging personal and professional goals" (p. 99). Although one of the flaws of achievement motivation is the difficulty to link all possible factors together (Al-Shabatat, et al., 2011), several categories presented in this study model the personality, situational, and goal factors of achievement motivation. The themes that emerged in this study are *mathematical identity, mathematical environment, mathematical crisis, and influences of mathematics*. One characteristic of personality factors included competiveness, which was one of the categories incorporated in the theme *mathematical environment*. Situational factors include the expectation of success, which relates to the expectations and feelings categories presented under the theme of *mathematical identity*. In addition, the theme of *influences of mathematics* is closely related to the goals factor. Achievement motivation states that the goals must be specific, challenging but achievable, and positive (Al-Shabatat et al., 2011). Wanting was a category that was used to describe why the participants of the study decided to pursue PhDs. This category was a component of the theme influences of mathematics. In addition, the category wanting also helped to identify the contributing factors related to the desire of the participants to achieve the specific goal of obtaining a doctorate in mathematics education. Therefore the category wanting related to the theme goal factor presented in achievement motivation. There is a connection from the personality, situational, and goal factors of achievement motivation to the themes that emerged

in this study *mathematical identity, mathematical environment, mathematical crisis, and influences of mathematics*.

While conducting this study, I explored the framework of critical race feminism. Although not every aspect of critical race feminism was presented here, there were two major components revealed in the findings. One was that of counternarratives. These alternative or counternarratives are what the women of this study presented. Their stories of achievement in mathematics, particularly in the area of mathematics education, helped to formulate counternarratives to those that do not include Black women in the area of mathematics education. Another apparent and important component of a critical race feminist view was anti-essentialism. No single portion of the participant's identity was negligible. Although many of the participants admitted that being a Black woman was not something they acknowledged early on, it is a component of their identity that was continuously pointed out to them as they pursued PhDs in mathematics education.

The theme of mathematical identity was also supported throughout the literature. Mathematical identity is a relatively new construct with various definitions. Martin's (2000) research presents one of its definitions, which coincides with the findings in this study and the categories that were revealed. Martin's (2000) work utilized the framework of mathematical identity in his analysis of high school students. The framework that he proposed included "personal identities and goals, perceptions of school climate, peers and teachers, beliefs about mathematics abilities and motivation to learn, beliefs about the instrumental importance of mathematics knowledge, [and] beliefs about differential treatment from peers" (p. 29). These themes of individual mathematical identity, which demonstrated agency and mathematics success among African American students, echoed the following categories presented in this

study: mathematical identity, environment, crisis, and influences. The high level of confidence expressed by the participants of Martin's (2000) study, as well as the value they placed on mathematics, were mirrored by the participants of this study.

Martin's (2000) study noted that "high level[s] of achievement oriented individual agency and bold defiance of the negative influences that surrounded" his participants (p. 86). In this study, there was evidence that, once the participants faced challenges, they boldly defied the critics by working differently and moving beyond negative influences. One difference that was expressed between the results of Martin's (2000) study and my results were the teasing that Martins participants relived. The participants of this study were not questioned specifically about being teased, and it was not mentioned in any of the discussions about their mathematical experiences. This could be explained by the fact that the participants were tracked and mainly experienced courses with other high achievers.

McGee (2015) utilized a fragile and robust mathematical identity framework in her examination of the mathematical experiences of two high achieving college students. In her findings, the appearance of the robust and fragile identities revealed themselves at various times throughout the participants' academic journeys and in various contexts. In this study, both robust and fragile identities were also present. The majority of the participants described robust identities throughout their K-12 experiences. However, once they reached a crisis, many of the participants' identities became fragile. They began to look to others to validate their abilities instead of focusing on themselves and their capabilities. It was not until they decided to move beyond the crisis that they began to view their identities more robustly.

Horn's (2008) work argued that mathematical identities extend beyond a single mathematics classroom or teacher. This was true for the participants of this study. Each

mentioned several moments throughout their academic careers that contributed to their mathematical confidence and their overall enjoyment for the subject. By having continuously high expectation of the curricula of their advanced courses, and teachers who were either extremely positive or unmemorable, the participants of this study were able to move forward continually. Although Horn's (2008) study focused primarily on students who were entering high school underprepared, the conclusion concerning the resources available to develop a positive mathematical identity among students was supported.

Part of Anderson's (2007) conclusion suggested that the images the participants had for themselves determined whether they felt that they needed mathematics in the future. Most of the participants in this study took courses that exceeded the high school graduation requirements for mathematics. This indicated that either they saw a need for mathematics in their future or they enjoyed the subject. The participants of this study also support the claim presented by Anderson (2007) that the nature component of identity was the most unrelated. The participants of this study came from various backgrounds that were not all strong in mathematics or academics.

The categories of *feelings*, *confidence*, *expectations*, and *ability* were similarly identified as categories and factors presented in other studies. Miller, Snow, and Lauer (2004) discussed that one of the major concerns with the implantation of students programs for success in mathematics was motivation. Many participants of the study exhibited motivation in relation to Black women's success in mathematics. One aspect of motivation revealed in this student was included within the theme of mathematical identity. The category of *feeling* is where the participants' thoughts of themselves were revealed, and this gave a great deal of insight into their personal motivating factors through an expression of their positive feelings about mathematics.

Picucci and Sobel's (2002) findings included several recommendations for stakeholders, various policy makers, and teachers, some of which included knowing that minority students can be successful in advanced mathematics courses when they are held to the same high expectations of success as other students. This also supports the categories of *ability* and *expectations* as presented in this study within the theme of mathematical identity.

The theme of mathematical environment and its categories, *class diversity, class placement, teachers, enrichment,* and *competition*, presented a clear connection to the literature. In relation to class placement, Ellington and Frederick (2010) found that one of the factors that emerged from the participants involved in school experiences were that the "majority of these students, [had] access to accelerated programs [that] occurred in the third grade" (p. 76). This was supported by the participants' comments that referred to being in advanced courses as early as elementary school. A study conducted by Mayer (2008) concluded that "successful AP and IB programs were characterized by teachers' beliefs in their students' abilities to meet the high expectations of the curricula" (p. 212). This characterization of success supports my study's categories of teachers. This category was utilized within the theme of *classroom environments* as well.

The participants in this study also spoke of their mathematical experiences with tracking. Ability tracking is one way mathematics is used as a gatekeeper. Ability tracking is the "practice of placing students in stratified classes based on the students' perceived abilities" (Welner, 2002, p, 565). This was also evident in the participants' experiences with class placement. Some students are tracked as early as kindergarten, and this tracking typically follows them through high school. Tracking generally results in "separation of students along racial, ethnic, and socio-economic lines" (Ansalone, 2010, p. 11). Although this tracking can typically result in the lower

placement of minority students, the participants of this study were placed in advanced courses, and in many cases surrounded by other Black students in these courses, as seen through the category of *classroom diversity*.

Solomon (2012) suggests that the world of undergraduate mathematics for women is filled with "competitiveness, isolation, and group work for mutual support" (p. 179). This competitive nature was not only present for these participants during college, but in many of their educational experiences, as seen throughout the category of *competition*. Paek's (2008) findings on successful summer programs support the fact that enrichment opportunities such as participation in math teams and other summer STEM programs presented in the enrichment *category* helped to promote achievement in mathematics.

The sense of belonging that the participants experienced was also evident in the categories of *meeting an obstacle* and *moving beyond*. This supports the fact that one of the major obstacles to success in STEM fields for Black females was the sense of belonging either to the institution at which they were studying, or as a member of the STEM field (Hernandez, et al., 2013; Johnson, 2012; Perna, et al., 2010). Johnson (2012) spoke to this as the "double bind" effect:

> As a result of being in both the racial and ethnic and the gender minority groups, women of color experienced isolation from peers and a lack of support from faculty, while various socio-cultural factors influenced the way women of color negotiated the culture, values, and practices in the sciences. (p. 80)

The category *meeting an obstacle* also contributed to literature on the sense of belonging, which several of the participants expressed throughout this study. *Meeting an obstacle* led to a negotiation of practices, which was identified through the categories of this study titled *working*

differently and *moving beyond*. Borum and Walker (2012) also looked at the experiences of Black women with PhDs in mathematics. Their findings suggest that mentorship, a supportive program, and study groups were instrumental to these women's success in their doctoral studies. This was supported in this study within the category of *working differently*, where the participants worked with study groups in order to be successful after encountering a mathematical crisis.

The category of *teaching*, which was presented under the theme of *influences*, was supported by Herzig's (2010) study, in which the theme of "the importance of having and being a role model" emerged. The two are related by the participants' desire to use their teaching careers to serve as role models, and how they viewed this as an important factor in creating change.

Recommendations

The findings of this study suggest that *mathematical identity*, *mathematical environment*, and *mathematical crisis* all contribute to the experiences of Black women in pursuit of PhDs in mathematics education and the *influences of mathematics* presented through those experiences contributed to the capabilities that led these women to pursue PhDs. The Black women who participated in this study had confident mathematical identities expressed through positive feelings about their mathematical abilities. Based on these experiences and their influences, mathematicians and mathematics educators should make necessary changes in curricula, instruction, and policies that work to support Blacks in mathematics who are contributing to the positive identities of Black women in mathematics.

In examining the mathematical identity of the participants in this study, it clear that they had very high regards of themselves. Statements such as "I like math…."; "It was fun…."; "I

was good at it…." and "it was never a problem…." all reflected the fact that the participants enjoyed their mathematical experiences. The comments they used to describe themselves mathematically through their feelings also referred to their abilities to make good grades, the ease at which they were able to complete the work, the confidence they had in their mathematical abilities, their abilities in general, and the idea that being a Black woman who excelled in math was common. To further support Blacks in mathematics, the origins of these positive feelings and what I will refer to as a positive mathematical identity should be more closely addressed.

The mathematical environment is an area where stakeholders and policy makers could also have an impact. In examining the mathematical environments described in this study, the teachers, their expectations, enrichment diversity, and class placement all played a big role in the mathematical experiences of the participants. They mentioned diverse advanced-course classrooms where they were consistently placed with high academic expectations. In some cases, all of the students were Black and yet there was still a sense of high expectations from teachers. The enrichment activities that the study presented showed the participants having fun with mathematics outside of their classrooms. They enjoyed the experiences, and some enjoyed the competitive nature that was also present. Providing more opportunities for Black students to participate in enrichment opportunities could allow students to find more enjoyment in mathematics and continue into higher-level mathematics courses.

In order to have some additional understanding of the struggles faced by Black women in mathematics, there needs to be more understanding of what mathematical crises students may have. In this study, it was clear that, although the students started with strong mathematical identities, there was a time when each identity was challenged through a mathematical crisis. By

having a better understanding of what contributed to the crisis, stakeholders can implement additional policies and practices to eliminate these challenges for future students.

Conclusion

This study enriches literature on the mathematical experiences of Black women and how they engage in mathematics to become successful graduates with a PhD in mathematics education. The results indicate that the experiences of Black women in the pursuit of PhDs in mathematics education include those related to their mathematical identities, their mathematical environments, mathematical crises, and the influence of mathematics, which could all possibly explain how those experiences influenced their decisions to pursue PhDs in mathematics education. Both mathematicians and mathematics educators should make necessary changes in curricula, instruction, and policies that work to support Blacks in mathematics, including building up the mathematical environments of the students via enrichment opportunities that support Blacks in STEM. The results of this study also offer stakeholders and policy makers on all levels insight into the experiences that contribute to the success of Black women in mathematics at various levels as well as the experiences that could discourage Black women from pursuing degrees in mathematics education. In this study the participants expressed many positive feeling associated with mathematics. To further support Blacks in mathematics, the origins of these positive feelings and what I will refer to as a positive mathematical identity should be more closely explored. Finally, research should also be done to have a better understanding of what experiences can lead to a sense of confidence in the early stages of school and what activities can be done prior to starting school that can make a difference in the level of confidence that Black women have in mathematics.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

Please respond to the following questions:

1. Do you classify yourself as Black female? Yes or No
2. Are you currently in a mathematics education doctoral program? Yes or No
3. Do you attend a traditional college or university? Yes or No

If you have answered yes to all of the previous questions please answer the respond to the following questions:

Name:

Age:

Race:

Phone number:

Email address:

Mailing address:

Colleges attended and majors: Please indicate if you changed your majors at any point.

Profession:

Any additional information that you would like to share.

APPENDIX B

INITIAL INTERVIEW QUESTION

Early childhood.

1. What type of school did you attend for grades pk-5? Private, public etc.
2. What type of mathematical experiences do you remember from elementary school?
3. Did you participate in any special math programs in elementary school?
4. Did you participate in any summer programs with an emphasis in math while in elementary school?
5. What were your thoughts of yourself mathematically during elementary school?
6. Did you have any teachers of mathematics that stood out to you in elementary school?
7. During elementary school was there anything that stood out to you about being black during any of your mathematical experiences?

Middle grades

8. What type of school did you attend for grades 6-8? Private, public etc.
9. What type of mathematical experiences do you remember from middle school?
10. Did you participate in any special math programs in middle school?
11. Did you participate in any summer programs with an emphasis in math while in middle school?
12. What were your thoughts of yourself mathematically during middle school?
13. Did you have any teachers of mathematics that stood out to you in middle school?
14. During middle school was there anything that stood out to you about being black during any of your mathematical experiences?

Secondary

15. What type of school did you attend for grades 9-12? Private, public etc.
16. What type of mathematical experiences do you remember from high school?
17. Did you participate in any special math programs in high school?
18. Did you participate in any summer programs with an emphasis in math while in high school?
19. What were your thoughts of yourself mathematically during high school?
20. Did you have any teachers of mathematics that stood out to you in high school?
21. During high school was there anything that stood out to you about being black during any of your mathematical experiences?

Undergraduate

22. What type of college did you attend?

23. What was your major for undergrad? How did you come about this decision?
24. How would you describe your mathematical experiences during undergrad?
25. Did you participate in any mathematical internships or extracurricular experiences during college?
26. What were your thoughts of yourself mathematically during college?
27. Did you have any instructors of mathematics that stood out to you during college?

Graduate experiences

28. What career were you in prior to entering the doctorate program?
29. What mathematical experiences led you to that career?
30. Which mathematical experiences had the most impact on your decision to entering this doctorate program?
31. What mathematical experiences have helped you the most to reach your current level in the program?
32. Has being a Black women impacted you in any way in your program? If so how?

APPENDIX C

GROUP SESSION PROMPTS

Introduction: “Hello everybody, my name is Nathalie. I will conduct the discussion while observing and taking notes. I invited you all to discuss how the mathematical experiences of Black women influenced your decisions to pursue a doctoral degree in mathematics education. I will ask you several open questions. Your personal opinions and view are very important. There are no right or wrong answers. Please feel welcome to express yourself freely during the discussion.

This conversation will be recorded on video and audio tape. This is only for research purposes, only I will listen to the tape. No names or personal information will be used in the report.

Some practical issues: the discussion will last for two hours. I ask you to please silent your mobile phones. Please give everyone the chance to express their opinion during the conversation. You can address each other when expressing your opinion, I am here to assist in the discussion. Is everything clear about the course of the group discussion?

Questions:

1. Please share your name and your area of study?
2. What were your early years in mathematics like?
3. Have you ever considered yourself good at doing math or teaching math? If so when?
4. When did you decide to enter the doctorate program in mathematics education?
5. As a Black woman that has entered a doctorate program in mathematics education, what steps can be taken to promote girls' to succeed in mathematics?

6. From your perspective, why aren't there more Black women in the field of mathematics education?
7. Were there any programs in your k-post secondary experiences that helped to foster your interest in mathematics?
8. Did anyone in your K-post secondary experience comment on your mathematics abilities in a positive way? If so what was the experience.
9. Are there any other subjects you would like to discuss concerning your mathematical experiences?

APPENDIX D

FOLLOW UP QUESTIONS

1. After reviewing the transcript were there any questions or concerns that you had about transcript?
2. Is there any information that you would prefer me to omit?
3. Did you gain any insight from the group session that allowed you to reflect on your previous mathematical experiences?
4. Was there anything that you wanted add about your mathematical experiences now that you have had some additional time to reflect?
5. I would like to understand more about certain experiences that you shared in your initial interview; can you elaborate on the following?

APPENDIX E

TIMELINE OF DATA COLLECTION

Time	Activities
Phase 1 Month 1 December 2014	• Initiating entry by contacting schools to select participants • Distribution of Questionnaire • Selection of participants
Phase 2 Month 2 January 2015	• Distribution of Questionnaire • Selection of participants • Initial interviews 1-2 • Transcription of interviews • Initial coding • Coding, analysis, and interpretation of data
Month 3 February 2015	• Initial interviews 3-8 • Initial coding • Transcription of interviews • Coding, analysis and interpretation of data
Phase 3 Month 4 March 2015	• Group interviews • Initial coding • Follow-up interviews • Transcription of interviews • Coding, analysis, and interpretation of data
Month 5 April 2015	• Transcription of interviews • Coding, analysis, and interpretation of data
Month 6-10 May 2015- September 2015	• Coding, analysis, and interpretation of data